Vancouver's Dirty Laundry: Policy considerations and interventions to address synthetic (plastic) microfibre ocean pollution in a large urban centre

by

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Declaration of Committee

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Abstract

The environmental sustainability issues arising from growing global textile and fashion consumption have increasingly come under scrutiny. Reportedly, synthetic microfibre emissions during the use-phase of textiles account for the largest land-based source of microplastic pollution. Developing potential intervention strategies aimed at minimizing microfibre leakage into the ocean requires an examination of household-level sources. Previous studies have approximated the rate of microfibre release from washing machines. A number of intervention strategies have been recommended by experts and stakeholders. Some international jurisdictions may put forward legislation to address the issue. However, there is a knowledge gap in understanding the role the public plays as a key stakeholder group and their behaviours and policy preferences as they impact microfibre leakage. This study addresses that knowledge gap and investigates the drivers of the problem and the practicability, feasibility, and cost-effectiveness of interventions and policies to address synthetic microfibre emissions from households in British Columbia.

Keywords: microfibers; ocean marine pollution; fashion consumer; sustainable fashion; microplastics; environmental policy

Dedication

This work is dedicated to my nana Gisia, my maternal great grandmother, who was there from the start and has always been there and shown me the way.

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Here's one for unexpectedly special friendships and avocado-toast (consumed very infrequently to minimize the burden on the environment and farming communities).

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Executive Summary

At less than 5 mm in size, synthetic microfibres are tiny plastic particles that shed from synthetic textiles made from petroleum-sourced fibres (such as polyester, acrylic, and nylon) during their use-phase, in wear and tear and during the cleaning process in household laundries. Globally, synthetic microfibres released from domestic laundries are the predominant source of microplastic pollution. Worldwide, every environment and habitat investigated is polluted with microfibres shed from textiles. There is growing evidence that all microfibres have negative impacts on ecosystems and may pose risks to water and food supplies, affecting humans and other species. Despite the urgency of the issue, action to mitigate synthetic microfibre emissions has not been a priority in Canada. This study aims to address synthetic microfibres emissions from households as a key policy gap in local and global plastic pollution mitigation strategies.

This study investigates the synthetic microfibre pollution issue and addresses unregulated synthetic microfibres emissions from households as a key policy gap in local and global plastic pollution mitigation strategies. The investigation explores three core aspects of the issue to inform policy. First, the study covers the extent and potential environmental and human health implications of synthetic microfibre pollution. Second, it provides critical insights into the efficacy of interventions recommended by experts from the perspective of consumers gleaned from a household survey I undertook. Finally, drawing on the study findings and insights from academic, industry, and policy experts, and actions taken in other jurisdictions, the study analyzes and offers a set of policy recommendations for action in the province of British Columbia and Canada. BC's action plan to prevent and significantly reduce marine plastic pollution, including microplastics emissions from land-based sources, cannot be met effectively and efficiently without targeted action on synthetic microfibres emissions from the use-phase of textiles, specifically, household laundries.

Key Findings

The following summarizes findings from my review of the state of current knowledge about microfibres, findings from a representative household survey I undertook, expert consultations, and relevant analysis as they inform the recommendation outlined in the final chapter. The findings from the survey clearly illustrate that the problem

of ocean pollution caused by synthetic microfibres is not a polarizing issue for the sampled voting public. Moreover, consumers are willing to take some actions to help mitigate the problem. However, solely relying on consumers to address the issue would be highly ineffective in achieving pollution reduction.

Despite some uncertainties about the long-term environmental and health impacts of microfibre pollution, the evidence compiled in this study points to the urgency in adopting a precautionary approach to protect human health and ecosystems from the accumulating and persistent microfibre pollution and the associated hazardous substances.

- Electric washers & dryers are important sources of microfibre emissions.
- Continuous exposure to synthetic microfibres may have significant ecotoxicological impacts
- Early evidence and recent findings on human health risks indicate urgent need for further investigation.
- Natural microfibres are 10X more prevalent in the environment than synthetics and pose similar risks.

Although many organizations and researchers suggest behaviour change at the household level is an important point of intervention, British Columbians' households' laundry habits and apparel purchasing behaviour may be resistant to change.

- The microfibre footprint of nearly half of Metro Vancouver households may be 7X greater than the other half.
- Young people & children in the household drive demand for low-cost fashions.
- Consumers, as a group, cannot be relied upon to prioritize environmental sustainability.

At the local and global levels, residents of Metro Vancouver express a great deal of concern about environmental issues. However, the majority of them are not very knowledgeable about the synthetic microfibres pollution issue. There appears to be a correlation between knowledge about the issue and pro-environmental concerns and attitudes.

- Metro Vancouver residents are very concerned about ocean pollution caused by microfibres, irrespective of income or level of awareness about the issue.

- Nearly all consumers believe action on the environment is urgently needed.
- Fewer than 20% of individuals have a high level of awareness about microplastics & synthetic microfibres.

An overwhelming majority of citizen-consumers in Metro Vancouver support direct government actions to address the microfibre issue. They place a high value on a healthy marine environment and the majority of them are willing to play their part by reducing their emissions from their laundry appliances and paying a higher price for apparel that is less polluting.

Policy Action

The study's investigations to identify appropriate policy interventions are guided by three core objectives:

1. Reduce ocean plastic pollution by reducing direct discharge of synthetic microfibre emissions from households and transition the Province of British Columbia toward long-term emissions reductions.

2. Develop a long-term sustainability framework that is sufficiently financed and well-resourced to better manage future demand.

3. Establish a strategy that will meet the Province's needs for liquid and solid waste management and enable partnerships with the textile industry to transition to a circular economy.

The study's geographic scope, namely British Columbia, restricts the range of recommended polices to those which are within the jurisdiction of the BC government and include discharge points from laundry appliances and emissions management downstream at solid and liquid waste treatment facilities. Source control measures that would address emissions from textiles would require a federal-level policy framework and are, therefore, not within the scope of this study. The policy options are designed to be complementary to address short- and long-term considerations in emissions reductions while establishing the groundwork for meeting BC's sustainability objectives. I assess three options:

- Legislation to reduce emissions form laundry appliances that mandates preinstalled microfibre capture technologies for all new laundry appliances sold in BC.

- A subsidy for household purchases of filters to capture microfibre emissions from laundry appliances.
- Modified extended producer responsibility (mEPR) legislation that puts an eco-fee on apparel.

Each of these, taken together help achieve the sustainability goals for BC and I recommend all be implemented. Legislation to mandate standards for new appliances, a government-run CleanBC program, coupled with a strong economic instrument (mEPR), is a necessary and efficient model for leading BC to environmental and economic sustainability. Action to address synthetic microfibre pollution offers a unique window and opportunity for the BC Government to begin to lay the groundwork for lasting impact on a myriad of interrelated negative environmental externalities which impact the province and have plagued the textile and fashion industries worldwide. The policies examined in this study should be considered the beginning in developing a suite of policies to address microfibre pollution, from all sources. Ideally, the federal government and international bodies would address the issue in a cohesive and cooperative way and commit to binding short-term and long-term targets. However, the Province of British Columbia, and indeed other provinces, should not wait to take their lead from other jurisdictions. There is mounting evidence that government action on microfibre is needed. BC can be a policy leader on microplastic pollution and textile sustainability.

Chapter 1.

Introduction

At less than 5 mm in size, synthetic microfibres are tiny plastic particles that shed from synthetic textiles made from petroleum-sourced fibres (such as polyester, acrylic, and nylon) during their use-phase, in wear and tear and during the cleaning process in household laundries. Globally, synthetic microfibres released from domestic laundries are the predominant source of microplastic pollution, accounting for more than 35% of microplastics in the ocean (Boucher & Friot, 2017). Worldwide, every environment and habitat investigated is polluted with microfibres shed from textiles (Bergmann et al., 2019; Browne et al., 2011; Napper, Davies, et al., 2020). There is growing evidence that all microfibres (including fibres from renewable resources such as cotton) have negative impacts on ecosystems and may pose risks to water and food supplies, affecting humans and other species (Desforges et al., 2015; Henry et al., 2019; Rochman, 2013; Rochman et al., 2015a). Annually, Canadian households release 0.26 quadrillion (or 67 tonnes of) synthetic microfibres into bodies of water (Vassilenko et al., 2019). Synthetic microfibres have been identified in every Canadian site investigated (Ballent et al., 2016; Driedger et al., 2015; Erdle, 2020). Along the shorelines of coastal British Columbia, synthetic microfibres account for more than 75% of microplastic pollution (Desforges et al., 2014). Despite the urgency of the issue, action to mitigate synthetic microfibre emissions has not been a priority in Canada.

This study investigates the synthetic microfibre pollution issue as an important area for environmental policy action and addresses unregulated synthetic microfibres emissions from households as a key policy gap in local and global plastic pollution mitigation strategies. The investigation explores three core aspects of the issue to inform policy. First, the study covers the extent and potential environmental and human health implications of synthetic microfibre pollution. Second, it provides critical insights into the efficacy of interventions recommended by experts from the perspective of consumers. Finally, drawing on the study findings and insights from academic, industry, and policy experts, and actions taken in other jurisdictions, the study analyzes and offers a set of policy recommendations for action in the province of British Columbia and Canada.

Chapter 2.

The Policy Problem and Study in Context

The growing trend in international agreements, charters, and campaigns on ocean health and plastics reveals the gravity of the problem. In 2015, members of the United Nations (UN) General Assembly made a commitment to the global 2030 Agenda by adopting 17 interlinked global Sustainable Development Goals (SDGs) (G. A. United Nations, 2015). In 2017, the UN General Assembly met again to discuss the implementation of SDG 14, pertaining to ocean health and sustainability[1], and adopted a new resolution, *Our Ocean, our Future: call for action*, highlighting the need for critical action to reduce marine pollution (G. A. United Nations, 2017). Specifically, SDG 14.1 calls for prevention and significant reduction in marine debris, in particular from land-based sources, by 2025. The global conversation has mobilized Canada to take action.

During its presidency at the 2018 G7 Summit, in Charlevoix, Quebec, Canada launched the *Ocean Plastics Charter* (the Charter). By adopting the Charter, Canada committed to a "a more resource-efficient and sustainable approach to keep plastics in the economy, and out of the environment," and addressing the sources of microplastics, with targets set for 2030 and 2040 (Canada, 2018, p. 2). In 2018, the Canadian Council of the Ministers of the Environment (CCME) approved the Canada-wide Strategy on Zero Plastic Waste (CCME, 2020). The CCME have listed conducting and supporting research on the effects of plastics and microplastics on the environment and human health as 'ongoing' action areas for the CCME, jurisdictions, and stakeholders (CCME, 2020, p. 8). At the Province level, in 2018, British Columbia released the *CleanBC* initiative and the *Plastics Action Plan* (the action plan) policy consultation paper. The action plan proposed four[2] main options for amendments to the Recycling Regulations under the *Environmental Management Act* by September 2019 (British Columbia, 2019). Addressing microplastics emissions from textiles was not on the agenda. At the local level, the Plastics Advisory

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[1] SDG 14, Life Below Water, conserve and sustainably use the ocean, seas, and marine resources for sustainable development (D. of E. and S. A. United Nations, 2015) .

[2] The options suggested as amendments to the *Environmental Management Act*: 1. Bans on single-use packaging; 2. More recycling options, 3. Expanding plastic bottle and beverage container returns; 4. Reducing plastics overall (developing national recycled content performance standards) (British Columbia, 2019).

Panel to the National Zero Waste Council (NZW), an initiative of Metro Vancouver, have included textiles made from synthetic materials in their list of priority plastics.

The noted initiatives and targeted actions are necessary to reduce microplastics emissions caused by the fragmentation of land-based macroplastics (plastic waste) in the environment. However, as discussed earlier, synthetic microfibre emissions from the use-phase of textiles and domestic laundries may be the single largest source of land-based microplastics emissions. Despite the urgency of the problem, to date, Canada, the CCME, the Province of British Columbia, and the NZW have not identified any interventions or actions with reductions targets to address microplastic emissions from the use-phase of textiles. Globally, France, Sweden, the UK, and the State of California have taken various steps to address the issue, see **Chapter 4**.

The policy issue

The ambitious goals set out in SDG 14.1 for 2025, the Canadian Plastics Charter's 2030 aims, the CCME action plan, and the BC action plan to prevent and significantly reduce marine plastic pollution, including microplastics emissions from land-based sources, cannot be met effectively and efficiently without targeted action on synthetic microfibres emissions from the use-phase of textiles, specifically, household laundries.

Stakeholders

There are six main stakeholder groups to consider with respect to the policy problem: Consumers, apparel producers, garment & footwear sector factory workers, appliance producers, water utilities, and nongovernmental organizations (NGOs). Descriptions of these groups are provided in **table 2.1**.

Table 2.1. Six stakeholder groups may be impacted by policy action on microfibre emissions

Stakeholders	Description
Consumers	All British Columbians, indeed, all Canadians, are consumers of clothing and other apparel products. Their clothing purchase choices have implications for microfibre emissions per article of clothing. They are also consumers of laundry appliances.
Apparel producers	The apparel industry comprises a global and complex web of actors, ranging from textile fibre engineers to garment factory workers and consumer-end retailers (OECD, 2017). Nearly 90% of apparel sold in Canada are manufactured abroad[3] (Euromonitor International, 2021). Moreover, the global garment industry is the world's third biggest manufacturing industry (after automotive and electronics (Fashion Revolution, 2018). The industry is also deeply interconnected with other sectors, namely agriculture and petroleum. For the purposes of this study, all actors in the apparel and fashion manufacturing industry are considered under one umbrella group, apparel producers. These include retailers, fibre, chemical, and textile engineers, fashion designers, Canadian manufacturers, and international manufacturers or importers.
Factory workers in the garment & footwear sector	As one of the world's biggest employers, garment manufacturing is also one of the most labour intensive industries (Black, 2013; Environmental Audit Committee, 2019). In Canada, 44,500 people are employed in the production and administration of manufacturing apparel, 22,000 of which are employed in clothing manufacturing (FashionUnited, 2016) . China and Bangladesh are the world's largest garment exporting countries (Statista, 2020b). More than 65 million workers are directly employed in textile and garment supply chains in Asia and the Pacific, accounting for nearly 87% of the region's labour force, and the majority of whom, 35 million, are women (ILO, 2020).

[3] Large Canadian firms have off-shored their production to reduce their operating costs and meet the rapid turnaround rate of fast fashion, while generally retaining non-manufacturing and high value-added activities such as design, R&D, branding, marketing, logistics, etc. in Canada (I. Government of Canada, 2017).

	An early lesson from the COVID-19 pandemic was that a decrease in demand for apparel in Western countries can rapidly lead to worker lay-offs[4] and significant economic hardships[5] for global textile workers(ILO, 2020). Therefore, any local or national level policies for the sector should consider the potential impacts on the global textile worker.
Household appliance producers	This industry group primarily manufactures kitchen, bathroom, and other electrical household appliances and components. In the context of this study, they include all manufacturers, importers, and retailers.
Water utilities	Wastewater treatment plants are significant point sources of microfibre emissions. In Canada, all levels of government share the responsibility for managing the collection, treatment, and release of wastewater effluent. The Government of Canada is responsible for managing the risks posed by hazardous substances listed under CEPA (1999) (Canada, 2017). There are 1,259 wastewater treatment plants in Canada (Statistics Canada, 2018). These are owned by regional and municipal governments. In 2017, 90% of BC[6] was served by WWTPs (Canada & ECCC, 2020). However, only 9.6% of BC WWTPs were at the tertiary level treatment, and an additional 42.2% were secondary treatment. Although a major secondary Metro Vancouver WWTP captures 97-99% of microplastics, annually it releases ~ 30 billion particles (including synthetic microfibres) into the receiving environment (Gies et al., 2018). Due to the rich nutrients content, Metro Vancouver's treated sludge and/or biosolids are sold as fertilizer to some of BC's park and agricultural lands (Anonymous Expert #1, 2020).
Non-governmental organizations	The campaigns by Greenpeace on the environmental and social labour impacts of the global fashion industry have been instrumental in mobilizing the fashion sector, NGOs, and government actors. Similarly, Ellen MacArthur Foundation has published its own report and recommendations for addressing the negative externalities in the fashion value chain. The Surfrider Foundation and Plastic Soup Foundation are among other NGOs that have raised a red flag about ocean plastic pollution, including microfibres.

[4]In the shadow of the 2020 coronavirus pandemic, the typical garment worker in Asia and the Pacific experienced severe delays in wage payments, lost at least 2 to 4 weeks of work, while only 3 in 5 workers were called back to the factory (ILO, 2020).

[5] According to a survey of 75 manufacturers across Asia, Africa, and the Americas, conducted by Penn State University's Center for Global Workers' Rights and the Workers' Rights Consortium, since the start of the COVID-19 outbreak, more than half of manufacturers had accepted some orders below cost, effectively providing fashion brands with virtually free products (Deeley, 2021).

[6] There is a large degree of variation across the different provinces. BC has the highest proportion of the population (90%) served by WWTPs compared to other provinces, whereas Prince Edward Island has the lowest (54%).

2.1. Study Purpose and Core Objectives

Governments and non-governmental organizations from around the world have proposed interventions and policies to reduce microfibre release during the production and use-phase of textiles, see **Chapter 4**. Their recommendations largely target consumer behaviour. Consumers are encouraged to change their apparel purchasing and household laundry behaviours to minimize microfibre emissions. However, there is a knowledge gap in understanding the public as a key stakeholder group, their perceptions, and what sort of policy interventions they might respond to. The public's behaviour will impact textile sustainability and microfibre leakage. Moreover, the drivers of the problem and the practicability, feasibility, and cost-effectiveness of recommended interventions at the household level remain unexamined. This study aims to address synthetic microfibres emissions from households as a key policy gap in local and global plastic pollution mitigation strategies.

Drawing on the findings from the literature review, outlined in **Chapter 3**, and giving consideration to sustainability barriers outlined in **Chapter 5**, the study's investigations to identify appropriate policy interventions are guided by three core objectives, which also inform the BC Sustainability Objectives outlined in **Chapter 7**:

1. Reduce ocean plastic pollution by reducing direct discharge of synthetic microfibre emissions from households and transition the Province of British Columbia toward long-term emissions reductions.

2. Develop a long-term sustainability framework that is sufficiently financed and well-resourced to better manage future demand.

3. Establish a strategy that will meet the Province's needs for liquid and solid waste management and enable partnerships with the textile industry to transition to a circular economy.

2.2. Study Scope

The study scope is the province of British Columbia. This is primarily based on the way in which the study was executed. The provision of funding[7] for a report on consumer behaviour in the Metro Vancouver region enabled the study author to develop and administer a representative-sample survey of households in Metro Vancouver. With a population of approximately 2.5 million people as of the 2016 census, Metro Vancouver, which is a Federation of 21 municipalities, one Treaty First Nation, and one Electoral Area, represents the largest population in British Columbia (4.86 million, 2016 Census). Based on the population density of the region and the survey methodology, the findings of from the household survey may be reliably considered illustrative for the province[8]. However, findings from the Metro Vancouver-level study cannot be considered an accurate or dependable representation of Canada.

2.3. Study Methodology

The study utilizes a mixed-methods approach: academic literature review, a representative-sample survey of households, and stakeholder and expert interviews.

2.3.1. Literature review

An extensive academic and grey literature review, consulting the latest scientific evidence, describes the problem. The findings demonstrate the prevalence and urgency of the problem and provide an overview of the recommended intervention strategies.

2.3.2. Metro Vancouver household survey

I conducted a web-based representative-sample survey of Metro Vancouver residents in 2020. The Metro Vancouver Household Survey (the survey)[9] findings inform

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[7] A report on Metro Vancouver residents' microfibre knowledge, related behaviours, and interventions preferences was produced for Metro Vancouver. The report was entitled: "Metro Vancouver, A case Study: An examination of synthetic (plastic) microfibre knowledge and behaviours in Metro Vancouver households and expert recommended intervention strategies."

[8] I am preparing to undertake a representative household survey of Canada if sufficient funding is identified. The Canada wide survey is beyond the scope of this capstone.

[9] The survey instrument may be made available upon request to author.

the study's aims by elucidating households' priorities, motivations, behaviours, and policy preferences, as they pertain to the policy problem.

Data collection

The Survey distribution was managed by Angus Reid Forum. It was run from 10 May 2020 to 4 June 2020. The sample frame was Metro Vancouver households (2016 population: 2,463,431). The pre-set sample size was 1000 respondents with a margin of error of ±3.1 percentage points (19 times out of 20), stratified by gender and age. The margin of error for specific groups and subgroups will be larger, depending on the group. The actual sample size of N=1034 meets the targeted gender and age (nested) quota samples plus the additional 'prefer to self-describe' respondents. **Box 2.1** provides a summary of survey methodology and limitations. The demographic profile of the surveyed Metro Vancouver households is provided in **figure 1.1.** Although consideration must be given to the limits of such a study, the data presented here are critical to addressing issues of environmental sustainability in the textile and apparel sector, especially with respect to synthetic microfibre emissions at the watershed scale.

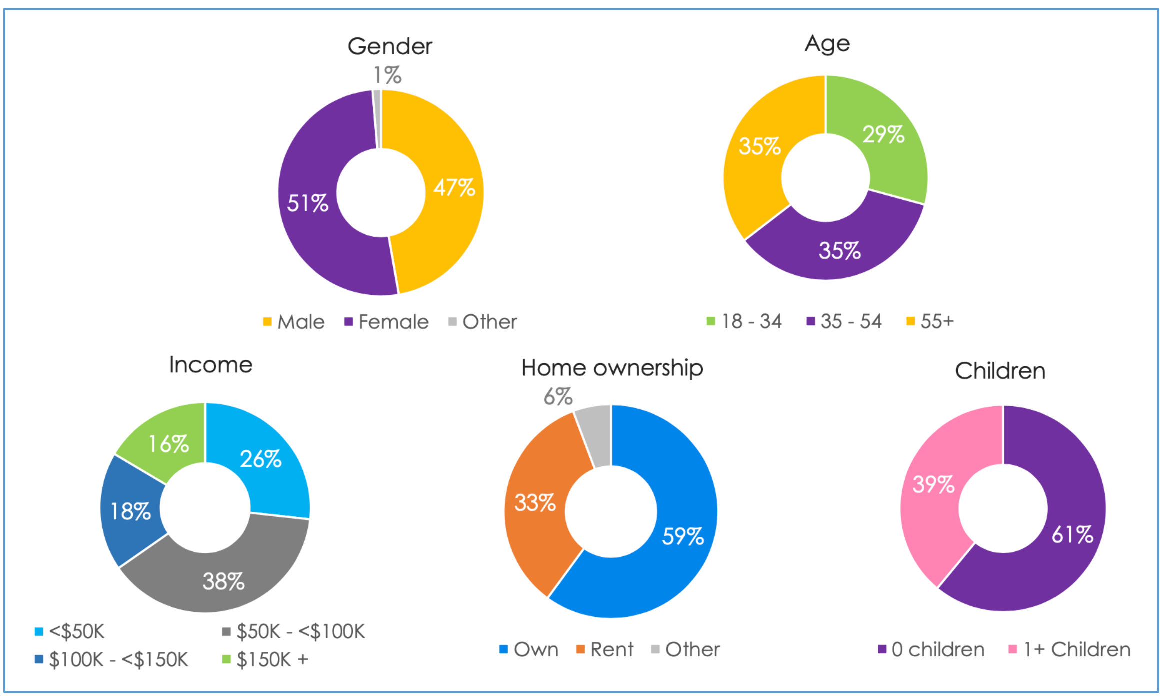

Figure 2.1. Metro Vancouver representative-sample survey
The sample was balanced to reliably represent Metro Vancouver households by gender, age, income, home ownership, and whether or not there are children in the household

Box 2.1. Survey methodology and study limitations

Data Collection & Analysis Methodology

With reference to Greater Vancouver, Regional District (Census division), 2016, data,[10] the final dataset was weighted according to age, gender, household income, home ownership, and whether or not there are children in the household. The dataset weighting efficiency is 94%[11]. Throughout the analysis, discrepancies in or between totals are due to rounding. All statistics presented have been generated from weighted data. The statistical significance level was set at alpha level of 0.05, 95% confidence.

The results presented in **Chapter 6** and **Appendix C** outline the findings from contingency and multiple regression analyses with respect to Metro Vancouver households' (respondents') laundry and clothing purchase behaviours, environmental concerns and attitudes, apparel sustainability attitudes, and interventions preferences. The information outlined in the charts provide insights regarding correlations between variables (demographic, attitudinal, and behavioural).

With the exception of multiple-choice questions, all closed-ended questions were numeric 11-point Likert scales with semantic anchors at 0, 10, and 5 as the 'neutral' position. The numeric Likert scale of 0 to 10 was employed so that, wherever necessary for analysis, the responses could be considered as continuous, enabling the use of statistical tests for continuous data. Further, the continuous nature of responses from 0 to 10 enables reliable and consistent collapsing of small categories into larger ones, in the form of categorical variables, providing ease of clear and consistent contingency analysis.

The numeric scale could function as both an interval scale, in response scales ranging from 'strongly disagree = 0' to strongly agree = 10' where the units are equidistant for every pair of adjacent values, and as a ratio scale where a response of zero is a true value of zero, such as frequency of a behaviour in 'Never = 0' and 'Always = 10' (Toepoel, 2015).

Unless otherwise stated, the responses to Likert scale questions were collapsed into 3 categories: Net: 0, 1, 2, 3; Net: 4, 5, 6; Net: 7, 8 ,9, 10.

In the contingency analyses, comparisons of category proportions (percentages) for statistical significance were conducted using Z-tests, comparisons of means for open-ended numeric responses were conducted using t-tests. Means comparisons for more than two groups were done using ANOVA -type analyses. Unless otherwise stated, a significant difference found in contingency analysis is typically reported in larger size, bold, and italics type face. The multiple regression analyses were done using Ordinary Least Squares (OLS).

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[10] https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CD&Code1=5915&Geo2=PR&Code2=59&SearchText=Greater+Vancouver&SearchType=Begins&SearchPR=01&B1=All&TABID=1&type=1

[11] Weighting efficiency is the degree to which sample proportions and population proportions overlap. It is an indication of the amount of skewing necessary to converge the weights (the sample proportions and the population proportions). The closer the figure is to 100%, the less skewing was needed. Typically, weighting efficiency of ≥80% is considered very good; weighting efficiency ≤70% is biased and problematic.

Study Limitations	Using an online panel of individuals through a reputable panel company, such as Angus Reid Forum, has important advantages such as efficiency in recruiting a representative sample and reducing the likelihood of socially desirable responses which may be observed in telephone or in person interviews. Further, survey respondents can be reached 'anywhere' on their mobile devices, potentially resulting in higher response rates from some hard-to-reach groups, such as professionals, minority groups, and young people. There are some drawbacks to using an online panel. The representativeness of the sample may be limited by the panel that is available (rather than the entire sampled public), attrition bias (participant drop-out), and panel conditioning (individuals' responses may be influenced by participation in prior surveys). Further, only respondents with access to internet services would be able to access the survey. However, according to the polling company the representativeness of the panel is highly reliable: > The Angus Reid Forum contains enough people in each major demographic group to draw randomized samples that represent the population as a whole. In order to ensure that all of our online research accurately represents the public in terms of both demographics and attitudes, our surveys are based upon representative samples from each panel that are randomized and statistically weighted according to the most current demographic and regional voting data available… Panels are maintained through advanced sampling techniques and frequent verifications of personal identity, contact information, and demographic characteristics. Relying on a combination of sampling regions based upon configurations of electoral districts and past voting trends, the Angus Reid Forum panels reflect the general population by continually verifying and recruiting so that the socio-demographic characteristics of each sampling region match actual sub-populations according to both the census and electoral data. Despite rigorous efforts made at stratification and quota sampling, there is potential for sampling bias. It is also important to note that the data analysed in this report are the self-reported perceptions, attitudes, behaviours (behaviour recall), and priorities. The sample statistics summarized (mean, median, and sample proportions) offer reliable estimates of the population parameters for Metro Vancouver. However, they may be less reliable in estimating the population parameters for the province of British Columbia's population.

2.3.3. Expert consultation

Two rounds of semi-structured consultations with 20 experts and stakeholders supplements the findings from the literature review and provides stakeholder input into interventions and policy considerations. The findings from the expert consultations are incorporated into the study analysis. For a complete list of interviewees and their affiliations please see **Appendix A**.

2.3.4. Policy analysis

The findings and behavioural insights from the previous steps are analysed to identify a set of recommendations and priority policy actions to address the policy problem.

Chapter 3.

From Plastic to Fibre

Globally, plastic debris is considered the most noticeable and recognizable pollutant impacting aquatic ecosystems and the ocean (United Nations Environment Program, 2016). In 2010, as much as 4.8 to 12.7 million metric tonnes of plastic waste (macro-plastics, plastic debris 5mm in size or larger) entered the world ocean; an estimate likely to increase with the growth of the consumer society and the demand for cheap and diverse plastics, which is linked with population size and economic growth (J. Jambeck et al., 2018; J. R. Jambeck et al., 2015; Lebreton & Andrady, 2019; Rhodes, 2019). Plastic litter is not biodegradable[12] and may take hundreds to thousands of years to decompose in the open environment (Barnes et al., 2009; NOAA Marine Debris Program, 2020; J. Peng et al., 2017). Rather, the wear and tear of plastics in use and the weathering, physical abrasion, and fragmentation of mismanaged waste are sources of microplastics (plastic particles 5mm to 1μm in length) in the environment (Andrady, 2017; Cózar et al., 2014; Desforges et al., 2014, 2015; J. R. Jambeck et al., 2015; National Oceanic and Atmospheric Administration, 2020; Rhodes, 2018).

Microplastics are ubiquitous, persistent, and accumulating contaminates (Geyer et al., 2017; Henry et al., 2019). They have been identified in every environment and ecosystem that has been investigated and have many sources such as microplastics which are micro-size by design (for example, plastic microbeads), or are the product of the wear and tear of various plastic products (such as vehicle tyres and apparel) (Boucher & Friot, 2017; Dris et al., 2015, 2016; Prata, 2018a, 2018b; Rhodes, 2019). An important land-based source of microplastics is household wastewater, which may carry plastic microbeads (from personal care and cosmetic products) and synthetic microfibres shed from plastic-based textiles (such as polyester, acrylic, and nylon) in the wash and released in the household washing machine effluent (Boucher & Friot, 2017; Browne et al., 2011; Prata, 2018a). While the share of each type of microplastic from land-based sources to the ocean are difficult to quantitatively estimate, the scientific community is increasingly

[12] Biodegradation is the process by which any material will naturally breakdown to its constituent elements.

convinced that more than one third of the microplastics in the world's ocean are microfibres released from household laundries[13] (Boucher & Friot, 2017).

3.1. Synthetic Microfibres, Sources & Sinks

Since 2011, when the seminal report by Dr. Mark A. Browne et al. identified washing clothes in household electric washing machines as an important source of microplastics contamination in urban wastewater, and from there the receiving environment, the profiles and predominance of synthetic microfibres as persistent environmental pollutants have been extensively investigated. Synthetic microfibres have been identified as the predominant microplastic in rivers, lakes, coastal regions, in fresh snowfall in remote regions such at the Arctic, Antarctica, and Mount Everest, even in deep-sea sediments and within some of the deepest ocean trenches (Dris et al., 2015; Huntington et al., 2020; Jamieson et al., 2019, 2019; Napper, Davies, et al., 2020; Rhodes, 2019; Ross et al., 2021). **Figure 3.1,** at the end of this chapter, provides a visual summary of microfibre emissions, sources, and sinks.

Household laundries are an important emitter of synthetic microfibres and a significant contributor to the global scale of microplastics in the environment (Boucher & Friot, 2017; Browne et al., 2011; Desforges et al., 2014; Magnusson et al., 2016). The mechanical agitation and abrasive action, use of detergents, and heat in washing machines cause the shedding of microfibres from all textiles, including synthetic and mixed fibre clothing which release synthetic (plastic) microfibres (Hartline et al., 2016; Laitala et al., 2011). A single article of clothing may shed 120 to 730,000 microfibres in the wash (Hartline et al., 2016; Henry et al., 2019; Roos et al., 2017). According to an Ocean Wise publication, the average Canadian household may annually release 444 million or 113g of microfibres in the washing machine effluent (Vassilenko et al., 2019, p. 11).

But washing machines are not the only source of microfibre pollution that can end up in the environment. According to a 2016 study, based on the mass of microfibres trapped in an electric dryer machine lint trap, household dryers may release 3.5 times

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[13] Whereas plastic microbeads from cosmetic products may makeup 2% of the microplastics from land-based sources, at the global scale, synthetic microfibres released from household washing machines account for 35% of microplastics in the world ocean (Boucher & Friot, 2017). Among the scientific and expert community, 35% is now largely considered a gross underestimate.

more microfibres from textiles than washing machines (Pirc et al., 2016). That study did not account for the amount of microfibres released from dryer vents. Most recently, the first ever study investigating microfibre release from dryer vents into the surrounding environment found one fleece blanket could, on average, emit approximately 404 to 1169 synthetic microfibres across a 30ft (9.14m) radial distance from the external dryer vent (Kapp & Miller, 2020; Miller, 2020). This corresponds with a much earlier study investigating the effects of electric dryers on fibres. The 1971 study found tumble-drying, especially over-drying, may lead to molecular-level changes that render fibres more brittle with deep cracks, that in combination with the mechanical action of the appliance, could expedite the breakdown of fibres (Goynes & Rollins, 1971; Laitala et al., 2011). Together, household washing machines and dryers are important point and nonpoint sources of microfibres in the environment.

The microfibres released from washing machines travel in the household wastewater to municipal wastewater treatment plants (WWTPs) where, depending on the types of treatment processes used in the facility, 50 - 99% of microplastics (including microfibres) are captured (Browne et al., 2011; Gies et al., 2018; Magnusson & Norén, 2014; Talvitie et al., 2017). Despite the potentially high retention rate, the supply of microplastics in a WWTPs' treated effluent is substantial (Browne et al., 2011; Carr et al., 2016; Gies et al., 2018; Magnusson et al., 2016; Magnusson & Norén, 2014). For example, although a Metro Vancouver wastewater treatment plant captures 97-99% of microplastics, annually it releases ~ 30 billion particles (including synthetic microfibres) into the receiving environment (Gies et al., 2018). As such, WWTPs are significant point-sources of microfibres.

Captured microplastics are retained by settlement in sewage sludge, which is typically further processed to create biosolids (organic matter recovered from the treatment process and commonly used for land applications such as fertilizer) (Magnusson et al., 2016; Mahon et al., 2017). Due to the rich nutrients content and potential for improving soil fertility, the land application of treated sludge and/or biosolids as fertilizer has become standard practice (Magnusson et al., 2016; Zubris & Richards, 2005). Although it calls for further investigation, an early study identified synthetic microfibres in soil samples from agricultural land treated with sludge 15 years earlier (Zubris & Richards, 2005). Runoffs from lands treated with biosolids is a known nonpoint source pollution pathway for synthetic microfibres (Magnusson et al., 2016). Similarly, synthetic microfibres shedding during the wear and tear of apparel and their release into the air in homes and the urban environment, and the aerial deposition (atmospheric fallout) from household dryer vents, contribute to another nonpoint source pollution pathway through stormwater and surface runoffs (Dris et al., 2016; Kapp & Miller, 2020; Sutton et al., 2016). The ocean serves as an important sink for synthetic microfibres.

3.2. The Environmental Burden: Organisms & Human Health

Due to their inert[14] nature, size, and shape, once in the environment, synthetic microfibres can function as both source and sink for hazardous substances and toxins (Lithner et al., 2011; Rummel et al., 2017; Waring et al., 2018). To improve fibre and textile performance, during the manufacturing process, textiles are often treated with a variety of chemical additives, such as plasticizers, stabilizers, flame retardants, dyes, and various chemical by-products (Lithner et al., 2011; J. Peng et al., 2017; Rochman, Hoh, et al., 2013). Many of these chemical additives are known carcinogens or endocrine disruptors[15] (Bejgarn et al., 2015; G. Peng et al., 2017). They may readily leach[16] into the surrounding environment, (Bejgarn et al., 2015; Lithner et al., 2011; Machado et al., 2018; J. Peng et al., 2017). Thus, synthetic microfibres pose a direct route for introducing toxins and hazardous substances into habitats.

Like other microplastics, synthetic microfibres also readily function as sinks for chemical pollutants already present in the environment. Many studies have reported hazardous substances can adsorb[17] in a complex matrix on the surface of microplastics,

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[14] Plastics are largely non-polar (not charged) and will not chemically react with other substances. They also will not undergo hydration, size, and density change. Their inert nature is one of the advantageous properties that makes plastics and plastic products such as synthetic textiles ideal for human use.

[15] Endocrine disruptors are compounds which can interfere with normal endocrine (hormonal) activity. For example, nonylphenol (NP) and its ethoxylates (NPEs) which have been used in detergents and emulsifiers for textile production and pulp and paper processing, mimic oestrogen and can disrupt the regulation of hormone levels, potentially leading to severe adverse health outcomes in organisms.

[16] Leaching is a naturally occurring process. It describes the mechanism by which substances may be emitted or extracted from materials into the surrounding environment and water, which may transport the soluble toxins throughout a wide area.

[17] Adsorption is the process by which liquid or gaseous chemicals in the environment can accumulate as a thin film on the surface of plastics.

including the heavy metals listed as priority pollutants[18] under the Canadian Environmental Protection Act (CEPA), and various organic chemical compounds that have been classified as persistent, bioaccumulative, and toxic (PBTs)[19] under the Stockholm Convention[20], (Barboza et al., 2018; Rochman, Browne, et al., 2013; Rochman, Hentschel, et al., 2014; Sendra et al., 2021; Squadrone et al., 2021). According to more recent studies, microplastics can adsorb and transport pharmaceutical substances such as antibiotics[21] in marine and freshwater systems (Jia Li et al., 2018; Santana-Viera et al., 2021). The ingestion of synthetic microfibres elevates the bioavailability of these toxins and their accumulation in the food chain (Avio et al., 2015; Jia Li et al., 2018; Rochman, Hoh, et al., 2013; Rochman, Lewison, et al., 2014). Furthermore, microfibres offer an ideal surface area for microbial and pathogen colonization, known as biofilm (Rummel et al., 2017; Zettler et al., 2013). The critical aspect of this is the capacity of microfibres to introduce and transport infectious and pathogenic organisms throughout food webs (Hall-Stoodley et al., 2004; Rummel et al., 2017).

3.2.1. The ecotoxicological burden

Depending on the organism and habitat, direct animal exposure to microfibres can occur via inhalation and ingestions. Indeed, the gastrointestinal tract and the respiratory system are considered the major locus of exposure (Lei et al., 2018). Terrestrial and aquatic organisms from a variety of trophic levels in local and remote regions have been shown to have ingested microplastics, the majority of which are synthetic microfibres (Baldwin et al., 2016; Carbery et al., 2018; Jiana Li et al., 2016, 2018; Sendra et al., 2021; Taylor et al., 2016). Once ingested by lower-trophic-level organisms, such as zooplankton or shrimp, synthetic microfibres can be transferred to higher organisms and predators throughout the food web, which may result in higher trophic organisms ingesting greater numbers of particles over time (Santillo et al., 2017; Setälä et al., 2014). Thus, synthetic

[18] The Canadian Environmental Protection Act (CEPA) has listed the following heavy metals as priority environmental pollutants: Lead (Pb), mercury (Hg), zinc (Zn), cadmium (Cd), nickel (Ni), and chromium (Cr) (Canada, 2010).

[19] Examples include, polychlorinated biphenyls (PCBs), organo-halogenated pesticides, nonylphenols, and dioxins, among others (Avio et al., 2015).

[20] The UNEP's Stockholm Convention on Persistent Organic Pollutants was adopted on 22 May 2001 in Stockholm, Sweden. The Convention entered into force on 17 May 2004.

[21] Antibiotics are considered another class of emerging environmental contaminants of concern (Jia Li et al., 2018; Santana-Viera et al., 2021).

microfibres may transfer between trophic levels and modulate the bioaccumulation[22] and biomagnification[23] of hazardous substances throughout food webs (Avio et al., 2015; Farrell & Nelson, 2013).

Ingested microfibres act as multiple stressors to organisms (Burns & Boxall, 2018; Jovanović, 2017; Rochman, 2013; Rochman, Hentschel, et al., 2014). In one respect, due to their shape and size, they are considered structural pollutants. They may damage feeding appendages or become lodged and cause obstruction, lacerations inside the gastrointestinal tract, and/or accumulation inside the organs, which have been shown to lead to false satiation, organ damage, and starvation (Lei et al., 2018; Martins & Guilhermino, 2018). Studies have also shown microfibres can become internalized by cells in the digestive system, potentially even translocate to the circulatory system and become taken up by other tissue types, leading to tissue and cellular-level damage, and/or endocrinal disfunction, caused by their presence and the contaminants they may carry (Browne et al., 2008; Jovanović, 2017; Martins & Guilhermino, 2018; Van Cauwenberghe & Janssen, 2014; von Moos et al., 2012; Waring et al., 2018). As combined structural and chemical pollutants, microplastics have also been shown to adhere to gills and reduce the organism's oxygen uptake (Guilhermino et al., 2018; Pacheco et al., 2018). A number of studies have also shown that microplastics, alone, and in combination with the contaminants they may carry (such as mercury and cadmium), can cause significant neurotoxicity[24] (Avio et al., 2015; Barboza et al., 2018; Guilhermino et al., 2018; Parra et al., 2021; Sendra et al., 2021).

According to one report on a model freshwater invertebrate,[25] the reduced individual growth, fertility, and the corresponding reduced population growth caused by chronic exposure to microplastics may be lasting (Martins & Guilhermino, 2018). In the model population, significant transgenerational impacts were observed up to 3 generations after initial exposure (Martins & Guilhermino, 2018). According to the

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[22] Bioaccumulation refers to the accumulation of toxic substances in the tissues (such as fatty tissue, gills, or liver) of any individual organism, at any trophic level, throughout a food web.

[23] Biomagnification is the increasing concentration of toxic substances in higher order animals. The pollutants are transferred between trophic levels from prey to predator.

[24] In one cited study, neurotoxicity occurs via the inhibition (by 64 to 76%) of acetylcholinesterase, AChE, an important enzyme involved in neurotransmission in the brain and muscle tissue (Barboza et al., 2018).

[25] The model invertebrate was Daphnia magna, a planktonic food source for many fish species.

investigators, the transgenerational impact suggests that continuous exposure over generations may have significant population level impacts which may lead to the potential extinction of that population.

3.2.2. The environmental burden on human health

Microplastic pollution and human health is an emerging field. However, a number of studies suggest human exposure occurs largely via inhalation and ingestion (Cai et al., 2017; Dris et al., 2015, 2017; Gasperi et al., 2018; van Dijk et al., 2021; Wright & Kelly, 2017). Recent investigations into urban aerial transport and atmospheric fallout conducted in two megacities (Dongguan City, China, and Paris, France) have revealed the great prevalence of microplastic particles in indoor and outdoor dust, majority of which are fibres (Cai et al., 2017; Dris et al., 2017). In Paris, indoor and outdoor microfibres concentrations were in the range of 1 - 60 fibres/m^3 and 0.3 - 1.5 fibres/m^3, respectively.

In August 2019, the World Health Organization published a press release on the presence of microplastics in drinking water, urgently calling for further investigations into human exposure and health impacts (WHO, 2019). To date, microplastics and microfibres have been found in processed foods and beverages such as honey, sugar, sea salt, beer, bottled water, and tap water (Karami et al., 2017; Kosuth et al., 2018; Liebezeit & Liebezeit, 2013, 2014). The marine and fresh-water field studies investigating the prevalence of microplastics and microfibres in the environment also point to the high degree of contamination in many commercially important seafood species, including molluscs, crustaceans, and fish (Dehaut et al., 2016; Rochman et al., 2015; Santillo et al., 2017; Seltenrich, 2015; Setälä et al., 2014; Van Cauwenberghe & Janssen, 2014). One study estimates that American adults and children are on average exposed to 74,000 to 113,000 microplastic particles (combined total inhalation and ingestion) annually (Cox et al., 2019, 2020).

3.3. Natural & Semi-synthetic Materials

Synthetic microfibres from clothing have been at the centre of much of the discussions and research on microfibres emissions from household laundries. This is in part because microfibres shed from 100% cotton and 100% rayon fabric (without any chemical additives) are readily biodegradable in aerobic environments (Zambrano et al., 2019). However, when controlling for fabric knit construction, cellulosic[26] fibres such as cotton and rayon, and semi-synthetic cotton/polyester blend fibres shed significantly more microfibres during the wash than polyester (Napper & Thompson, 2016; Sillanpää & Sainio, 2017; Zambrano et al., 2019).

So-called natural fibres and semi-synthetic materials pose significant negative environmental impacts. Indeed, according to experts, a “natural fibre” labelling typically indicates that the fibres originate from a renewable resource, such as cotton or wool, but have been anthropogenically modified to achieve the desired properties (Athey, 2020; Mertens, 2020). Natural fibres often require extensive chemical treatments to enhance their performance and may carry up to one third of their weight (5 ~ 30%) in synthetic chemistry including dyes, softeners, and various finishing chemicals (Athey, 2020; Ellen MacArthur Foundation & Circular Fibres Initiative, 2017; Erdle, 2020; Mertens, 2020). By contrast, dyeing polyester requires fewer chemical additives than cotton (NRDC, 2012 in Ellen MacArthur Foundation & Circular Fibres Initiative, 2017). The various synthetic chemical additives which coat many naturally-sourced fibers likely significantly hinder their biodegradation (Athey, 2020). For interest, a 2001 study investigating the microbial degradation of textiles from a shipwreck which had been submerged 2,200m deep in the Atlantic Ocean for 133 years found that dyed fibre samples were less degraded than undyed fibre samples from the same item of clothing (Chen & Jakes, 2001).

Studies investigating the prevalence and persistence of synthetic microfibres in remote regions have also reported high percentages of anthropogenically modified cellulosic and protein-based fibres (Athey et al., 2020; Barrows et al., 2018; Huntington et al., 2020; Peeken et al., 2018; Ross et al., 2021). In one study, cotton, wool, and an unidentified cellulosic fibre accounted for 32% and 30% of coastal and open ocean samples, respectively (Barrows et al., 2018). Anthropogenically modified cellulosic fibres have also been identified in remote Arctic sediments, ~1500m deep, where 51% of microfibres in sediment samples were anthropogenically modified cellulosic fibres, 41% of which were indigo denim (Athey et al., 2020).

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[26] Cellulose-based fibres are those which can be obtained from plants, such as cotton, rayon (also knowns as viscose), hemp, and linen. Other natural fibres include protein-based fibres, which are those from animal sources, such as silk and wool.

Another recent study which compiled global data from seawater samples collected from ocean basins around the world showed that anthropogenically modified cellulosic fibres (e.g. cotton) and animal protein-based fibres (e.g. wool and silk) account for 91.8% of microfibres from all samples collected (Suaria et al., 2020). According to the authors, "Most fibres floating in the world's oceans are not plastic but dyed cellulose" (Suaria et al., 2020, p. 3). The authors further suggest that misidentification of fibres of natural origins in many previous studies may have led to inflation of the microplastic count in the environment and organisms. Altogether, these findings indicate that, much like synthetic microfibres, microfibres shed during the laundering of so-called natural fibres are accumulating in remote regions and may be persistent in the environment over the span of, at least, decades (Athey, 2020). Moreover, the large majority of microfibres (67%) analysed from indoor air samples in Paris were from anthropogenically modified fibres of natural origins (Dris et al., 2017).

According to a freshwater biologist, microfibres shed from anthropogenically modified fibres have been found alongside synthetic microfibres in every taxon examined, from marine benthic organisms to birds and mammals (Erdle, 2020). Although the environmental impacts of microfibres shed from laundering so-called natural fibres remain largely unknown, a forthcoming publication from the Rochman Lab in University of Toronto indicates that even untreated fibres (fibres which have not been chemically modified in the production process) may pose a significant risk to biota. The preliminary findings from the study investigating the impacts of exposure to microfibres in marine organisms suggests there are no differences in the impact of 100% cotton microfibres and 100% polyester microfibers on growth, survival, or population-level effects. Another recent study comparing the impacts of natural-based versus petroleum-based microfibres report similar adverse effects and mortality, irrespective of fibre type (Kim, 2021).

Microfibres shed from anthropogenically modified fibres appear to be 10X more prevalent in the environment than their synthetic counterparts. An overwhelming majority of these are cellulosic (79.5%); cotton accounts for 50% of all fibres, proteinaceous fibres account for an additional 12.3% (Suaria et al., 2020). As recent studies indicate, anthropogenically modified fibres are persistent and accumulating in the environment. These considerations should be accounted for when evaluating policy actions to address the policy problem and indicate the importance of focusing on laundry practices and technologies that can reduce all microfibre pollution regardless of their source.

3.4. Risks & Policy

3.4.1. Ecosystem exposure and vulnerability

As was outlined in previous sections, microfibres have been shown to serve as both sources of and sinks for hazardous substances and can readily transport infectious and pathogenic organisms throughout local food webs and introduce them into food webs in remote regions. Various studies have shown that once ingested or inhaled, microfibres can leach toxins into the animal's bloodstream and pose adverse impacts on normal function. In model organisms, intestinal damage is a key effect which, depending on the microplastic and the co-contaminants they may carry, has been shown to lead to endocrine disruption and transgenerational reduction in growth and fertility (Erdle, 2020; Lei et al., 2018; Martins & Guilhermino, 2018). Other impacts include oxidative stress, inflammatory response, and neurotoxicity caused by the presence of heavy metals and microplastics, individually and in combination (Barboza et al., 2018; Guilhermino et al., 2018; Parra et al., 2021).

For many of the priority contaminants, adverse ecotoxicological impacts are dose-dependent (Bose-O'Reilly et al., 2010; Fernandes et al., 2020; Mansilha et al., 2013; Mueller, 2020; Yu et al., 2021). A recent publication on the interaction of microplastics and heavy metal pollutants in marine waters reports that plastics perform a key functions as vectors for toxicants in marine systems (Squadrone et al., 2021). Over time, plastics in the open environment not only become increasingly hazardous as they continue to accumulate greater concentrations of pollutants and pathogens from the surrounding environment, but are also able to concentrate heavy metals several orders of magnitude higher than the surrounding environment (Rochman, Hentschel, et al., 2014; Squadrone et al., 2021). Chronic exposure to microplastics, including synthetic microfibres, can potentially exert higher toxicity on organisms (Squadrone et al., 2021). Moreover, when considered within the context of a food web, negative impacts of microfibres on the survival, growth, and fertility of zooplankton may in turn impact fish and cetaceans for which they are an important food source (Desforges et al., 2014, 2015; Nobre et al., 2015; Squadrone et al., 2021).

Indeed, synthetic microfibres account for ~75% of plastic particles sampled from sub-surface seawaters in coastal British Columbia (Desforges et al., 2014). An investigation into two foundation invertebrates (zooplankton) species[27] along the same region found that the lower trophic organisms are mistaking microplastics for food (Desforges et al., 2015). The authors estimate that, by consuming microplastic-containing zooplankton, juvenile salmon ingest 2–7 microplastic particles per day, while returning adults ingest ≤91 particles per day. Likewise, not including plastic particles ingested directly from water, a humpback whale (*Megaptera novaeangliae*) in coastal British Columbia which would daily consume 1.5% of its body weight in zooplankton and krill would ingest >300,000 microplastic particles/day (Desforges et al., 2015). As was described earlier, the trophic transfer of microfibres can modulate the bioaccumulation of microplastics in an organism's digestive tract and other tissues and biomagnification of hazardous substances throughout food webs (Avio et al., 2015; Browne et al., 2008; Desforges et al., 2014; Farrell & Nelson, 2013; Wright et al., 2013).

With respect to interactions of microplastics with persistent organic pollutants (POPs) the impacts are less clear. Microplastics are not the only sink for hydrophobic organic pollutants[28] (i.e., other materials in the marine environment may sorb more pollutants than plastics), and likely not the biggest (Koelmans et al., 2016; Lohmann, 2017; Ziccardi et al., 2016). However, as human population grows, the corresponding growth in plastic and textile consumption may change that balance. Further, as noted by Lohmann (2017, p. 464), even in the case that microplastics and synthetic microfibres may not significantly impact the transport of POPs, their potential for other detrimental impacts (described in previous sections) on the environment should not be underestimated.

3.4.2. Human exposure and vulnerability

As early as the 1970s, a number of studies investigated exposure to synthetic microfibres such as nylon flock[29] and the occupational health and safety among textile

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[27] Also known as keystone species, a foundation species is an organism that defines an ecosystem by controlling and modulating critical processes that impact a great variety of features of the ecosystem and impacts the biological diversity of associated organisms. As it is not a formal scientific designation, there may be some debate among scientists about which species in an ecosystem are foundation species.

[28] Hydrophobic (water-repelling) organic chemicals (HOCs) include organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocabons (PAHs).

[29] Flocking is a process by which many small fibres are glued to a surface in order create a fluffy or velvet-like texture. It is commonly used in fabrics for clothing, textured wallpaper, and upholstery.

workers (Burkhart et al., 1999; Muittari & Veneskoski, 1978; Pauly et al., 1998; Pimentel et al., 1975; Washko et al., 2000). Their findings suggest a link between chronic exposure to microfibres (chronic inhalation) and respiratory conditions such as inflammation of the nasal mucous membrane, shortness of breath, pulmonary inflammation, asthma, and lung cancer. Although the majority of inhaled fibre particles may be eliminated from the human respiratory system via mucociliary action, some may persist and cause localized inflammatory responses (Gasperi et al., 2018; Wright & Kelly, 2017). According to Pauly et al. (1998), much like asbestos, synthetic and natural (cellulosic) fibres' resistance to biodegradation "may contribute to different pulmonary diseases, including lung cancer" (p. 427).

More recent studies report microplastics, including synthetic microfibres, in all samples tested from human intestines (Ibrahim et al., 2021; Schwabl et al., 2019). The current trend in investigating human health impacts is via simulation experiments. A simulation study investigated the release (bioaccessibility and bioavailability) of heavy metals (specifically chromium (Cr) and lead (Pb)) carried by microplastics in an in vitro model of the human gastrointestinal tract (Godoy et al., 2020). The study showed that more than 23% of the Cr and Pb initially present in microplastics were able to translocate across tissue boundaries during intestinal absorption. Results from a lung organoid study, a cultured model of human lung epithelial cells, indicate that leachate[30] from nylon microfibres can drive toxicity, potentially inhibiting cellular repair pathways (van Dijk et al., 2021).

Perhaps, human health vulnerability is most emblematically understood when considering maternal and fetal exposure to neurotoxic heavy metals such as lead (Pb) and mercury (Hg) and the resultant epigenetic[31] aberrations (Cardenas et al., 2017). Indeed exposure to these metals have been linked to significant neurotoxicity, especially for foetuses and young children (Bose-O'Reilly et al., 2010; Kayaalti et al., 2015). Most

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[30] Leachates are the substances leaking from the fibre, which in this case are nylon leachates.

[31] An epigenetic aberration is a defective change in DNA expression and the genetic programs that are heritable and necessary for healthy tissue function. Epigenetic aberrations may occur due to exposure to toxins. Such aberrations have been linked to maternal and fetal exposure to neurotoxicants such as mercury (Cardenas et al., 2017).

recently, microplastic particles[32] were isolated from 4 out of 6 samples of human placenta, highlighting the potential exposure of the foetus to plastics and the chemical toxins[33] they may carry (Ragusa et al., 2021).

The implications of exposure to microfibres for human health may take some time to be adequately understood. Moreover, the correlation between microfibre exposure and potential epigenetic aberrations and resultant diseases such as lung cancer[34] remains to be fully established. However, it may be that similar to inorganic fibres (including fibre glass, mineral wool, and slag wool) that replaced asbestos, and which have been investigated for decades, the health impacts of synthetic and anthropogenic microfibres are correlated with dose (the number of fibres deposited in an organ), dimension (longer fibers are more persistent because they readily become lodged in tissue), and the durability (the biopersistence and resistance to degradation) of inhaled or ingested fibres (Pauly et al., 1998; Warheit et al., 2001). It is, therefore, important to consider a precautionary approach to protecting human populations from the potential health risks posed by microfibre emissions.

3.4.3. The Precautionary Principle

As global and local populations grow and become increasingly industrialized, mitigation and adaptation strategies to address microfibre emissions from domestic sources and targeting the lifecycle of textiles may become necessary. The previous sections illustrated that there is need for concern about the long-term adverse effects on humans and ecosystems. However, the current knowledge gaps about risks necessitate a precautionary approach to reduce current impacts and minimize potential future threats.

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[32] Due to lack of access to technology that would minimize likelihood of contamination from airborne synthetic microfibres, any synthetic fibres found in the samples were not counted in the results (Ragusa et al., 2021, p. 3)

[33] For example, in the case of mercury (Hg), transplacental absorption is a known pathway for foetus exposure (Bose-O'Reilly et al., 2010). Moreover, foetal exposure to mercury via maternal seafood consumption is well documented.

[34] There is a strong correlation between epigenetic aberrations in cellular activity and cancerous lesion formation (Ducasse & Brown, 2006).

The precautionary principle, Principle 15[35] of the Rio Declaration on Environment and Development, states that "… Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation"(European Commission, 2017; UNEP, 1992). The 1987 Montreal Protocol[36] is an example of the Principle's implementation. The experts and stakeholders interviewed for this study widely promote the adoption of the precautionary principle as a necessary first step to address the environmental impacts of microfibres emissions from apparel (Athey, 2020; Coffin, 2020; Erdle, 2020; Laitala, 2020; Mertens, 2020; Stevens, 2020; Wyer, 2020). Indeed, policy actors in the State of California may apply this principle as they develop a risk assessment framework to set health and ecotoxicological thresholds for microplastics, including synthetic fibres (Coffin, 2020; Wyer, 2020).

When examined through the lens of the precautionary approach set out in UNEP Principle 15 and the Stockholm Convention on Persistent Organic Pollutants, with the objective of protecting human health and the environment, microfibres (shed from fibres made of renewable and non-renewable resources) meet the majority of the qualifying criteria[37] to be categorized as persistent organic pollutants. Namely:

- ✓ They are carbon-based compounds.
- ✓ They are persistent (resist degradation) in the environment.
- ✓ They are widely transported throughout the environment, by air, water, migratory species, across international boundaries, and are deposited far from the origin of their release, where they accumulate in terrestrial and aquatic ecosystems.
- ✓ They accumulate in tissues of living organisms.
- ✓ They are toxic to humans and wildlife.

According to a report made for the European Commission, "We may not fully understand the impacts of microplastics in the terrestrial, freshwater, or marine environments, but […] we know the impacts are negative, and expect that furthering our

[35] The precautionary principle is Principle 15 of the United Nations Environment Program (UNEP) 1992 Rio Declaration on Environment and Development.

[36] The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer (The Montreal Protocol, 1987) is widely considered the most innovative and successful international environmental intervention and protection agreement (Gonzalez et al., 2015). Its success is attributable to the application of the precautionary principle.

[37] The list of criteria was extracted from (UNEP, 2001).

understanding will highlight new and potentially more severe impacts" (Hann et al., 2018). Another report suggests "… there are significant grounds for concern and for precautionary measures to be taken" (European Commission, 2019). Some scientists and textile experts go further to recommend applying the precautionary approach to all fibre types, to address the persistent synthetic chemistry associated with so-called natural and mixed fibres (Athey, 2020; Mertens, 2020).

3.5. Source Control

According to a recent global material flow analysis, the combined annual synthetic[38] microfibre emissions to terrestrial environments and landfills have been historically large and are now exceeding emissions to bodies of water (Gavigan et al., 2020). The flow chart provided in **figure 3.1** illustrates the sources, flow, and sinks for microfibres. It is clear that source reduction is the only way to reduce microfibre emissions into the environment. Textiles are the primary source of microfibre emissions and require targeted policies to reduce emissions during the production-phase (fibre engineering, textile manufacturing, fashion design, cutting and sewing), use-phase (wear and tear, and laundering), and end-of-life (landfilling v. recycling).

Policies which do not target textiles directly will only succeed in shifting the emissions burden from one source to another. Put differently, in the absence of policies targeting textiles, indirect interventions can reduce emissions from appliances but the captured microfibres will need to be disposed of in landfills and/or incinerated (if disposed of appropriately). And depending on the type[39] of landfill facility, either the microfibres will be introduced directly into the environment from poorly managed open dumpsites (by becoming airborne or reaching bodies of water via surface runoffs) or, in the case of sanitary landfills, some of the microfibres and the hazardous substances they carry may be released in the landfill leachate and potentially reach the open environment. These potential sources of emissions have not been investigated. However, in either case,

[38] It's worth emphasising that the cited study investigated synthetic microfibre emissions; global historical flow of microfibres shed from natural fibres (e.g. cotton or wool) were not estimated. It may be assumed that a similar investigation of microfibre emissions from natural fibres would arrive at much larger estimates.

[39] Depending on the level of environmental regulatory oversight on waste generation and disposal, waste management in Canada and around the world may vary from poorly operated dumpsites to sanitary landfills.

although direct emissions from household laundries would be diminished in the short-term, landfilling of microfibres is not a viable long-term pollution reduction strategy.

As this chapter illustrated, microfibres and the complex chemistry they carry can be considered hazardous substances in domestic waste flow. In general, the consequences of poor waste management on the environment and human health are manifold but are not the topic of this study. It is important to note, however, that policies which redistribute the microfibre burden form air and water emissions to landfills do not eliminate the pollution issue but only divert it from one site to another.

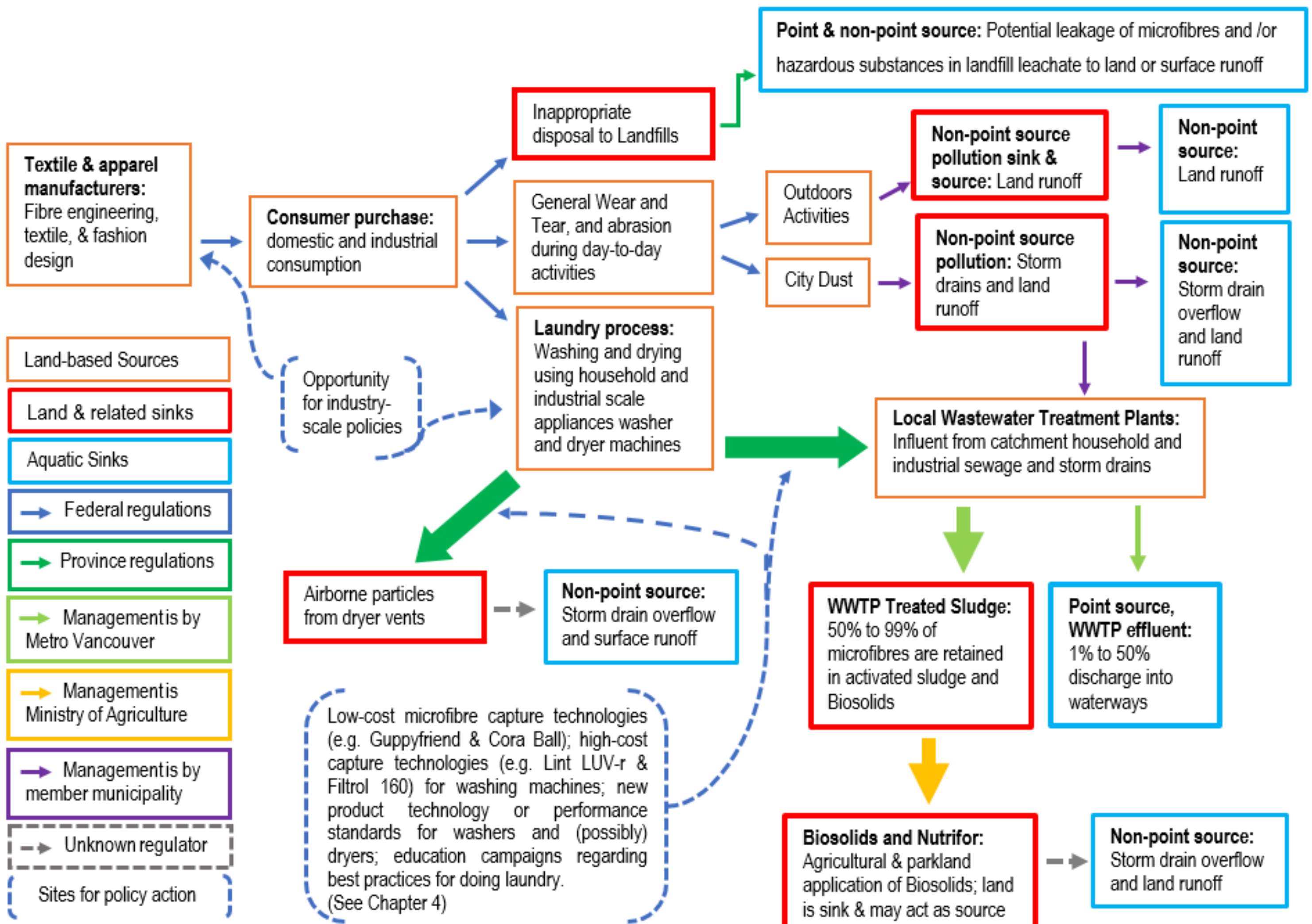

Figure 3.1. Microfibre emissions, sources and sinks, logic flow chart

The figure excludes microfibre emissions from households which are not connected to a centralized wastewater treatment system, such as sceptic tanks.

Chapter 4.

Recommended Interventions

The previous chapter illustrated that microfibre emissions from clothing and fashion consumption is a critical un-costed in-use externality of textile and fashion consumption[40]. A number of organizations such as Ocean Wise, Ellen McArthur Foundation, the International Union for the Conservation of Nature (IUCN), Eunomia and ICF (report for the European Commission), and the National Zero Waste Council[41] (NZW), have proposed intervention options and strategies to reduce synthetic microfibre release during the use-phase of textiles (Boucher & Friot, 2017; Ellen MacArthur Foundation & Circular Fibres Initiative, 2017; Hann et al., 2018; NZW, 2019; Surfrider Foundation, 2020). A summary of the recommended interventions and, where possible based on existing literature, their estimated efficacy is outlined at the end of this chapter in **tables 4.1** to **4.4**.

A majority of the interventions, in both demand- and supply-side, are source reduction measures that aim to reduce the release of microfibres at either the production and/or point-of-purchase of clothing and/or during their use-phase, thereby reducing emissions into the WWTP influent. For example, given the differential shed rate of textiles based on fibre type, water temperature, detergent use, wash cycle length, and laundering frequency, interventions to improve laundry behaviours and habits are considered a first step household-level intervention (Lant et al., 2020; Surfrider Foundation, 2020). This approach requires the provision of information regarding sustainable laundry practices and consumer engagement with product care instructions. Point-of-purchase product labelling is another information-based approach to address the issue. Other source-reduction measures include incentivising consumer adoption of microfibre capture technologies and implementing taxes or subsidies on apparel merchandise.

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[40] Other negative externalities during the use-phase of textiles include emissions of synthetic chemistry used to treat textile to meet consumer product performance preferences, emissions of laundry detergents which may be harmful to the environment, and energy consumption of laundry appliances, among others.

[41] In 2019 the National Zero Waste Council recommended a 'modified EPR' system in which clothing manufacturers would contribute to research and interventions strategies (NZW, 2019).

In jurisdictions where legislative action has been taken, legislation has focused on microfibre capture technologies in washing machines. In North America, the State of California, and the Province of Ontario[42] have developed policy bills that would mandate pre-installed filters on washing machines. In France, all new washing machines must have a pre-installed filter by 2025 (Van Holsteijn, 2020).

Setting product performance standards for apparel that would mandate a maximum fibre shed threshold is another regulatory approach to minimize the market availability and consumption of apparel made of high shedding synthetic fibres. Critically, experts report that implementing a credible metric for assessing shedding of microfibres as part of textiles' sustainability profile is a realistic opportunity to implement and monitor mitigation strategies (Henry et al., 2019; Laitala, 2020; Mertens, 2020; Stevens, 2020). The Microfibre Consortium and American Association of Textile Chemist and Colourists are currently developing standardized shed rate measurement techniques (Mertens, 2020; Stevens, 2020).

Other options are WWTP upgrades and extended producer responsibility (EPR). WWTP upgrades would address the capture and retention of synthetic microfibres (and other microplastics). EPR programs would offset the costs of necessary capital expenditures for WWTP upgrades to meet higher capture rates and promote the household level adoption of capture technologies. At present there does not appear to be any publications that address the safe capture and disposal[43] of microplastics from WWTPs. Nor have any bodies put forward a framework for developing and deploying an extended producer responsibility (EPR) program to address microfibre emissions from textiles and apparel.

[42] In the province of Ontario, a new Private Members Bill is in the works, but details have not yet been publicly disclosed.

[43] Although, depending on the WWTP treatment efficiency level, up to 99% of microplastics may be captured, the retained microplastics are trapped in the treated sludge which is commonly used as biosolids for agricultural land treatments.

Table 4.1. Summary of proposed management options for microfibre reduction, examples and related consideration: Provision of information

Demand-side management		
Provision of information	*Information campaigns*	The State of Connecticut House Bill HB5360 implemented a law mandating the establishment of a working group to develop consumer awareness campaigns and education programs that address microfibres shedding from apparel (Substitute House Bill No. 5360; Public Act No. 18 - 181, 2018; The Act Concerning Clothing Fiber Pollution, 2018)
	Product care instructions	The State of New York Bill A10599 (May 8, 2018) was referred to the Committee on Environmental Conservation. The new legislation would have required that by January 1, 2020, all new clothing composed of 50% or more synthetic material include an additional care and maintenance label to note handwashing is either recommended or required (Bill A10599, 2018). The Bill failed (Bill Track 50, 2018).
	Sustainability hang tags point-of-purchase intervention	California Assembly Bill AB-2379, 2017 – 2018, would have required that new clothing made from new fabric containing more than 50% synthetic material to carry a point-of-sale label (such as a hangtag or sticker) warning that the garment releases plastic microfibers when machine washed. Product care label should provide the same information. The label would, in that case, recommend consumers to hand wash the clothing item. If passed, sale of clothing without this label would have been prohibited from 1 January 2020. AB-2379, "died on inactive" (AB-2379 Waste Management: Plastic Microfiber., 2017) . France may introduce a labelling requirement for apparel brands to display an environmental rating based on a set of sustainability criteria, including carbon emissions and chemical use in the production process (Remington, 2020b; The Connexion, 2020).

Table 4.2. Summary of proposed management options for microfibre reduction, examples and related consideration: After-market technologies

Demand-side management		
After-market technologies	*Microfibre capture washing machine filter retrofit*	An external filter that can be retrofitted to the washing machine drainage pipe works via dynamic filtration action. That is, after the initial wash load and before each filter cleaning event, the filter capture rate becomes more efficient with subsequent wash loads. The filter must be cleaned every 10 to 15 loads of laundry (Jollimore, 2020). According to one study, Lint LUV-R may capture on average 87% of microfibres (by count) per wash-cycle (McIlwraith et al., 2019). However, another study has reported only a 29%, by mass, reduction in microfibres release (Napper, Barrett, et al., 2020). The differences may be due to different experimental and measurement protocols. For the purposes of a pilot study, in the town of Parry Sound, Ontario (population: 6000 year-round residents) 100 Wexco Environment Filtrol160 systems were installed on 100 domestic washing machines (a catchment of 1000 households). Preliminary findings indicate 10% reduction in microfibres emissions from 1000 households to the wastewater treatment plant, proving the filters work. Findings will be published in summer 2021.
	Microfibre capture wash bag *(e.g., Guppyfriend, ~$40.00 + taxes and shipping)*	Guppyfriend is a 100% polyamide washing bag (50x75cm). According to the product website, the Fraunhofer Institute UMSICHT has confirmed that the Guppy Friend can reduce the breakage of synthetic textiles by 86% and has 90% microfibre retention rate (Global, 2018). However, a recent study reported a 54% capture rate, by mass (Napper, Barrett, et al., 2020).
	Cora Ball	The Cora Ball is and in-wash laundry machine accessory that may trap up to 31% of microfibres from a load of laundry (McIlwraith et al., 2019; Napper, Barrett, et al., 2020). Unlike the Guppyfriend, it may capture microfibres from all apparel in a wash cycle.
	Wastewater treatment plant upgrades	At present scalable technologies for the capture and safe disposal of microfibres and microplastics at the WWTP do not exist. Captured microplastics are retained in the sludge which may be sold as biosolids for treatment of agricultural and park lands.

Table 4.3. Summary of proposed management options for microfibre reduction, examples and related consideration: Product performance standards

Supply-side Management		
Product emissions & performance standards	*Washing machine manufacturer installed microfibre filter*	California Assembly Bill AB-3232, required that by January 2023 all commercial washing machines have a preinstalled filtration system with 90% or greater filtration rate, reportedly at a mesh size of 150 microns. (Bill AB-3232 Commercial Washing Machines: Microfiber Filter., 2020). The bill failed on 08, 21, 2020. More recently, a member of the California Assembly has put forward AB-622, which requires that on or before 01 January, 2024, all new washing machines sold in California must be fitted with a microfibre filtration system with a mesh size of 100 microns or smaller. In the coming weeks, two Members of Provincial Parliament in Ontario will introduce a Private Member's Bill: "Environment Protection Amendment Act: Microplastic Filters for Washing Machines, 2021." The Bill would require all new residential washing machines in Ontario be equipped with microfibre filter technology 100 microns or smaller. No further details have been disclosed.
	Transforming fibre engineering and textile (clothing) design and construction	Today, >60% of all new textiles on retail store shelves are made from synthetic fibres. Designing new materials which are biodegradable and have a low microfibre shed rate is considered a critical step in microfibre reduction (Ellen MacArthur Foundation & Circular Fibres Initiative, 2017; Environmental Audit Committee, 2019)
	Phasing out substance of concern from textile production *(supply-side management)*	There are numerous substances and chemicals used in the production of textiles which are persistent organic pollutants. Industry must commit to phase these out (Ellen MacArthur Foundation & Circular Fibres Initiative, 2017).

Table 4.4. Summary of proposed management options for microfibre reduction, examples and related consideration: Market-based instruments

Indirect Demand-side Management		
Market-based Instruments	*Modified extended producer responsibility*	In 2019, the National Zero Waste Council recommended a 'modified EPR' system in which manufacturers of clothing made from synthetic fibres would contribute to research and interventions strategies (NZW, 2019).
	Consumer rebate program	Tax or rebate programs to shift the balance of producer and consumer incentives toward reuse, repair, and recycling of apparel and/or production and consumption of textile products containing recycled PET (Environmental Audit Committee, 2019).
	Consumer tax program	Sweden has halved the VAT on product repairs, including apparel repairs, from 25% to 14% (Orange, 2016).

Chapter 5.

Barriers to Emissions Reductions

Developing effective and efficient policies for reducing microfibre emissions from household laundries requires identifying the barriers to interventions; albeit they are largely attributable to the barriers to sustainability in the textile and fashion industry. In recent years, in part due to the global media coverage of synthetic microfibre pollution, the sustainability of an article of clothing throughout its lifespan has come under increasing scrutiny (Messinger, 2016). There is a strong consensus that long-term sustainability in the fashion industry and reduction in microfibre emissions can only be brought about by transforming the industry from the existing linear system to a circular economic model, (Ellen MacArthur Foundation & Circular Fibres Initiative, 2017; Environmental Audit Committee, 2019). Accordingly, addressing synthetic microfibre emissions from home laundries necessitates systems-level solutions.

This chapter provides a brief summary of a set of barriers that are deeply interlinked in how they thwart progress toward sustainability and circularity. Effective and efficient policies for addressing microfibre emissions should be able to address or overcome many, if not all, of these barriers. However, as will be apparent, the large-scale changes needed are beyond the scope of this paper and focus is on actions that are within the feasible realm of a provincial government.

5.1. Cheap Fashion

Since the 1990s, the market price of apparel products has been in continual decline while consumption has been on the rise. Between 2000 and 2014, globally, the average consumer purchased 60% more garments per year (Remy et al., 2016). In the same period, clothing production more than doubled. Looking forward, the industry anticipates an 81% increase in production by 2030 from 2019 levels (Kent, 2020). Moreover, consumers keep their garments half as long as they did 20 years ago and discard them after 7 to 8 wears (Remy et al., 2016). In the US, the volume of discarded clothing doubled in the last 20 years, from 7 to 14 million tonnes (Fuhr & Franklin, 2019). According to some reports, consumers tend to treat the lowest-priced products and apparel as disposable because it is cheaper to buy a new item than repair an old one (Canada & ECCC, 2019, p. 10; Remy et al., 2016, p. 2). Reportedly, a UK study published in November 2020 which investigated Google Trends during the first UK lockdown in response to the coronavirus pandemic, found that online searches for ‘cheap clothes’ increased by 46.3% compared to the previous year (Remington, 2020a). Estimates suggest by 2030, the global consumption of apparel will increase by 63% from 2017 levels (Environmental Audit Committee, 2019; Whiting, 2019).

Figure 5.1 illustrates the declining trend in the Canadian annual average consumer price index (CPI) of clothing in comparison with food products between 2003 and 2020. The declining trend has been global (Mertens, 2020; Remy et al., 2016). Shown in **figure 5.2**, women’s and children’s clothing have seen greater declines in price than other categories. With respect to fashion consumer spending in constant dollars (USD, base year 2017), Canadians ranked 4th in the world (among 148 countries) in per capita expenditure on fashion, see **figure 5.3.** In 2019, Canadian households spent an average of 3,340 CAD[44] on clothing and accessories (Statista, 2021c).

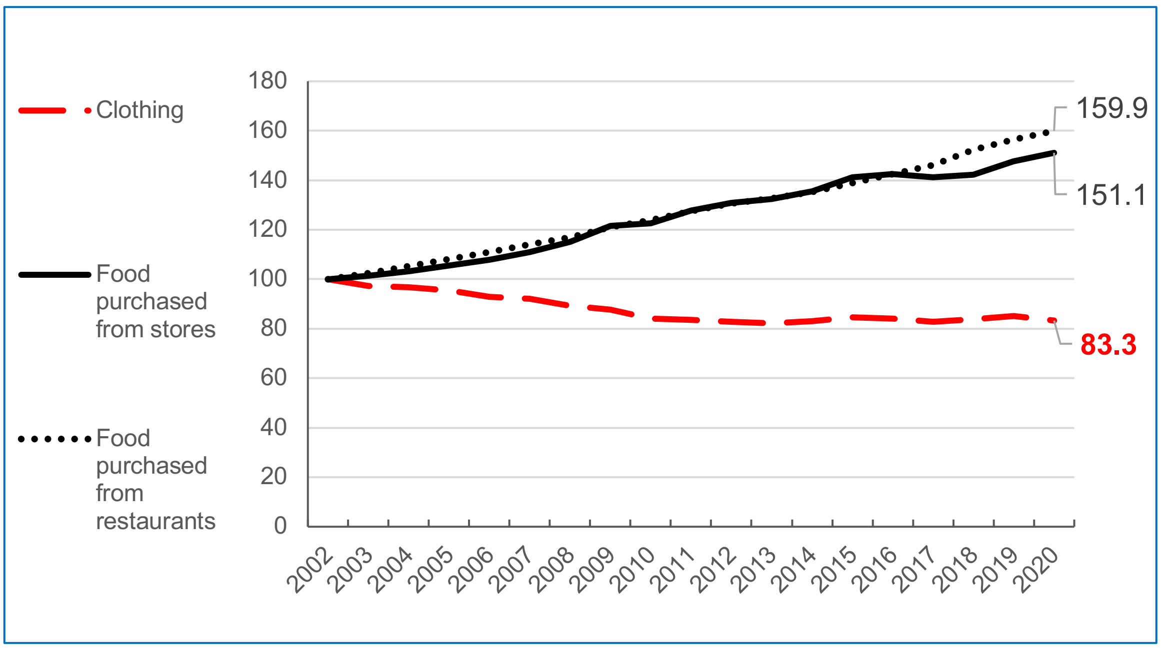

Figure 5.1. Consumer Price Index of clothing and food consumption in Canada, base year 2002 = 100
Data were obtained from: (Statista, 2021a; Statistics Canada, 2021).

[44] The original source for the statistic from Statista (2021) is Statistics Canada.

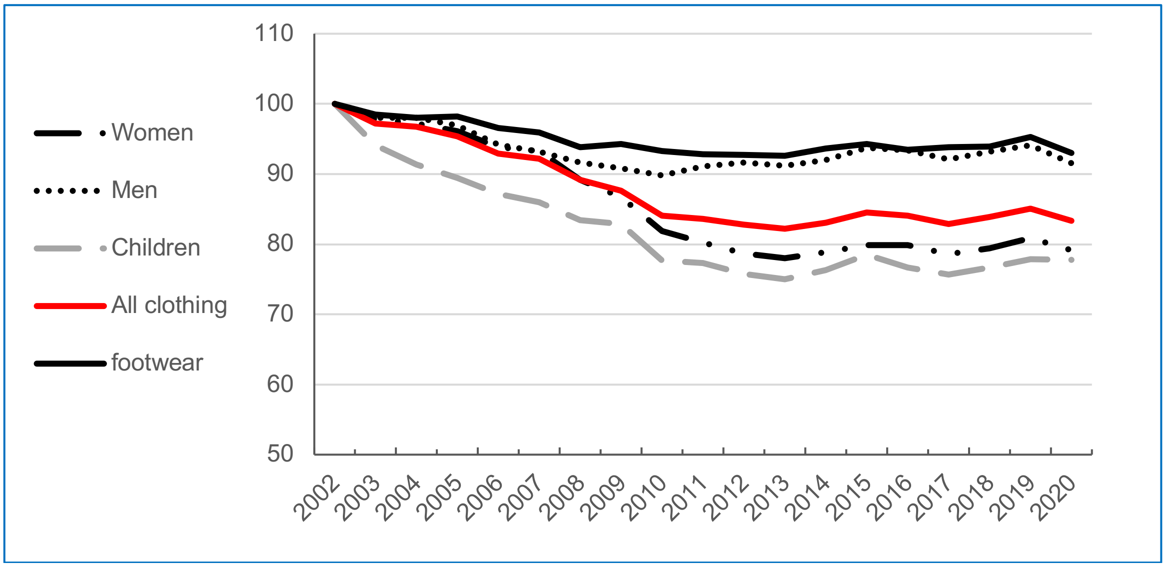

Figure 5.2. Consumer Price Index of clothing compared by categories, base year 2002 =100

Data were obtained from (Statistics Canada, 2021).

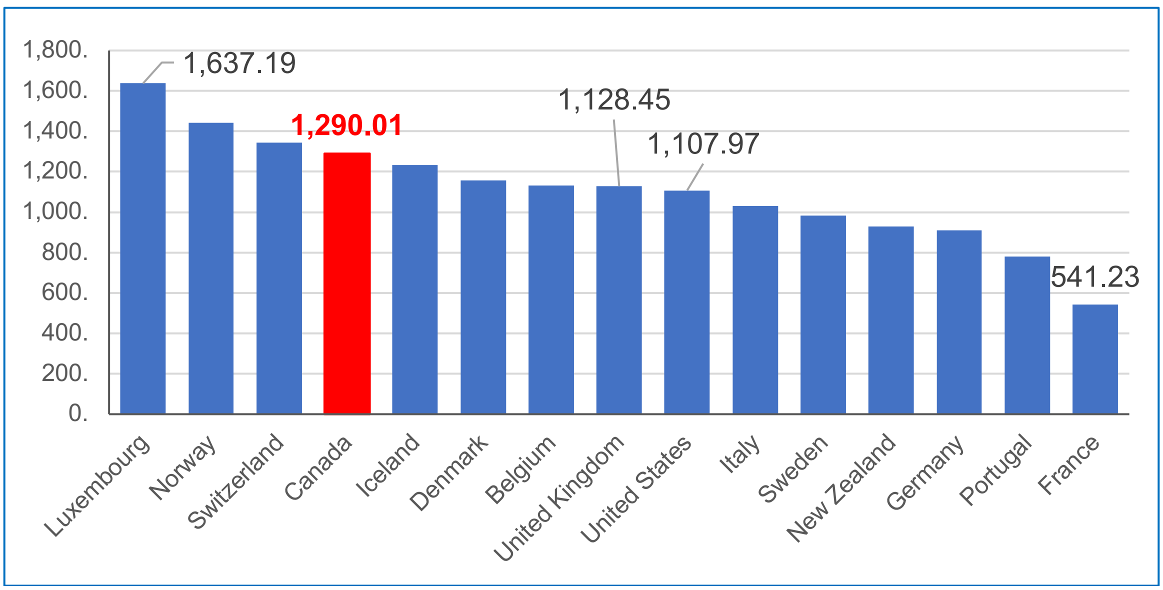

Figure 5.3. Real fashion consumer spending per capita, in 2020, by country, in USD.

The forecasts shown are based on a blend of multiple dataset inputs, including the Statista *Global Consumer Survey* and datasets from the IMF, the World Bank, the UN, and national statistics offices. The data has been converted from local currencies to USD using the average constant exchange rate of the base year 2017 (Statista, 2021b).

5.2. Cheap Plastic

Fibres which are produced with sustainability and low microfibre leakage in mind must compete with cheaper alternatives. Like other plastics, synthetic fibres such as polyester and nylon are dependent on the petrochemical sector for raw materials. In 2000, global polyester production exceeded cotton production by weight (Textile Exchange, 2019). According to a recent global material flow analysis, between 1950 to 2016, the global stock of synthetic fibres in apparel increased from 0.10 Mt to 196 Mt in 2016 (Gavigan et al., 2020). Today, synthetic fibres dominate the textile market and polyester accounts for more than 60% of all garments on retail shelves (Environmental Audit Committee, 2019; Textile Exchange, 2019).

In Canada, mechanical recycling[45] is currently the main method of value recovery from plastics and synthetic fibres[46]. Even so, the end-use markets for textiles is very weak, accounting for only 6% of the of the end-use market for plastics (Canada & ECCC, 2019). Chemical and thermal recycling of end-of-life fibres are the principal methods for recovering virgin fibres from recycled sources, facilitating continual circulation of raw materials, and limiting the leakage of persistent chemistry (Chile, 2021; Mertens, 2021; Stevens, 2020). However, Canada lacks robust infrastructure for chemical and thermal recycling of end-of-life for plastics and fibres, thereby inhibiting the transition away from the linear economy model (Canada & ECCC, 2019).

Producing fibres from renewable resources, such as cotton, wool, viscose, lyocell, costs more than plastic-based fibres and impose significant negative environmental externalities. For example, cotton is a water intensive crop and requires a great deal of chemical treatments for dyeing and crease-resistance[47] (Ellen MacArthur Foundation & Circular Fibres Initiative, 2017). The production of viscose, which is sourced from wood, requires the use of carbon disulphide (a highly toxic solvent), among other chemicals, and additional high use of water and energy. Protein-based fibres such as wool are also very expensive and require significant amounts of land and livestock, which release methane

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[45] The products of mechanical recycling include shredded fibre for insulation purposes.

[46] In Canada, textile waste is among the main sectors generating plastic waste, accounting for 7% of Canadian plastics waste (Canada & ECCC, 2019).

[47] Unlike synthetic fibres, cotton does not absorb dyes well and must undergo additional chemical treatments for dyeing.

gas, a potent greenhouse gas. Importantly, unlike naturally sourced fibres, petroleum-based fibres are not impacted by agricultural fluctuations and are therefore more stable commodity fibres as feedstock for apparel. The production of fibre from fossil fuels is also a source of greenhouse gases.

5.3. Product Design

The low cost of fashion can also be attributed to fibre engineering and product design (Laitala, 2020; Mertens, 2020). Low-cost fashion is designed to be worn very few times and quickly replaced by the latest trend. Apparel which is not designed to last may shed more fibres during its use-phase (Vassilenko et al., 2019). Fibres and clothing which are produced with sustainability in mind must compete with cheaper alternatives. Large and global low-cost fashion corporations such as H&M, Zara, and Wal-Mart have unbeatable economies of scale (Anonymous Expert #3, 2020; Mertens, 2020).

5.4. Hazardous Substances of Concern

The main chemicals used in textile production and processing include, pesticides, solvents, surfactants, dyes and pigments, plasticizers, and water- and stain-repellents. The large range of synthetic chemistry used in the processing of any type of fibres is not biodegradable and is, often, untraceable (Mertens, 2021). Any fibre treated with chemistry (dyes or performance treatments) exits the biosphere of biodegradability and enters the techno-sphere where the degradation of the chemical additives can only occur via appropriate chemical technologies. With the exception of 100% natural fibres that are entirely untreated, all fibre types may be considered synthetic and no-longer compost safe[48].

5.5. Challenges in Achieving a Fair & Sustainable Value Chain

The apparel supply chain in Canada is part of a highly complex and fragmented global web of direct and indirect industry stakeholders (Ellen MacArthur Foundation &

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[48] For example, when composting so-called 100% cotton fabrics, the cotton component may biodegrade via composting. However, the chemicals and dyes with which the fibre was treated will not biodegrade and may be released into the environment (Mertens, 2021).

Circular Fibres Initiative, 2017; Environmental Audit Committee, 2019; Remy et al., 2016). In 2019, 89.3% of apparel products sold in Canada were imported[49], the large majority of which were from developing countries[50] (Euromonitor International, 2021; Statista, 2020a). Consequently, industry transparency is very poor in every aspect of production (BOF & McKinsey, 2019; Ellen MacArthur Foundation & Circular Fibres Initiative, 2017; Environmental Audit Committee, 2019).

In part, due to the highly disjointed nature of the industry, transparency on product sourcing, product contents (e.g., information on treatments with hazardous substances), production-phase history, product durability, and care information is largely lacking (BOF & McKinsey, 2019; Ellen MacArthur Foundation & Circular Fibres Initiative, 2017; Environmental Audit Committee, 2019). It follows that, supply-chain transparency on low wages, workplace health and safety, and the use of child labour and garment sweatshops is also lacking. As was noted in **chapter 3**, airborne microfibre in factories and emissions in factory effluent pose a significant health risk to workers and the local environments (Stevens, 2020). On the whole, the lack of industry transparency is perhaps the most significant contributor for the cheap cost of fashion and the most important hindrance to long-term environmental sustainability and microfibre emissions reductions. Environmental sustainability and fair labour practices are not mutually exclusive (Laitala, 2020). Furthermore, as this study's findings indicate and has been reported by industry insiders, consumers are very distrustful of the industry (BOF & McKinsey, 2019).

5.6. Existing Policies & Regulations Stymie the Development of Sustainability

Fueled by increasing globalization, the historically unprecedent low fashion prices observed in recent decades are due the increasingly uneven power dynamics which favour large fashion corporations and bulldoze sustainability-oriented firms. The race to the bottom has led to industry-wide cost cutting measures which in turn have led to

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[49] According to *Passport*, the Euromonitor database, imported apparel sold in Canada has grown from 50.6% in 1997 to 89.3% of products in the total Canadian apparel market in 2019 (Euromonitor International, 2021).

[50] In 2019, the top 5 apparel suppliers to Canada, accounting for nearly 75% of all import value, were developing countries, China, Bangladesh, Vietnam, Cambodia, and the USA (Statista, 2020a).

increasingly un-priced and unmitigated negative externalities. The policy problem is a systemic and global one.

In Canada, there is a lack of robust government action at both the federal and provincial levels to encourage sustainability in the textile and fashion industry. Continued inaction by the government will further entrench consumer and producer norms. Specifically, the following factors are key policy points lacking in the existing Canadian regulatory program.

1. Despite the OECD recommendations and guidance on due diligence for responsible supply chains in the garment and footwear sector, Canada lacks an effective framework for action on the UN Guiding Principles on Business and Human Rights and the International Labour Organization's (ILO) Declaration on Fundamental Principles and Rights at Work for this sector (Mertens, 2020).

2. At present, Canada lacks a centralized regulatory framework for action on environmental pollution from plastics and textiles. This has led to jurisdictional fragmentation and differing regulatory approaches to the management of plastics and textile waste, pollution emissions, and different extended producer responsibility schemes (Valiente, 2020).

3. Canada also lacks legislation that would include expectations related to supply chain transparency in the textile and fashion industry[51] (Mertens, 2020).

[51] Although they may have notable shortcomings, currently, Section 54 of the UK Modern Slavery Act, Section 3017 of the US Tariff Act, and the California Transparency in Supply Chains include expectations on supply chain transparency in the garment and footwear sector which is mandated by law (Environmental Audit Committee, 2019; OECD, 2017).

Chapter 6.

The Metro Vancouver Household Survey

The following is a brief summary of the key findings from a representative household survey study I conducted in Metro Vancouver, British Columbia, Canada. A summary of the survey findings is in **Appendix C**. At the time of writing, it is the first ever representative household-level survey and assessment of consumer behaviours, perceptions, attitudes, and preferences as they pertain to the synthetic microfibre pollution issue. The survey focused on synthetic microfibre emissions, not all microfibre types.

The survey was designed to address the following questions, among others.

- How do households' (respondents) laundry and purchase behaviours correlate with microfibres emissions?
- How do households' attitudes toward the environment (e.g., prior knowledge of the microfibre pollution issue and related concern about the environment) correlate with their policy preferences?
- How likely or unlikely are households to invest in microfibre reduction measures? Would households take advantage of rebates or subsidies for investment in abatement technologies?
- What is the potential impact of microfibre related eco-labelling on consumer purchase behaviour? What trade-offs do households make regarding their purchase decisions?
- How much value do households place on a healthy environment with less microfibre pollution? What is consumer willingness-to-pay for sustainable clothing and abatement technologies? Does willingness-to-pay vary across household groups?
- What is the potential efficiency of each potential intervention opportunity as a source-control measure?

I answer these questions following by outlining a brief summary of the key findings from my Metro Vancouver survey.

Analysis methodology

With the exception of multiple-choice questions, all closed-ended questions were numeric 11-point Likert scales with semantic anchors at 0, 10, and 5 as the 'neutral' position. Unless otherwise stated, Likert scale responses were collapsed into 3 levels: Net: 0, 1, 2, 3 (disagree, oppose, etc.); Net: 4, 5, 6; Net: 7, 8 ,9, 10 (agree, support, etc.).

6.1. Key Findings

Half of households have a microfibre footprint 7X greater than the other half.

The key drivers of microfibre emissions from domestic laundries in Metro Vancouver include the type of washing machine (top/front loading), household size, children, and gender. Of all households, 46% use a top-loading washing machine, the emissions from which may be 7-fold greater than the alternative front loading machines (Hartline et al., 2016). Families and professionals report higher weekly laundry frequency than other households, **figure 6.1**. The convenient access to an ensuite washing machine is also a strong predictor of high weekly laundry frequency, **figure 6.2**. A majority of people engage with clothing care instructions; younger people and families are less likely to do so than their counterparts.

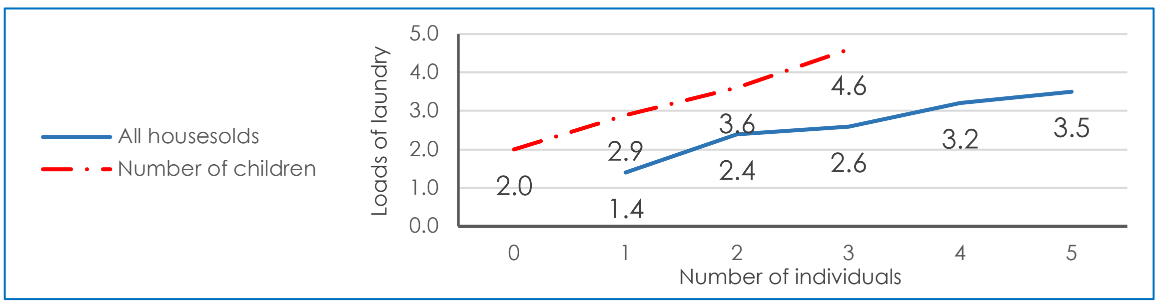

Figure 6.1. Average number of loads of laundry per week by household size and number of children.
The graph shows that, for example, 2 children are more laundry intensive than a household with 4 people where the 4 people might not be children

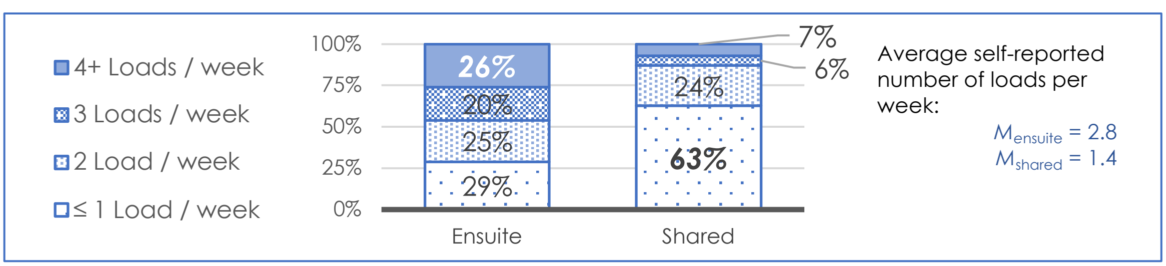

Figure 6.2. Number of loads of laundry per week by laundry facility

Young people & young parents drive demand for low-cost fashions.

In Metro Vancouver, fast fashion retailers, bargain retailers, and big-box department stores are the top three preferred places to shop, see **table 6.1**. All income brackets favour low-cost options. However, the lowest income group are more likely to buy fewer articles of clothing per year than their higher income counterparts. The difference between genders, though significant, is marginal[52].

Table 6.1. Top-shopped fashion retailers in Metro Vancouver

Fast Fashion designers and retailers (e.g., H&M, Zara, Uniqlo)	***62%***
Bargain retailers (e.g., Amazon, Winners)	***59%***
Big box department stores (e.g., Walmart, Costco)	***54%***
Department stores (e.g., The Bay, Simons)	45%
Second-hand retailers (e.g., Mine & Yours, Value Village, Hunter & Hare)	44%
Athleticwear designers and retailers (e.g., Nike)	40%
Mid-range retailers and designers (e.g., Aritizia, Brandy Melville)	38%
Outdoor specialty designers and retailers (e.g., Patagonia, MEC)	36%
Neighbourhood boutique	34%
Professional clothing retailers (e.g., Mark's Work Warehouse)	32%
Yoga athletics (e.g., Lululemon)	20%
Upper mid-range designers and retailers (e.g., Kate Spade)	17%
High-end designers and retailers (e.g., Holt Renfrew, Vivienne Westwood)	16%
Specialty size (Mr. Big & Tall)	15%
Sustainable designer retailers (e.g., G-Star Raw, Frank & Oak)	12%

Proportions of respondents who purchased at least one item from each of the 15 retailer groups.

Consumers cannot be relied upon to prioritize environmental sustainability.

At the point-of-purchase, consumer's prioritize price, performance, and suitability to personal preferences. There does not appear to be any trend that would suggest a correlation between economic ability and prioritizing the environment. Whether purchasing a new washing machine or a new article of clothing, environmental sustainability is not a priority for any income bracket, see **figure 6.3** and **table 6.2**.

[52] The difference between two groups is considered marginally different or slightly different when the difference between two groups is significant but less than 10%.

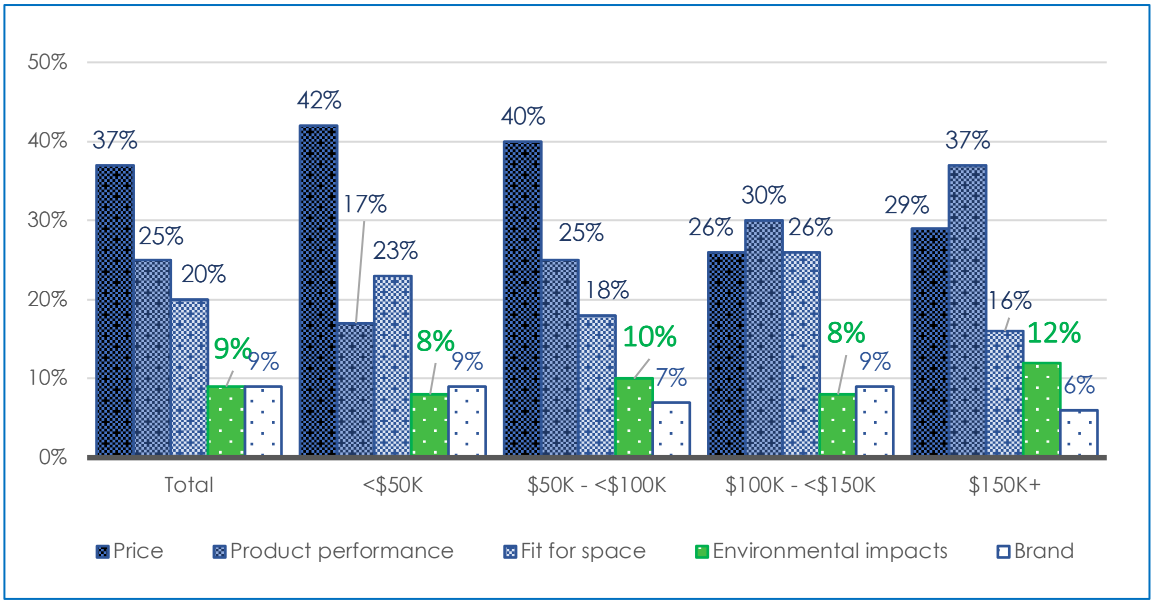

Figure 6.3. Which appliance criterion is ranked first at the point of purchase? Compared by household income

Table 6.2. Which of 9 clothing criteria is the primary consideration at the point of purchase? Compared by househod income

Income bracket	**N = 1034**	**<$50K**	**$50K-<$100K**	**$100K-<$150K**	**$150K+**
Price	57%	64%	57%	54%	47%
Fibre type	11%	10%	11%	10%	13%
Brand name	8%	4%	9%	6%	12%
Material performance	7%	2%	8%	10%	10%
Care instructions	5%	5%	4%	8%	5%
Locally produced	4%	4%	3%	5%	8%
Fair trade	4%	6%	4%	3%	2%
Organic fabric	2%	3%	0%	3%	1%
Env sustainable production	2%	2%	4%	2%	3%

Fewer than 20% of individuals have a high level of awareness about microplastics & synthetic microfibres.

Slightly more than 1 in 5 people are not at all knowledgeable about microplastics and synthetic microfibres, **figure 6.4**. Knowledgeability about microplastics and synthetic microfibres is correlated with pro-environmental attitudes and concerns. A university-level education is the strongest predictor for knowledge. Women are also slightly more knowledgeable than men

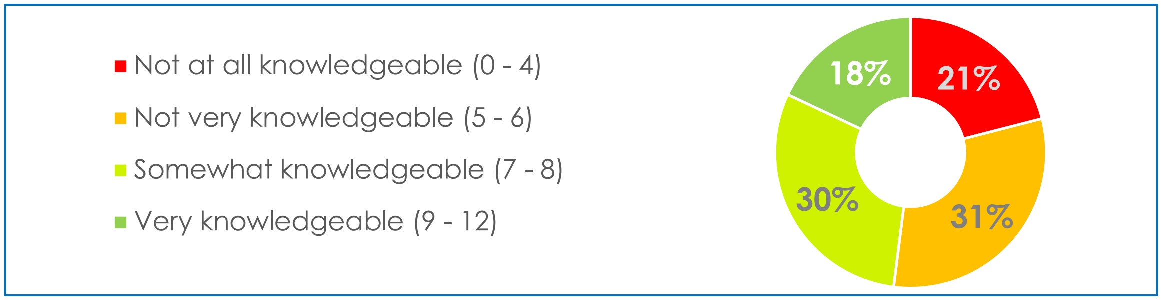

Figure 6.4. An index of knowledge about microplastics and synthetic microfibres
Each category represents the proportion of respondents in each knowledge level on the 12-point knowledge test-score scale.

Metro Vancouverites are greatly concerned about synthetic microfibres.

At the local and global levels, residents of Metro Vancouver express a great deal of concern about environmental issues, in general. After the provision of information, 85% of respondents rated the ocean pollution caused by synthetic microfibres as an issue of serious concern, **figure 6.5**. However, there appears to be a correlation between the level of knowledge about synthetic microfibres and the level of concern. Their concern about the issue is independent of education, household income, awareness level, and 2019 voting behaviour.

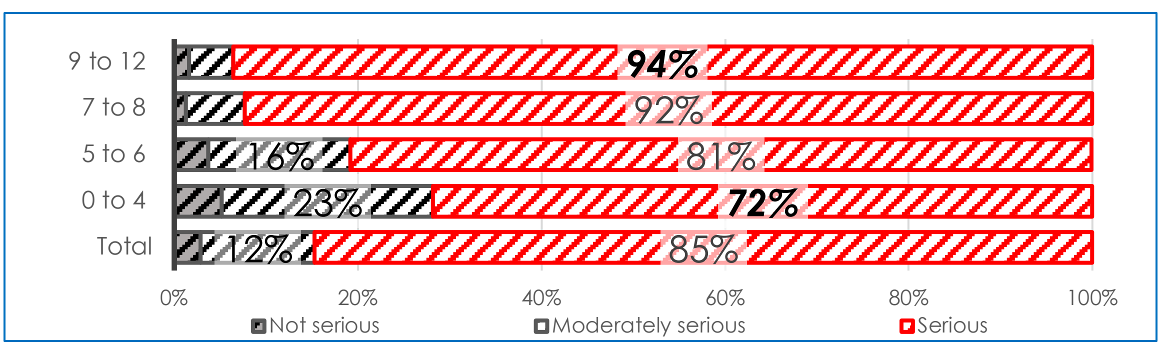

Figure 6.5. Concern about synthetic microfibre ocean pollution, after the provision of information, compared by scores in the knowledge test

Consumers highly value significantly reducing microfibre ocean pollution.

Based on questions trying to elicit willingness to pay for different methods of reducing microfibre emissions, low-cost ($40) and easy to use technologies appear to have the greatest likelihood of adoption among all demographic groups, **figure 6.6**. Even high-cost ($350) technologies elicit a positive response from nearly half of respondents, **figure 6.7**. Consumers are willing to pay more for apparel that shed 90% less microfibres than the equivalent which may shed more, **figure 6.7**. Environmental concern and knowledge are the strongest predictors of willingness-to-pay.

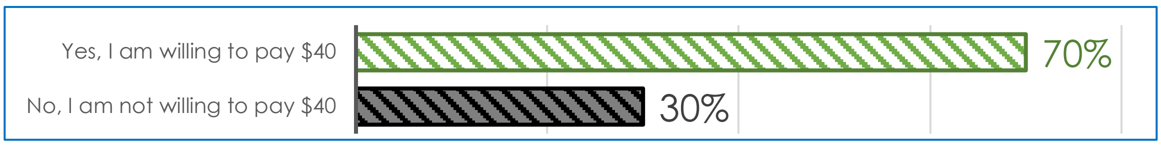

Figure 6.6. The proportion of respondents willing to pay at least $40.00 for a washbag that captures synthetic microfibres

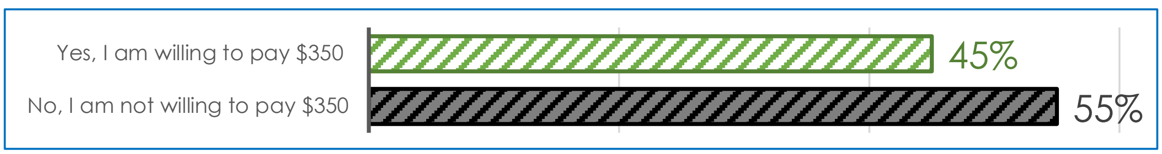

Figure 6.7. The proportion of respondents willing to pay at least $350.00 for a washing machine filter attachment to capture synthetic microfibres

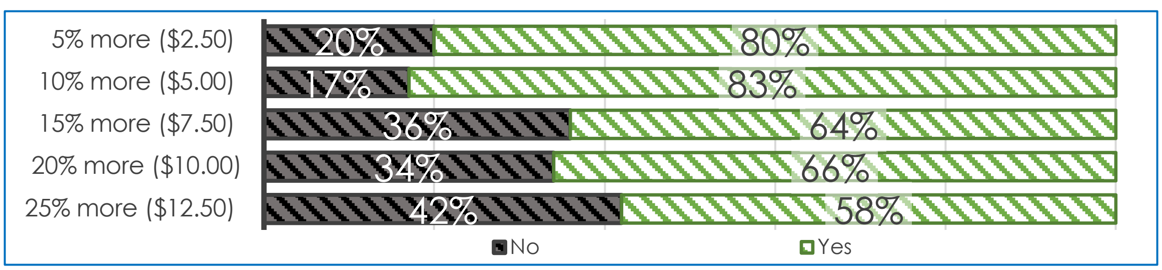

Figure 6.8. Willingness to pay more for an article of clothing that sheds 90% fewer synthetic microfibres than the lower cost ($50.00) equivalent alternative which sheds more microfibres; each price level was presented to ~200 respondents

Consumer trust in manufacturers is weak.

Although consumers appear to be willing to pay for sustainable options, they are concerned about greenwashing. Government regulatory certification is trusted above any other environmental certification schemes. The difference in preference for government certification and independent/third party certification is negligible. This indicates both schemes may be equally likely to address consumer trust in environmental certification.

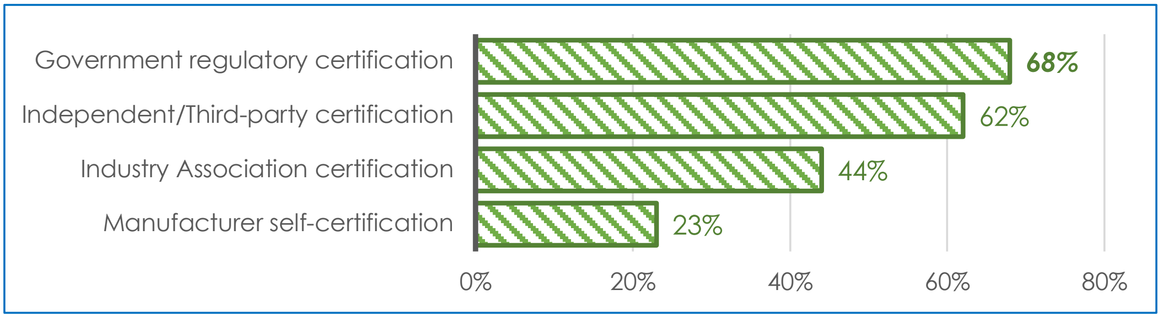

Figure 6.9. Which environmental sustainability certification body is most trusted by consumers?

Pro-environmental concerns, attitudes, and knowledge are the strongest predictors of intention and willingness-to-pay.

The findings from the contingency analysis were reflected in a regression analysis. Whereas concern about the environmental impacts of microfibres was the strongest predictor for willingness-to-pay and intention to adopt pro-environmental behaviours to reduce microfibre emissions, knowledge was the key predictor for environmental concern. Based on this, improving consumer knowledge about the issue may drive consumer acceptability of policy interventions. The multiple regression results are provided in **Appendix C**.

Metro Vancouver consumers support government action on microfibres.

Perhaps this study's most critical finding is the very high level of support for government regulatory action. According to 3 out of 4 respondents, if the microfibres emissions problem persists into the future, the fashion industry is the primary group to hold accountable; the appliance industry is second. This is reflected in the strong support for government action from across all demographic groups, **figure 6.10**. Metro Vancouver's citizen-consumers strongly support government policies and regulations to institute performance standards for fashion and appliance industries. Strong support for government action can be found among the knowledgeable supporters of any Canadian Parties.

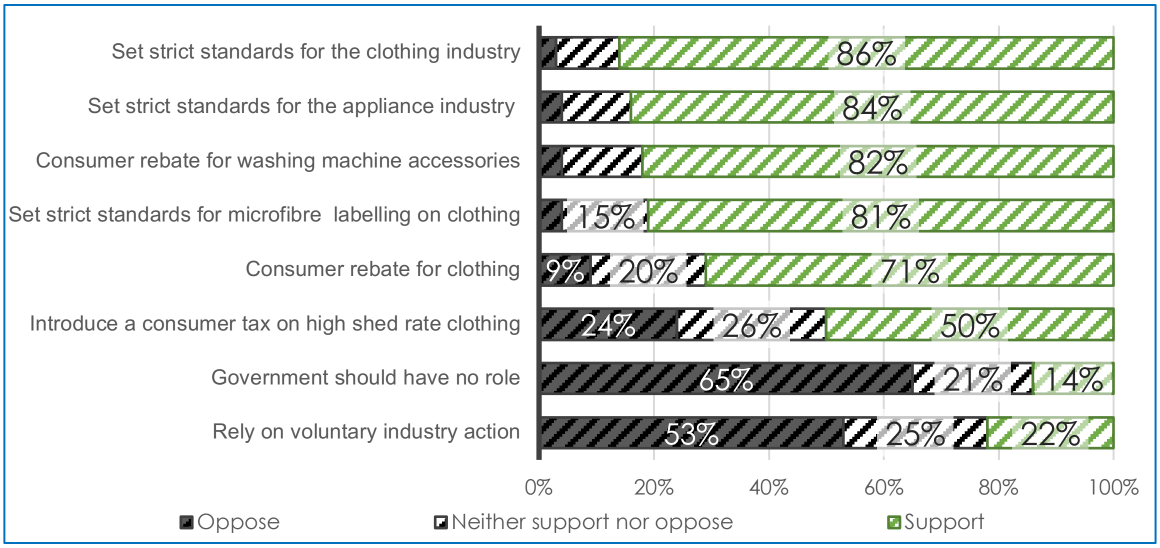

Figure 6.10. Consumer support for various actions taken by the government to reduce synthetic microfibre emissions into the environment

6.2. Revisiting the Research Questions

The key findings presented above address the core issues noted in the research questions. In this section, some of the questions are revisited to highlight the overarching ideas which guide the policy design and policy options presented in later chapters.

How do households' (respondents) laundry and purchase behaviours correlate with microfibres emissions?

The survey findings point to key factors driving the microfibre load entering WWTPs, including family size, convenient access to ensuite laundry, using top loading washing machines, and high demand for low-cost apparel which shed more microfibres. With 82% of respondents using ensuite appliances, people's motivation to wash apparel less frequently will be low. The continual trend of declining fashion prices will incentivise unsustainable consumption. Although various organizations and researchers suggest education campaigns for behaviour change at the household level is an important point of intervention, Metro Vancouver households' laundry habits and apparel purchasing behaviour may be resistant to change without government regulatory action or incentives.

How do households' attitudes toward the environment (prior knowledge of the microfibre pollution issue and concern about the environment) correlate with policy preferences?

As was illustrated in **figure 6.5**, after the provision of information, the most knowledgeable respondents (scores 7-8 or 9-12/12) were at least 20% more likely than the lowest knowledge group (scores 0-4/12) to rate microfibre pollution as a serious environmental concern. The knowledge trend is reflected in consumer WTP for technology adoption and support for government regulatory action on the apparel industry, see **figure 6.11** and **6.12**. The strongest predictor for pro-environmental attitudes, technology adoption[53], and/or support for direct government action is knowledge about the presence and negative environmental impacts of synthetic microfibres. Although consumer behaviour may change little, information campaigns can motivate consumers to adopt capture technologies and support government action on the microfibre issue

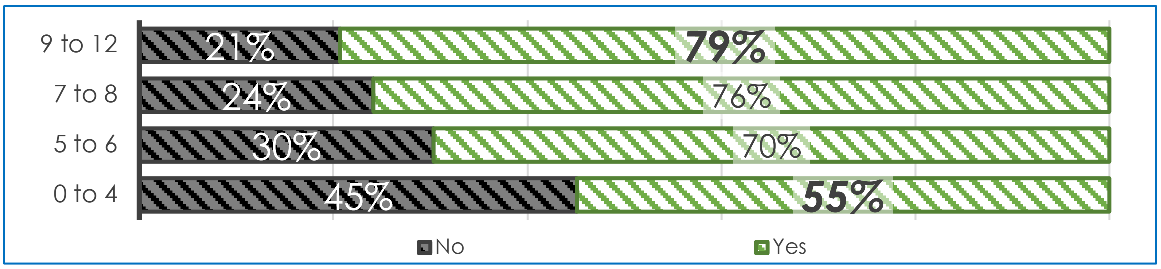

Figure 6.11. Consumer willingness-to-pay for low-cost ($40.00) microfibre capture technologies, compared by scores out of 12 in the knowledge test

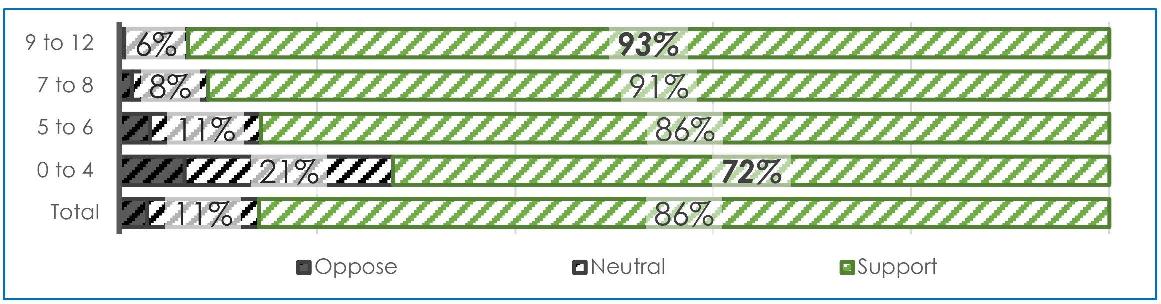

Figure 6.12. Support and opposition to strict emissions standards for the clothing industry, compared by scores out of 12 in the knowledge test

[53] **Figure C.38**. in **Appendix C** provides a comparison of consumers' WTP for high-cost ($350.00) technology by their knowledge levels. The trend is similar to figure 6.11. However, the difference between the highest and lowest knowledge groups is less pronounced.

How likely or unlikely are households to invest in microfibre reduction measures? Would households take advantage of rebates or subsidies for investment in abatement technologies?

Consumers' stated willingness to pay for abatement technology is promising. However, the noted technologies have been available on the market for nearly 4 years. Yet, voluntary consumer adoption has been very low (Anonymous Expert #3, 2020; Mertens, 2020). The current trend in low technology adoption may be attributed to lack of consumer awareness and consumer trust the technology efficacy[54]. The low adoption of effective but high-cost washing machine attachments, however, may be addressed by offering a price subsidy coupled with a wide-reaching information campaign. Shown in **figure 6.10**, 82% of respondents support the option of a subsidy for washing machine accessories.

What is the potential impact of microfibre related eco-labelling on consumer purchase behaviour?

As was illustrated in **figure 6.3** and **table 6.2**, at the point-of-purchase, consumers' personal priorities are not aligned with environmentally sustainable behaviours. In the absence of other interventions, eco-labelling products to motivate voluntary consumer selection of sustainable products, i.e., low-microfibre shedding apparel or appliances with built-in microfibre capture systems, may fall very far from substantial emissions reductions.

How much value do households place on a healthy environment with less microfibre pollution?

Consumers' apparently strong WTP for abatement technologies and higher quality apparel which shed fewer microfibres is illustrative of the degree to which they value significantly reducing ocean pollution caused by these pollutants and the degree to which they may support decisive government action to protect the ocean. However, no one action taken alone is likely to be as successful as a combination that includes, for example, the government providing wide-reaching information campaigns to close the knowledge gaps identified in this study.

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[54] For example, the Cora Ball and Patagonia's Guppy Friend have less than 50% capture rating (by weight) and both are manufactured from plastics. Moreover, some consumers have reported concerns about the Guppyfriend preventing thorough cleaning of apparel (Anonymous Expert #1, 2020). Concern has also been raised about the Guppyfriend potentially causing damage to appliances because of the weight imbalance it may cause in the washing machine.

What is the potential efficiency of each potential intervention opportunity as a source-control measure?

As was noted earlier, indirect interventions alone, such as the provision of information, and reliance on voluntary consumer behaviour change is unlikely to drive substantial emissions reductions. Overall, the findings from the Metro Vancouver Household Survey clearly illustrate that the issue of ocean pollution caused by synthetic microfibres is not a polarizing issue for the sampled voting public. The synthetic microfibres issue appears to be highly salient, which may be attributable to the personally relevant context of the problem. Moreover, consumers are willing to take some actions to help mitigate the problem, but policy intervention in the form of regulation and incentives (positive and negative) are needed. Relying on consumers to address the issue of their own accord will be unlikely to lead to significant reductions in microfibre emissions.

Chapter 7.

An Evaluation Framework for Testing Policy Efficacy

The study's core objectives and the barriers to industry sustainability, which were discussed in **Chapter 5**, inform a set of three sustainability objectives for British Columbia. BC's Sustainability Objectives offer a framework for devising and analyzing policy options that can be shown to have tangible and efficient pollution reduction outcomes. BC's Sustainability Objectives are as follows:

1. Sustainable microfibre emissions reductions
    - Effective short-term and long-term emissions reductions.
    - Sustainable financing.
    - A long-term strategy for waste treatment capacity building.
2. Dynamic sustainability
    - Equitable access to capture technologies.
    - Balance households and industry priorities with environmental sustainability.
    - Buttress long-term emissions reductions with textile waste management strategies needed today and into the future.
3. Accountability and public buy-in
    - Improve industry transparency on negative externalities.
    - Shift consumer norms toward sustainability.
    - Secure voter support for textile sustainability strategies.

Based on these BC Sustainability Objectives, this chapter outlines a set of eight priority policy objectives and evaluative criteria for the critical assessment of policy alternatives. Criterion weight accounts for the relative importance of each criterion. Further, when evaluating the efficacy of each policy option, the scores allocated to each criterion are not relative among the options. Rather, they are estimates I have been able to make based on findings from literature, the survey, and expert consultations.

7.1. Sustainable Reductions

7.1.1. Effectiveness (environmental sustainability)

The primary objective of any policy designed to address synthetic microfibre emissions is effectiveness. Therefore, the final score of each policy on the effectiveness objective will be double-weighted. There are two top-level criteria considered for achieving the effectiveness objective: emissions reductions during the use-phase of textiles and emissions reductions in the production phase. Emissions reductions from each intervention is best measured as based on the degree to which it may reduce emissions from different laundry product categories. In the absence of existing data on the extent to which each intervention reduces emission, policy impacts have been estimated on a three-point scale of *low, some*, and *high* degree of reductions.

The effectiveness during the use-phase is measured at three levels: emissions reductions from washing machines, from dryer machines, and during the wear and tear of clothing. The categories of appliances are separated further by ownership. These are privately owned appliances, commercially owned in residential settings (rental homes), and commercial laundry facilities (laundromats and drycleaners). Given that 68% of British Columbians are homeowners and an additional 31% are renters, privately owned appliances and shared appliances in rental facilities are weighted, respectively, 6X and 3X greater than other categories (Statistics Canada, 2017). **Table 7.1** provides a breakdown of weighting and the index/measure at each level.

Table 7.1. Policy objectives and evaluative criteria: Effectiveness

Objectives	Primary Criteria	Levels of criteria	Levels of intervention	Weight	Measure or Index	Max Score
Effectiveness	Emissions reductions during the use-phase of textiles	Emissions reductions from washing machines (WMs)	Privately owned WMs	X6*	Whether or not the intervention will lead to reductions from each household group at level of intervention: 1 = None to low reductions 2 = Some reductions 3 = High reductions	18/66
			Commercial WMs (Rentals)	X3*		9/66
			WMs in Laundromats	X1		3/66
		Emissions reductions from dryer machines	Privately owned dryers	X6*		18/66
			Commercial dryers (Rentals)	X3		9/66
			Dryers in laundromats	X1		3/66
		Emissions reductions during wear & tear	N/A	X1		3/66
	Emissions reductions from the production-phase	Projected impact of policy on the likelihood of emissions reduction during the textile and clothing manufacturing process	N/A	X1**	1 = Negative or no impact 2 = Some positive impact 3 = Very positive impact	3/66
Total Score				**66**		**66/66**
Score Percentage						**/100%**
Score ratio in the final tally – The effectiveness policy objective is double weighted, accounting for 20% of total score.						**20/100**

* In BC, there are at least twice as many homeowners (68%) with access to privately owned appliances as there are renters (31%) (Statistics Canada, 2017).

** Interventions, such as better fibre engineering would lead to emissions reductions from the production phase and the use-phase of textiles.

7.1.2. Immediacy of emissions reductions

How efficient a policy may be in reducing microfibre emissions is a function of policy effectiveness (**section 7.1.1**) and how quickly the policy will achieve emissions reductions. Again, due to the persistent and accumulating nature of microfibres as a pollutant, priority must be given to policies which can immediately cut down on point-source emissions. **Table 7.2** provides the framework for measuring policy efficiency.

Table 7.2. Policy objectives and evaluative criteria: Immediacy of reductions

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Policy efficiency	Time factor of policy efficiency	Time (in years) to maximal emissions reduction from the phase in textile lifecycle which is targeted by the policy	X1	3 = 1 to 5 years 2 = 6 to 10 years 1 = more than 10 years	3/3
Total score					**3/3**
Score ratio					**/100%**
Score ratio in the final tally of all objectives.					**10/100**

7.1.3. Minimized cost to government

The cost burden to government may pose a large barrier to policy action. The impact on government budget is measured as the potential maximum upfront capital costs, and/or the maximum potential revenues generated annually, see **table 7.3.** Reportedly, the Federal, Provincial, and Municipal governments have set aside $240 million for water and wastewater infrastructure upgrades across BC (On-Site, 2019). However, in Metro Vancouver, for example, between 2019 and 2023 operating and capital expenditure on liquid waste treatment will exceed $200 million and $600 million per year, respectively (metrovancouver, 2019). The planned upgrades will not address microplastics and microfibre emissions[55]. Source control for microfibres is the necessary next step.

The upfront capital costs of policy options are measured relative to the current government commitments. Given that Metro Vancouver is home to nearly half of the BC population, for the purposes of this analysis, I assume that operating and capital expenditures for the province will be double the projected costs for Metro Vancouver. **Table 7.3** outlines the minimized cost evaluation measure.

Table 7.3. Policy objectives and evaluative criteria: Minimized cost

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Minimized administrative cost	Impact on government budget	Estimated upfront capital costs, or estimated revenue generated annually	X1	3 = Less than $400 million 2 = $400 to $1,200 million 1 = more than $1,200 million	3
Total score					**3/3**
Score ratio					**10/100%**
Score ratio in the final tally of all objectives.					**10/100**

* Given that implementation is the first step in taking policy action, upfront capital costs can be considered the more important cost factor or potential hurdle impacting policy adoption

[55] As discussed in **Chapter 3**, captured microplastics will be retained in sludge which may be used for treating agricultural and park lands in BC (Anonymous Expert #1, 2020).

7.2. Dynamic Sustainability

7.2.1. Distributive Equity

There are two critical factors which impact whether or not a policy is equitable: the cost burden and the societal/environmental exposure burden, see **table 7.4.** The cost burden evaluates the degree to which the financial cost may disproportionately impact the two lowest income categories.

The societal/environmental burden of exposure is measured on three levels: the degree to which consumer lifestyles (fashion shopping options) may be impacted by the policy, the impact on worker health and safety due to change in exposure to microfibres in the factory setting, and the impact on the degree to which citizens of production countries can enjoy the environment if there is a change in microfibre emissions during production. Although the effectiveness objective also accounts for emissions reduction during the production phase, the global nature of microfibre pollution necessitates global equity considerations.

Table 7.4. Policy objectives and evaluative criteria: Distributive equity

Objective	Primary Criteria	Levels of criteria	Income bracket affected	Weight	Measure or Index	Max Score
Distributive Equity	Cost Burden	Monetary cost to low-income households	<50K	X1	1 – Significant negative impact 2 – Limited negative impact 3 – No negative impact	3/24
			50 - <100K	X1		3/24
	Exposure Burden	Lifestyle cost to consumers	<50K	X1		3/24
			50 - <100K	X1		3/24
			100K – 150K<	X1		3/24
			150K+	X1		3/24
		Health exposure burden for factory workers	N/A	X1		3/24
		Lifestyle cost (enjoyment of environment) for citizens of manufacturing country	N/A	X1		3/24
Total score						**24/24**
Score ratio						**/100%**
Score ratio in the final tally of all objectives.						**10/100**

7.2.2. Progress toward a circular economy

As was illustrated in chapter 3, all microfibres shed from textiles are persistent and accumulative environmental pollutants. Furthermore, microfibre emissions from household laundries is only a fraction of total emissions from textiles. Accordingly, halting microfibre emissions from all stages of textile lifespan (production, use-phase, and end-of-life) must be considered a priority objective. Policy makers should shift policy action toward achieving long-term environmental and economic sustainability and circularity. The policy objective of progress toward circularity can be measured based on where in the lifecycle of textiles the policy has the greatest impact, and how many of the steps in the lifecycle are impacted, see **table 7.5**.

Table 7.5. Policy objectives and evaluative criteria: Progress toward circularity

Objective	**Primary Criterion**	**Level or stage in lifecycle**	**Consideration measured**	**Weight**	**Measure or Index**	**Max Score**
Progress toward circularity	Policy contribution to initiating transition toward a circular economy	Production phase	Product design	X1	Projected level of impact on progress: 1 = Low 2 = Med 3 = High	3/12
		Use-phase	Product durability	X1		3/12
		End-of-life recyclability	Contribution to establishing infrastructure	X1		3/12
		Industry transparency	Supply-chain transparency about product lifecycle	X1		3/12
Total score						**12/12**
Score ratio						**/100%**
Score ratio in the final tally of all objectives.						**10/100**

The lack of supply chain transparency is one of the most important barriers to environmental and social sustainability in the garment and footwear sector. Improvements in transparency at any stage of product lifecycle can have the potential to motivate industry toward transparency in other stages and ultimately circularity.

7.2.3. Administrative ease for government

The specific criterion for evaluating how well a policy meets this objective is the relative ease with which a policy can be implemented, monitored, and enforced. The administrative burden can be minimized by utilizing existing government programs and infrastructure rather than developing new frameworks. Instituting new regulations may add more complexity. How well a policy meets this objective is measured based the likelihood that existing government policy platforms and infrastructure can be utilized to implement, monitor, and enforce the policy, see **table 7.6**.

Table 7.6. Policy objectives and evaluative criteria: Administrative ease

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Administrative ease for government	Ease of policy management	The ease of implementation	X2*	1 = Low 2 = Med 3 = High	6/12
		The ease of monitoring compliance	X1		3/12
		The ease of enforcement	X1		3/12
Total score					**/12**
Score ratio					**/100%**
Score ratio in the final tally of all objectives.					**10/100**
* Given that implementation is the first step in taking policy action, it can be considered the most important factor or potential hurdle impacting administrative ease					

7.3. Accountability & Public Buy-in

7.3.1. Accountability

The Metro Vancouver survey asked, if ocean pollution caused by microfibres persists in the future, which stakeholder group should be held most accountable. The objective of improving stakeholder accountability measures the strength of the signal that the policy sends to stakeholders to increase the likelihood of future emissions reductions, **table 7.4**. The weighting of each group's accountability is based on the Survey findings, where respondents rated clothing manufacturers as the stakeholder group to hold most accountable, followed by the appliance industry, the government, and consumers. Although the government is not typically considered a stakeholder group, recall that respondents strongly indicated the government must take action on synthetic microfibre pollution, see **figure 6.10**[56].

Table 7.7. Policy objectives and evaluative criteria: Accountability

Objective	Primary Criterion	Stakeholder groups	Consideration measured	Weight	Measure or Index	Max Score
Accountability	Policy visibility	Apparel industry companies	The projected strength of the signal to motivate action on reducing microfibre emissions	X4	1 – Low 2 – Med 3 – High	12/30
		Appliance industry		X2		6/30
		Governments		X3*		9/30
		Consumers		X1		3 /30
Total score						**30/30**
Score ratio						**100%**
Score ratio in the final tally of all objectives.						**10/100**

* The triple weighting for government accountability accounts for the degree to which a policy sends a signal for action to local/provincial government, federal governments, and the international community of policy actors.

[56] Two out of three respondents (65%) indicated the government should take action on addressing synthetic microfibre pollution, 21% were neutral, 14% believe government should have no role.

7.3.2. Political feasibility

Political feasibility measures the degree to which each stakeholder group may accept or support a policy. Once again, it is worth noting that policy action on local synthetic microfibre pollution may have global consequences. An important consideration is the impact on labour, job availability, and fair wages. Therefore, the potential impact of a policy on job (or wage) losses in the global garment and footwear sector and potentially lower international acceptance is taken into account.

Table 7.8. Policy objectives and evaluative criteria: Political feasiblity

Objective	Primary Criterion	Stakeholder groups	Consideration measured	Weight	Measure or Index	Max Score
Political feasibility	Stakeholder acceptance	Consumers	Voter support	X1	1 – Low 2 – Med 3 – High	3 /18
		Apparel industry companies	Projected support for policy	X1		3/18
		International labour in the apparel industry	Projected change in job availability (and cuts in wages)	X1	1 = Decrease 2 = No change 3 = Increase	3/18
		Appliance industry	Projected support for policy	X1	1 – Low 2 – Med 3 – High	3/18
		Water utilities	Projected support for policy	X1		3 /18
		Non-governmental organizations	Projected support for policy	X1		3/18
Total score						**18/18**
Score ratio						**100%**
Score ratio in the final tally of all objectives.						**10/100**

Chapter 8.

Policy Options & Policy Evaluation

This chapter offers a set of policy options that have emerged from the study and evaluates their efficacy in the BC context. The study's geographic scope, namely British Columbia, restricts the range of recommended polices to those which are within the jurisdiction of the BC government. Referring back to **figure 3.1**, province-scale policy actions are limited to discharge points from laundry appliances and emissions management downstream at solid and liquid waste treatment facilities. Source control measures that would address emissions from textiles would require a federal-level policy framework and are, therefore, not within the scope of this study. The policy options outlined in the first section of this chapter are designed to address short- and long-term considerations in emissions reductions while establishing the groundwork for meeting BC's sustainability objectives, which were outlined in the previous chapter. Although the three options function independently, they are not intended as policy substitutes. They are complementary policies and will best achieve the sustainability objectives in combination.

In the second section of this chapter, the evaluation framework outlined in the previous chapter is applied to the individual options to assess their relative strengths and weaknesses in achieving BC's three sustainability objectives and the core objective of significantly reducing synthetic microfibre emissions from household laundries.

8.1. Policy Options

8.1.1. Policy option 1:

Legislation for all new laundry appliances

In BC, industrial and municipal waste discharge, pollution, and hazardous waste are regulated by the Environmental Management Act (EMA) (British Columbia, 2021). Under the EMA, a requirement would be placed on all appliance producers to protect the environmental quality against microfibre emissions from laundry appliances. Amendments to the Act would address both washing machines and electric dryer machines for private and commercial use.

The amended legislation would require that by 01 January 2025[57], all new washing machines sold in the province of British Columbia must be equipped with a microfibre capture system with a mesh size of 100 microns or smaller. The prescribed technology is available and has been assessed in laboratory settings in the Rochman Lab at UofT and the University of Waterloo (Anonymous Expert #8, 2021; Erdle, 2020). Due to the lack of standardized techniques for measuring washing machine emissions rates, at present, it is not possible to set a performance standard for washing machine filters.

The amended legislation would also require that on or before 01 January 2025[58] all new electric dryer machines sold in the province of British Columbia must meet zero (0%) microfibre air emissions performance standard. The standard permits manufacturers to develop new technologies or use existing options[59]. In the absence of industry data on product turnover, it is assumed that the 2025 timeline (which follows the France model) takes industry transition and preparation time into account.

8.1.2. Policy option 2:

CleanBC subsidy for microfibre capture technologies

As part of the existing CleanBC Plastics Action Plan program, a consumer rebate would be offered to subsidize 50% of the purchase price[60] of microfibre capture technologies for all existing laundry appliances in all privately or commercially owned (rental) homes in BC and commercially owned laundromats. The policy would be an opt-

[57] The date is to coincide with the legislation passed in France which requires that, on or before 2025, all new washing machines must be fitted with a microfibre filtration system. The same requirement under the California Assembly Bill no. 622 will come into to force for on or before 01 January 2024. In the absence of industry data on product turnover, it is assumed that the 2025 timeline takes industry transition and preparation into account.

[58] There are existing dryer models which would meet the 0% microfibre emissions requirement. For this reason, it may be assumed that the appliance industry will be able to adopt and adapt existing technologies to meet the new performance standard by the required date in 2025.

[59] Some existing electric dryer models are ventless, knowns as *condenser dryers,* and do not emit any microfibres into the surrounding environment. According to an appliance retailer, condenser dryers are also significantly more energy efficient than the vented models and more gentle on clothes, which may reduce fibre shed (Prelusky, 2018).

[60] The 50% subsidy is based on the consumer willingness-to-pay (WTP) that was observed for high-cost abatement technologies, see **figure 6.7** and **figure C.31-32** in the appendix. Although the survey assessed WTP for $350.00 (including shipping and installation fees), expert reports and product information indicate consumers may be able to easily install the filters themselves without need of hiring the services of plumbing experts.

in program. Consumers may submit the proof of product purchase by using the existing CleanBC online home renovations rebates platform.

The subsidy would only apply to products that would be included in an up-to-date list[61] of capture technologies based on scientific evidence and approved by the Province. Currently, these options would include: *Lint Luv-r* by Environmental Enhancements and *Filtrol 160* system by Wexco for washing machines. The Parry Sound Ontario pilot program[62] which used the *Fitlrol 160* system, further attests to product efficacy and safety for use in households. The efficacy of existing external microfibre capture technologies for dryer vents have not been assessed. However, experts suggests that they may be in development (S. N. Athey, personal communication, April 3, 2021; L. M. Erdle, personal communication, April 3, 2021). When available, the subsidy would also apply in the same way to dryer filters.

According to the 2016 BC Census[63], there are 1,881,970 private households in the province, 1,279,020 of whom are owners and 599,360 are renting. The exact number of households which occupy a rental home in a multi-unit building that share a common laundry facility is not known. The Metro Vancouver Survey found that less than half (37%) of renters in Metro Vancouver use a shared facility. In the absence of BC-level data, for the proposes of this study, I assume that 50% of rental households use a shared facility. I further assume that in a shared setting, a single laundry appliance set may be used by up to 10 household. Based on these assumptions, an approximate maximum of 3.2 million washers and dryers could need filters if every current owner of a laundry appliances responded to the subsidy. It is also important to note that these purchases will not happen in an single year but over time as a function of the specific design of the program (e.g., if there is a maximum budget allocated to the subsidy per year and once expended, people have to wait to the next year. This is how a number of existing environmental incentive programs work, e.g., electric vehicle subsidies).

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[61] In the coming years, there may be significant advances in greywater treatment and microfibre capture technologies for laundry appliances, which should be considered when providing product subsidies.

[62] The pilot study found that 100 Filtrol 160 filters installed on washing machines in 100 of 1000 households which release effluent into an influent pipe of the local WWTP, reduced microfibre emissions by 10%.

[63] At the time of writing this report, the 2020 BC Census information is not available.

Ideally, the program would be managed such that point-source emissions would be significantly reduced to meet the 2025 UN SDG 14.1 target. Further, given that new laundry appliances may be expected to have a 10-year operating life, it is unlikely that appliances purchased in 2021 will be soon replaced by newer models that address microfibre emissions (Janeway, 2019). Therefore, I assume, the Province may allocate funding to subsidize 20% of households per year.

8.1.3. Policy option 3

Modified Extended Producer Responsibility

Policy option 3 recommends that the Government of British Columbia create an amendment to the Recycling Regulations under the Environmental Management Act and place a requirement on all apparel producers to protect the environmental quality against microfibre emissions from their products. The legislation would require that by 01 January 2022, all new apparel (garments, footwear, and accessories) sold in BC be subject to an environmental levy of $0.50 per item at the point of purchase by end-consumers. The levy would be listed on the consumer sales receipts as an Eco-fee and may be increased over time[64]. The program would target all types of fibres, from both renewable and non-renewable resources.

Exceptions:

- All children's apparel sizes 6X and under
- Essential undergarments not for specialty purposes (excluding hosiery[65]).
- All previously owned apparel

The mEPR program would be coupled with a recycling program that offers consumers $0.25/kg of textiles, for all textile product categories (as can be met by the facility's capacity). If apparel producers such as H&M wish to collect their own products

[64] The mEPR levy would be analogous to existing EPR programs such as the BC Paint Environmental Handling Frees which is subject to fee rate increases.

[65] Hosiery is commonly made from nylon fibre, which is a synthetic fibre and a source of synthetic microfibre emissions.

for recycling, they may do so. They would be permitted to develop consumer incentives to compete with the $0.25/kg offered by the Province.

Revenues generated from the eco-levy could be prioritized to finance the following:

- The CleanBC microfibre capture technology subsidy
- Infrastructure development for chemical and thermal textile recycling
- Research and development of microplastic capture and safe disposal technologies at WWTPs
- Environmental remediation programs
- Environmental information campaigns

8.2. Policy Analysis

In this section, the policy options are analysed, and the results are summarized in **table 9.1** (chapter end). The detailed evaluation of policy option 1, 2, and 3 are provided in **Appendix C**, **tables C.1.1 – C1.8**, **C.2.1 – C.2.8**, and **C.3.1 – C.3.8,** respectively.

8.2.1. Policy option 1:

Legislation for all new laundry appliances

Option 1 directly addresses point source emissions from household laundries by mandating preinstalled microfibre capture technologies for all new laundry appliances sold in BC. As the Survey findings demonstrated, consumer demand for environmentally sustainable appliances is very weak. In the absence of a legislative measure for all new appliances, consumer will not prioritize reducing microfibre emissions as a key consideration when selecting a new washing machine for purchase.

The total score for Policy Option 1:	54.0/ 100

Sustainable Reductions

Effectiveness

By implementing Option 1, consumers who purchase new laundry appliances from any brands will get the filter as a mandated part of the products. Their only decision is when and whether to buy a new or used machine. Existing appliances may be in good working order for 10 years or longer. Consumer demand for new appliances would make a marginal impact on emission reductions in the short term. Similarly, commercial demand for new appliances in laundromat facilities or commercially owned appliances in rental housing will depend on the life of the machine. Upon implementation, Option 1 very thus be viewed as low effectiveness in meeting reductions from all households, as it will take time to turn over the capital stock.

The effectiveness score of policy option 1:	22 / 66
The weighted score in the total policy score:	6.7 / 100

Immediacy of reductions

Consumers will likely replace their appliances after at least 10 years of use. According to a consumer report survey, laundry appliances may be expected to last at least 10 years (Janeway, 2019). Therefore, policy option 1 scores very low on how quickly it can cut emissions from all households.

The efficiency score of policy option 1:	1 / 3
The relative rating in the total policy score:	3.3 / 100

Minimized cost to government

In terms of the Province’s budget outlay, there are no anticipated costs for government.

The cost score of policy option 1:	3 / 3
The weighted score in the total policy score:	10 / 100

Dynamic Sustainability

Distributive equity

According to experts, the anticipated manufacturer cost of a preinstalled filter in washing machines will be approximately $10.00 per appliance. The same cost may be assumed per dryer machine. For consumers, the price change will be minimal relative to the total cost of new appliances. Overall, this policy is projected to have no negative impact at any level of the cost burden and exposure burden criteria.

The distributive equity score of policy option 1:	24 / 24
The weighted score in the total policy score:	10 / 100

Progress toward circularity

Action on the appliance industry will do little to address textile durability and ongoing emissions due to poor product design. Policy option 1 scores low on every circularity criterion.

The circularity score of policy option 1:	4 / 12
The weighted score in the total policy score:	3.3 / 100

Administrative ease

Option 1 requires direct government regulatory action via legislation under EMA. The current majority NDP BC government may be able to pass the amendment to the EMA[66]. The monitoring and enforcement of the new standards may be managed by existing government and independent third parties that currently perform other product monitoring and certification for appliances. For example, Natural Resources Canada, provides energy efficiency testing for laundry appliances. However, it would not be possible to ensure that consumers clean the filters and appropriately discard microfibres for landfilling. Option 1 is projected to be a relatively easy policy for governments to deliver.

The administrative ease score of policy option 1:	8 / 12
The weighted score in the total policy score:	6.6 / 100

[66] The Ontario bill was written by an NDP Member of Provincial Parliament. The MPP noted that the Majority NDP Parliament in BC may be able to pass a similar bill.

Accountability & Public Buy-in

Accountability

Regulatory action on appliances will send a strong signal to the appliance industry, which is largely global. However, the policy's visibility for consumers will be low and will do little to motivate consumer behaviour change. The apparel industry may feel they have been given a get out of jail free card. Although consumer demand for action on the industry will be met, on its own (without other policies that would lead to larger emissions reductions), other governments may perceive this intervention as an easy win without need of more decisive measures with immediate impacts (medium accountability).

The accountability score of policy option 1:	17 / 30
The weighted score in the total policy score:	5.6 / 100

Political feasibility

Based on expert consultations and the appliance industry's prior resistance to the introduction of product standards (**Appendix D**), the appliance industry will not welcome new standards. However, the Survey found that consumers would welcome regulatory action on the appliance industry. Water utilities' experts have been clear in their preference for source control (Anonymous Expert #1, 2020). Further, the apparel industry strongly support action on emissions from appliances. The policy will not impact job availability for textile workers. Option 1 scores high on political feasibility.

The political feasibility score of policy option 1:	15 / 18
The weighted score in the total policy score:	8.3 / 100

8.2.2. Policy option 2:

CleanBC subsidy for microfibre capture technologies

Recall, the CleanBC program is an opt-in program targeting all existing laundry appliances in all privately or commercially owned homes in BC. CleanBC, through its online rebate platform, would provide a 50% consumer rebate for the cost of purchase and installation of up to 3.2 million microfibre capture filters for washers and dryers.

The total score for Policy Option 2:	72.1 / 100

Sustainable Reductions

Effectiveness

Although Option 2 fails to address emissions during the production-phase and textile wear and tear, it is able to address emissions from household laundry appliances in BC. As the findings from the Parry Sound pilot study indicate, installing filters on washing machines can cut down on 100% of microfibres released form households to the local WWTP. A similar technology for dryers may lead to equally large emissions reductions. Therefore, in terms of cutting emissions from nearly all households in BC, Option 2 is very effective if it is popular and taken up by appliance owners.

The effectiveness score of policy option 2:	62 / 66
The weighted score in the total policy score:	18.8 / 100

Immediacy in emissions reductions

Despite its failure to meet the circularity goals, Option 2 is uniquely able to immediately halt microfibre emissions from domestic appliances (if the technology were purchased and installed). Depending on the uptake by households, a substantial portion of point source emissions reductions may be achieved within 5 years.

The efficiency score of policy option 2:	3 / 3
The weighted score in the total policy score:	10 / 100

Minimized cost

Although there will be minimal cost associated with developing a new online rebate platform, the upfront cost of the policy is very high. The estimated price[67] of a washing machine filter is $200.00. The estimated price of a dryer vent filter is $50.00. If 50% (up to $125.00) of the product costs were subsidized, the projected impact on the Province's budget over the life of the program (if every eligible private or commercial owners of appliances applied for the subsidy) would be approximately $201 million[68]. The Province may cap the amount of funding available per year for over a period of 5 years. Moreover, the potential capital expenditure is significantly lower than the province's annual expenditure on operations and capital costs which may be much higher if a WWTP technology that could safely separate and dispose of microplastics from sludge were identified.

The minimized cost score of policy option 2:	3/ 3
The weighted score in the total policy score:	10 / 100

Dynamic Sustainability

Distributive equity

Lower income households may be at a significant disadvantage for purchasing and installing filters on existing appliances. Further, in commercially owned homes, the responsibility of appliances maintenance and purchase of plumbing fixtures lies with the property owners. Depending on the percentage of the cost covered, the CleanBC subsidy would reduce but not entirely eliminate any cost burden equity considerations for British Columbians. The policy will not negatively impact consumers' lifestyles. Further, Option 2 does not impose any negative international labour and environmental impacts.

The distributive equity score of policy option 2:	20 / 24
The weighted score in the total policy score:	8.3 / 100

[67] According to the manufacturer website and expert interviews, installing microfibre filters is relatively easy. The manufacture website and product packaging provide step by step video and written installation instructions. Therefore, Option 2 will only subsidize the product price.

[68] An analogous program by Fortis BC offers up to $250 in rebates for Energy Star Certified laundry appliances.

Progress toward circularity

Similar to Option 1, Option 2 fails to address microfibre issues that are due to poor product design, low product durability, and end-of-life landfilling. Further, it fails to address textile supply chain transparency. Option 2 scores very poorly on long-term progress toward circularity and thereby sustainability.

The circularity score of policy option 2:	4 /12
The weighted score in the total policy score:	3.3 / 100

Administrative ease

Option 2 does not require any legislative action. The policy can be readily implemented with the political will, and the consumer uptake can be monitored by using the existing online CleanBC platform for sustainability rebates. However, given the opt-in nature of the program and the lack of regulatory oversight that would monitor the appropriate use of external plumbing fixtures[69], it would not be possible to monitor and enforce consumer compliance with appropriate product usage and landfilling of microfibers.

The administrative ease score of policy option 2:	5 / 9
The weighted score in the total policy score:	5.6 / 100

Accountability & Public Buy-in

Accountability

Option 2 fails to send a strong message of sustainability to consumers and the apparel industry, appearing as a carte blanche to carry on with business as usual. The appliance industry, however, will receive a strong signal that action will be required on their part – even if Option 1 were not carried out in the near future. With respect to government accountability, Option 2 sends a strong signal to voters that their elected

[69] Based on exploratory interviews with BC Plumbing Code experts, there are currently no policy levers in place that would enable monitoring to ensure appropriate filter use. This is the case for both commercially owned and privately owned buildings.

government is addressing critical environmental issues. Moreover, it will send a signal to other governments that it is entirely possible to decisively reduce microfibre emissions.

The accountability score of policy option 2:	20 / 30
The weighted score in the total policy score:	6.7 / 100

Political feasibility

The Survey data indicate all voter groups greatly value reducing microfibre emissions into the receiving environment. Further, 82% of respondents supported the government taking action by providing a subsidy for capture technologies. The apparel industry, water utilities, and NGOs will also strongly support the source control measure. However, if consulted, the appliance industry may oppose any action that would target appliances as the source of the pollution problem.

The political feasibility score of policy option 2:	15 / 18
The weighted score in the total policy score:	8.3 / 100

8.2.3. Policy option 3:

Modified Extended Producer Responsibility

Recall that Option 3 would place a $0.50 “price” on the previously un-priced negative environmental externalities of apparel, irrespective of a product’s retail price. A consumer may choose to purchase 5 low quality t-shirts which costs $10.00 each but have a high microfibre shed rate and pay a total eco-fee of $2.50. Alternatively, the same person may purchase one high quality t-shirt which is more durable and sheds fewer microfibres at $50.00 and pay an eco-fee of $0.50.

The total score for Policy Option 3:	**61.5 / 100**

Sustainable Reductions

Effectiveness

With respect to halting microfibre emissions reductions, Option 3 is highly ineffective. It does not lead to any direct emissions reductions from household laundries; nor does it lead to emissions reductions during wear and tear of apparel and the production phase.

The effectiveness score of policy option 3:	22 / 66
The weighted score in the total policy score:	6.7 / 100

Immediacy of emissions reductions

Although option 3 does not lead to immediate reductions in microfibre emissions, it should be considered a future-ready system, offering a strong and scalable starting point for addressing fashion's sustainability issues and building BC's circular textile economy. Further, the program's revenues can finance direct microfibre reduction strategies. Its impact on changing norms for the industry and consumers may take 5 to 10 years.

The immediacy of reductions score of Option 3:	2 / 3
The weighted score in the total policy score:	6.7 / 100

Minimized cost to government

Option 3 will be a source of revenue for the Province. In 2016, children under the age of 10 accounted for 9.8% of the BC population. That is an estimated 500 thousand children among the 2020 BC population of 5.15 million. Using the lower estimate of 29 articles of clothing per year and the 2020 BC population[70] of people who are 10 years or older, the total revenues generated from the suggested mEPR program would be an estimated, $67.4 million per year. Note that this figure does not account for accessories and footwear. Using the higher estimate of 70 articles of clothing per year, the estimated revenue would be $162.8 million per year (not including accessories and footwear).

The minimized cost score of policy option 3:	3 / 3
The weighted score in the total policy score:	10 / 100

[70] Using an estimated population of 4.65 million British Columbians 10 years old and above.

Dynamic Sustainability

Distributive equity

With a $0.50 eco-fee, the total estimated cost per individual who purchases 29 non-exempt items[71] per year is $ 14.50 ($35.00 for 70 items[72] per year). However, contrary to what may be expected, a levy of $0.50 is unlikely to pose a significant financial burden on low-income households. The additive eco-toll will be lower for consumers who buy fewer items. The Survey findings suggest that lower income individuals are significantly more likely to purchase fewer items per year than their higher income counterparts, see **table C.1** in **Appendix C**. The cost burden to individuals and young families will be further minimized by the exemption made for young children's clothing and non-specialty essential undergarments, and the payment of $0.25/kg of textiles. It is also worth repeating that the CPI of clothing has seen a 20% decline since 2002 (see **Chapter 5**). Moreover, nearly 3 out of 4 survey respondents stated they would be willing to pay at least $2.50 (5%) more on an article of clothing that sheds 90% fewer microfibres than a $50.00 item which would shed more. However, despite the projected low financial and lifestyle impacts on low-income groups, they will be impacted relatively more than higher income households. For this reason, Option 3 scores medium (2/3) on the criterion of cost burden to low-income groups.

With respect to the exposure burden, the mEPR program will have no impact on the consumers' lifestyles. They will be able to choose whichever articles of apparel they prefer. Perhaps most importantly, there is a clear consensus among experts that in the current economic system, the best way for consumers to help mitigate their environmental footprint is to buy fewer items of apparel but buy better quality products which will suit multiple needs and last longer (Laitala, 2020).The health and safety of factory workers and the lifestyles of citizens in textile manufacturing countries will be minimally impacted.

The distributive equity score of policy option 3:	20 / 24
The weighted score in the total policy score:	8.3 / 100

[71] The self-reported average number of articles purchased by Metro Vancouver consumers was 29 articles of clothing per person per year, see **Appendix C, figure C.11**.

[72] According to a CBC Marketplace report, on average, Canadians purchase 70 new articles of clothing per year (CBC, 2018).

Progress toward circularity

A robust EPR system may be considered the first step toward a circular textile economy. In 2019, Metro Vancouver residents landfilled more than 44 million pounds (20,000 tonnes) of textiles, or about 44 t-shirts per person, which is expected to increase by 5% each year[73] (Metro Vancouver, 2021; Zeidler, 2020). The mEPR program would help address this large and un-priced negative externality and utilize it to finance other programs that directly target microfibre emissions reductions. The revenues generated from the program may directly finance establishing infrastructure for thermal and chemical recycling of plastics and textiles. The recycled polymers may be reintroduced into the textile sector as new fibre for sustainable product design. In this way, Option 3 will decrease demand for continued resource extraction. However, in the absence of product performance standards for new fibres and textiles, Option 3 will do little to motivate the fashion industry to improve product design for better durability and reduce microfibre emissions from the use-phase of textiles. On the other hand, it will offer a first step in improving industry transparency about the true cost of fashion.

The circularity score of policy option 3:	8 / 12
The weighted score in the total policy score:	6.7 / 100

Administrative ease

The implementation of the program will require amendments to the recycling regulations under EMA, which may pose some initial administrative challenges. However, once legislated, the program can be monitored and enforced by the Ministry of Finance division that administers the provincial sales tax program. The end-of-life collection and recycling can be readily managed by the existing programs. There are currently two pilot clothes recycling programs in BC, the *Return-It* by Encorp Pacific and *Think Thrice* by Metro Vancouver. Reportedly the Return-It program will be expanding outside of Metro Vancouver.

The administrative ease score of policy option 3:	10 / 12
The weighted score in the total policy score:	8.3 / 100

[73] The estimate for BC is not known.

Accountability & Public Buy-in

Accountability

The Survey respondents unequivocally placed the burden of responsibility for addressing microfibre emissions with the fashion industry, see **figure 6.10**. However, with respect to the "polluter pays" principle, both the manufactures who increase their profits by producing unsustainably and the consumers who choose to buy low-cost high shed rate textiles should be considered polluters. Option 3 will increase the visibility of unsustainable production and consumption, especially if the EMA amendment couples the levy with sustainability labelling requirements and identifying garments as a source of microfibre pollution. However, as the Metro Vancouver Household Survey findings indicated, only 2 out of 3 shoppers pay attention to product labelling, see **Appendix C**. For this reason, the visibility to consumers is rated as medium (2/3).

In the absence of policies that target the appliance industry, Option 3 does little to incentivize the appliance industry to develop technologies to cut emissions from their products. With respect to government accountability, Option 3 will increase visibility of microfibre pollution to voters and the international community.

The accountability score of policy option 3:	21 / 30
The weighted score in the total policy score:	7 / 100

Political feasibility

The Canadian and international media focus on unsustainable fashion consumption and microfibre pollution has led to growing calls from consumers, apparel manufacturers, and NGOs for government action. The survey findings indicate a potentially strong voter support for government action on the apparel industry. The strong consumer WTP for higher quality apparel (see **figure 6.8**) indicates that consumers are willing to accept some of the responsibility for the environmental impacts of their fashion choices. However, due to the potential for perceived "inconvenience" for consumers and their preference for action on manufacturers rather than them, the projected initial voter support of Option 3 is medium (2/3).

Various groups have explicitly called for EPR programs (Ellen MacArthur Foundation & Circular Fibres Initiative, 2017; Environmental Audit Committee, 2019;

Mertens, 2020; Moody Wood & Box, 2021). The sustainable fashion brands will support programs that would make their products more competitive. In contrast, there will likely be strong resistance from large international corporations that profit from selling high quantities of cheap fashion products. Balancing these opposing interests, the projected apparel industry's support for the proposed mEPR program is medium.

It is unlikely that an EPR program in one jurisdiction may lead to significant job losses in the international garment and footwear sector. Further, if Option 3 causes decreased demand for low-cost fashion, it will promote and may, however marginally, increase demand for higher quality products which may have better internalized the social cost of labour. Therefore, Option 3 will likely lead to little or no change in the size of the global fashion workforce.

The appliance industry has largely remained silent on the microfibre issue. However, Miele, a global high-end appliance manufacturer has clearly expressed that the responsibility for the problem lies with consumers (Miele, personal communication, December 9, 2020). The industry would welcome Option 3.

Globally, NGOs such as Greenpeace and Ellen Mac Arthur Foundation were the first to raise concerns about the sustainability of growing fashion consumption. It is projected that NGOs will strongly support Option 3.

The political feasibility score of policy option 3:	14 / 18
The weighted score in the total policy score:	7.8 / 100

8.3. Analysis Results

Analyzed through the lens of BC's Sustainability Objectives, **Table 8.1** provides a summary using the BC Sustainability Objectives framework. **Table 8.2** provides and summarizes the analysis results based on individual criterion weights and measures.

Overall, Option 2, CleanBC subsidy for microfibre capture technologies, fairs best with respect to sustainable reductions. It is an effective and efficient measure in halting microfibre emissions from household laundries in a timely manner to meet the 2025 UN SDG 14.1 commitment. This option may have a larger budgetary impact for the Province than the other option. However, it does not exceed the threshold of existing annual expenditure on WWTP operations. In this light, the *minimized cost to government* objective illustrates that all three options are financially feasible alternatives to the status quo of continued microfibre emissions.

Option 3, *modified* extended producer responsibility does best as a policy that offers dynamic sustainability to the proposed policy package. The policy is designed to be equitable and easy to administer. Due to the slow turnover of laundry appliances, Option 1, product standards for new appliances, fails to effect short-term reductions. However, it does enable the province to dynamically anticipate and meet future demand for sustainable appliances.

With respect to accountability and public buy-in, all three options improve accountability. But more work will need to be done in this regard, especially with respect to textile industry. Importantly, based on this study's survey findings, if coupled with a wide-reaching public information campaign, all three options could have strong public support.

Table 8.1. The BC Sustainability Objective framework and options analysis

BC's Sustainability Objectives		Appliance legislation	CleanBC filter subsidy	mEPR
Sustainable Reductions	*Effectiveness*	✗ (red)	✓ (green)	✗ (red)
	Immediacy	✗ (red)	✓ (green)	✓ (yellow)
	Minimized cost	✓ (green)	✓ (green)	✓ (green)
Dynamic Sustainability	*Distributive equity*	✓ (green)	✓ (green)	✓ (green)
	Progress to circularity	✓ (yellow)	✗ (red)	✓ (yellow)
	Administrative ease	✓ (yellow)	✓ (yellow)	✓ (green)
Accountability & Public Buy-in	*Accountability*	✓ (yellow)	✓ (yellow)	✓ (yellow)
	Political feasibility	✓ (green)	✓ (green)	✓ (green)
Policy Ranking		3	1	2

Table 8.2. Summary of policy analysis using criteria and measures

Objectives	Weight	Appliance legislation	CleanBC filter subsidy	mEPR
Effectiveness	20	6.7	18.8	6.7
Immediacy	10	3.3	10	6.7
Minimized cost	10	10	10	10
Distributive equity	10	10	8.3	8.3
Progress to circularity	10	3.3	3.3	6.7
Administrative ease	10	6.7	6.7	8.3
Accountability	10	5.7	6.7	7
Political feasibility	10	8.3	8.3	7.8
Total score	100	54.0	72.1	61.5
Policy ranking		3	1	2
Scores Legend		*0 to 4 (0 to 8)*	*4.1 to 7 (8.1 to 14)*	*7.1 to 10 (14.1 to 20)*

Chapter 9.

Recommendations to the Province

As the population of British Columbia grows and increasingly moves to large urban centres, and as textile and fashion production increase to meet growing demand, human and ecosystems' exposure to the environmental and health impacts of microfibre pollution will only grow. The burden of water treatment will increase and must be met with technological innovations and advancements in environmental and economic policies that can buttress and balance clean production, a clean environment, and a sustainable and just local and global economy as outlined in the UN Sustainable Development Goals (SDGs). This is a tall order. However, action to address synthetic microfibre pollution offers a unique window and opportunity for the BC Government to begin to lay the groundwork for lasting impact on a myriad of interrelated negative environmental externalities which impact the province and have plagued the textile and fashion industries worldwide. This is a crucial opportunity which should be taken.

The study presented here contributes to local and global action on microfibres by providing critical insights from the perspective of consumer-citizens, the key stakeholder group whose views have largely been excluded from the discussion despite the success or failure of interventions hinging on their actions. The evidence presented shows that when informed about microfibres and related environmental threats, British Columbian are greatly concerned about the environment and offer equally great support for direct government action. Indeed, fashion and related plastic pollution are highly salient for British Columbians.

The remainder of this discussion will outline the policy recommendations that emerged from this study. This is with the hope to motivate policy actors in British Columbia to take prompt and decisive action.

9.1. Priorities in the Short Term

The findings of the policy analysis demonstrate the CleanBC subsidy for microfibre capture technologies is an important measure for meeting the Province and the federal government's ambitions for cutting microplastics emissions. The CleanBC subsidy makes a contribution to Canada's commitments to SDG 14.1, *Life Below Water,* and cutting plastics emissions from land-based sources by 2025. Moreover, by offering a technology that captures all microfibres, not just plastic (synthetic) microfibres, the policy goes further to cut emissions of hazardous substances that are coating much of the textile fibres in use today. It would be even stronger if followed by all provinces. The CleanBC subsidy, in part, also fulfills Government aims on SDG target 12.4 (achieving the environmentally sound management of chemicals and wastes, and significantly reducing their release to air, water, and soil) (G. A. United Nations, 2015). The up-front capital cost to the Province can be managed with policy design. Reducing emissions in the short-term will significantly reduce greater future costs of environmental remediation and the future healthcare costs due to increasing human exposure to hazardous microfibres.

However, despite the CleanBC program's promise of reducing emissions at the source, it is merely a stopgap to a larger systems-level problem; it is necessary but not sufficient. At this time, it is not possible to predict how many BC households will purchase and appropriately use the microfibre filters. There are also the added problems from microfibre emissions during the wear and tear of apparel and the leaching of hazardous substances from the landfilled microfibres affecting the local environment and health. Microfibres can readily travel long distances by air and water to reach remote regions around the globe. As global microfibre emissions escalate, the microfibre pollution observed in Coastal BC will continue to intensify. It is clear that the CleanBC program is an important first step that must be implemented in conjunction with other policies that can address the bigger picture.

9.2. Looking to the Long Term

Innovations in the textile and fashion industries with commensurate innovation in laundering technologies are at the core of long-term mitigation strategies to meet the new local and global picture of growing fashion consumption and associated emerging pollutants. Policy Options 2 and 3 bridge emissions reductions in the short term with long-term sustainability goals. They are essential complements to the subsidy program.

BC, the first province to set standards for laundry appliances

Governments, including France and the State of California, are taking legislative action to mandate technology standards for washing machines. Policy Option 1 addresses emissions from washing machines but goes farther than has been done in other jurisdictions to halt air emissions from electric dryers. There are ventless dryer machines currently available on the market that have zero air emissions. Zero emissions dryer machines should be made the new standard. By adopting Option 1, it will be possible that in 30 years all existing appliances will be replaced with new models that meet or exceed the legislated requirements. Until then, Option 2, the CleanBC program would be a step in the right direction to help BC achieve its environmental goals.

A barrier to a single province implementing Option 1 is the size of its market. Producers would be more likely to support this policy if other Provinces or the federal government took action. In the coming weeks (in 2021), two Ontario Members of Provincial Parliament will introduce a Private Member's Bill, Environmental Protection Amendment Act (Microplastics Filters for Washing Machines) (2020). "If passed, this bill will require residential washing machines sold in Ontario to be equipped with a microplastics filter to capture microfibres shed by clothing during laundering" (Anonymous Expert #8, 2021). However, the current political climate and the ongoing health crisis in Ontario may strongly hinder progress on this bill. According to the author of the bill, if presented to the BC Legislature, a similar bill may have a greater likelihood of passing and implementation. Unlike BC, California has a large share of the market (Coffin, 2020). If implemented, BC's amendment to the EMA along with California's AB-622 would send a strong signal to the industry and other jurisdictions to take action.

Filters are only a small part of the answer

Although the aforementioned policies are critical to reducing microfibres emissions from existing textiles and clothing which are cleaned in existing appliances or new appliances, these interventions will not fully achieve long-term goals of reducing emissions from textiles' use- and production-phase. Firstly, they rely on consumers, who are unreliable actors, for appropriate laundry and microfibre disposal behaviour. Second, captured microfibres must be landfilled and the hazardous substances they carry may escape via the landfill leachate. Thirdly, the wear and tear of textiles, be they household upholstery and carpeting or apparel, is a significant source of microfibres in atmospheric fallout. Interventions that target laundry behaviours and single out the appliance sector will fall regrettably short of the necessary emissions reductions. Textiles are the primary source of microfibres emissions. As such, long-term interventions and incentives should be targeted toward the textile and fashion industries.

mEPR, a clear business case for a BC circular economy

The Survey and policy analysis results confirm that the Government of British Columbia has a strong mandate to provide clear economic incentives for consumers and producers to do the right thing. The steady decline in the CPI for clothing, see **Chapter 5,** demonstrates there is little evidence that fashion businesses and designers are taking meaningful action to address the negative externalities of their sector. By implementing the mEPR program, the BC government will signal that clothing generates dangerous pollutants and raise revenues to help offset the costs of the CleanBC subsidy. More importantly, the mEPR program calls attention to fashion's linear economic model and provides a first step toward a "closed-loop" circular economy for textiles and fashion in BC. Long-term revenues from the program would enable BC to develop a new market for textile and plastic waste. BC could help invest in thermal and chemical recycling technologies and offer innovative ways of extending the life of plastics and fibres and reduce industry reliance on resource extraction. As the infrastructure develops, the Province may wish to also implement a requirement for recycled content on new textile products. Specifically, under enhanced EMA Recycling Regulations, all new textile products made of synthetic fibres could be made to meet new chemically recycled polymer content requirements. By doing so, the Province would be developing a local market for locally recycled fibres.

In short, via the mEPR program, BC can buttress local strategies to halt point-source microfibre emissions and offer a strong counterbalance to the huge economies of scale in plastics and cheap fashion production. By building infrastructure for recycling textiles, BC can further contribute to SDG 12 and enable Canada to meets its commitments to the Plastic Charter for "a more resource-efficient and sustainable approach to keep plastics in the economy, and out of the environment" (Canada, 2018, p. 2).

Why a modified EPR program?

According to an EPR expert from the BC Ministry of Environment and Climate Change, the process of regulating a product would require consultations with the target producers and providing them the option to form a stewardship agency. Once the legislation is passed, producers, represented by the steward ship agency, would develop an EPR plan to operationalize the regulation's requirements.

Whereas CleanBC is a government initiative, the current BC EPR system is fundamentally producer driven. In existing EPR programs, producers are provided guidelines about their responsibilities. They can address the economics however they choose to achieve the regulations' goals. Producers may choose to internalize the cost.

According to the expert, in the case of addressing point source emissions from appliances, the Ministry may require the stewardship agencies to setup a program in partnership with municipalities. The agency would then provide free or partially subsidized microfibre capture technologies to all residents through their municipalities.

There are critical problems and unintended consequences that fundamentally undermine this approach. Firstly, and it bears repeating, despite the long-known environmental and social labour externalities associated with the fashion industry, the sector has made little headway in managing its problems (Kent, 2020). Recall, the global industry is singularly growth-focused (**figure 9.1**) and anticipates an 81% increase in production by 2030 from 2019 levels (Kent, 2020). Sustainability innovations are not progressing fast enough to keep pace (Kent, 2020). Very few sustainability-oriented producers, if any, are able to compete in a market dominated by fast fashion economics (Anonymous Expert #3, 2020; Mertens, 2020; Stevens, 2020). Despite the calls from their own industry representatives for EPR programs, the industry has failed to offer any recommendations to governments. Any action by an industry agency may take years to lead to meaningful emission reductions. Like climate change, the problem of microfibre pollution has reached crisis proportions. Decisive government action is necessary to stop the hemorrhaging. Doing so necessitates equally decisive and efficient action on the fashion industry.

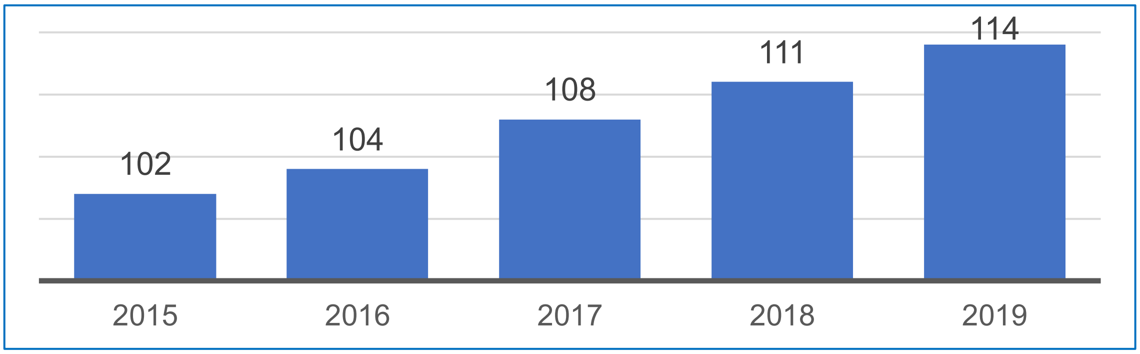

Figure 9.1. Growth in the size of the global apparel market in billions of units sold
Source: Euromonitor International, in (Kent, 2020).

Secondly, and perhaps more importantly, if producers were to internalize the cost of capture technologies, those costs would not disappear. They will either trickle down to the consumer or they will lead to cost cuts along the production phase. In the case of the former, the consumer will pay more hidden fees without improvements in industry transparency. However, the latter case is more likely. Cost cuts in the production phase may lead to further environmental degradation in the production country and wage and jobs cuts for workers who have already suffered[74] the devastating impact of the COVID-19 outbreak on their industry.

Thirdly, the approach recommended by the expert would limit the economic opportunities in BC. It would not enable the Province to institute and develop new markets for plastics and textiles. Although the recommended *modified* EPR program diverges from existing EPR models, it lays the foundation for developing a new market and new jobs as the Province works to move away from reliance on resource extraction. There is a clear business case for implementing the recommended mEPR in BC.

9.3. Microfibre Pollution, a Catalyst for Action

Legislation to mandate standards for new appliances, a government-run CleanBC program, coupled with a strong economic instrument (mEPR), is a necessary and efficient model for leading BC to environmental and economic sustainability. The policy analysis in

[74] Recall: According to a survey of 75 manufacturers across Asia, Africa and the Americas, conducted by Penn State University's Center for Global Workers' Rights and the Workers' Rights Consortium, since the start of the COVID-19 outbreak, more than half of manufacturers had accepted some orders below cost, effectively providing fashion brands with free products, in (Deeley, 2021).

Chapter 8, however, illustrates the large sustainability gaps for long-term outcomes. While the recycling of clothing is important, it will do little to address the underlying problem of microfibre emissions. Improvements in liquid waste treatment technologies and the implementation of policies which improve microfibre capture from laundries will not necessarily lead to a long-term overall decrease in emissions. Rather, these options merely divert microfibres from bodies of water to landfills and terrestrial sinks.

An in-depth benefit/cost analysis was not within the scope of this study. Even so, the evidence presented in earlier chapters and the referenced studies warrant the invocation of the precautionary principle and urgent policy action. In accordance with the precautionary principle, the Canadian Minister of Environment and the Minister of Health have recommended adding plastics to Schedule 1 (List of Toxic Substances) to the *Canadian Environmental Protection Act*, *1999* (CEPA) (P. W. and G. S. C. Government of Canada, 2020; Valiente, 2020). The Schedule 1 designation does not impose any regulatory measures. However, it enables ministers to develop and propose risk management measures under CEPA. The recently published *Science Assessment of Plastic Pollution* (2020) recommended action to reduce microplastics emissions, including synthetic microfibres (Government of Canada, 2020). The Government of British Columbia may wish to recommend expanding the Schedule 1 designation to include microfibres shed from all textiles and fibres, from renewable and non-renewable resources. The designation may enable the Province to develop the mEPR and associated sustainability programs further.

Fibre and textile construction play significant roles in product durability and microfibre shedding (Carney Almroth et al., 2018; Chile, 2021; Ellen MacArthur Foundation & Circular Fibres Initiative, 2017; Zambrano et al., 2019). This study's findings strongly indicate the urgency of prioritizing product performance standards for microfibres emissions from textiles. A Schedule 1 designation under CEPA would be the viable policy instrument for ease of regulatory intervention on microfibres and industry adoption of standards and quality benchmarks. Reportedly, the Microfibre Consortium, a textile industry organization tasked with investigating the microfibre issue, and the American Association of Textile Chemist and Colorists will be launching two databases of fabrics and fibres and standardized methods of measuring shed rates (Stevens, 2020). This will allow in-depth assessment of the impact of fibre type and textile construction on shed rate (Stevens, 2020). However, any forthcoming emissions standards must also take to into account and address emissions during the *production-phase*. Anecdotal evidence from textile industry experts and a number of published studies have highlighted the prevalence of the issue in factory settings and the health risks facing textile workers (Pauly et al., 1998; Pimentel et al., 1975; Stevens, 2020; Washko et al., 2000; Wright & Kelly, 2017).

The policies examined in this study should be considered the beginning in developing a suite of policies to address microfibre pollution, from all sources. Ideally, the federal government and international bodies would address the issue in a cohesive and cooperative way and commit to binding short-term and long-term targets. However, the Province of British Columbia, and indeed other provinces, should not wait to take their lead from other jurisdictions. There is mounting evidence that government action on microfibre is needed. BC can be a policy leader on microplastic pollution and textile sustainability.

It is also worth considering that, globally, textile production is a larger contributor to climate change than aviation and shipping combined, and a polyester shirt has more than double the carbon footprint of a cotton equivalents (Ellen MacArthur Foundation & Circular Fibres Initiative, 2017; Environmental Audit Committee, 2019). Perhaps in part brought-on by the global and local challenges from the COVID-19 outbreak and in part due to growing media attention on social (labour) and environmental sustainability issues, sustainable global economic recovery and circularity have taken centre stage in policy discussions. As the ideas of circular economy and a just economic recovery dominate interventions considerations in many sectors, there is an urgent need for a closer look at ways to address water pollution, carbon emissions, and fair treatment of labour in textiles and fashion production and consumption. The synthetic microfibre issue presents governments and policy actors with a clear and critical opportunity to take targeted steps and decisive action on an industry very much in need of intervention.

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Appendix A.

Expert and Stakeholders Consulted

Sam Athey	PhD Candidate, Diamond Lab; University of Toronto
Dr. Love-Ese Chile	Principal Researcher and Consultant, Grey to Green Sustainable Solutions
Dr. Scott Coffin	California State Water Resources Control Board
Lisa Erdle	PhD Candidate, Rochman Lab; University of Toronto
Brooke Harrison	Project Coordinator, Parry Sound Divert & Capture; Georgian Bay Forever
Dr. Kirsi Laitala	Consumption Research Norway; Oslo Metropolitan University
Halley McIlwraithe	Rochman Lab, University of Toronto
Joël Mertens	Director of Higg Product Tools; Sustainable Apparel Coalition
Rachael Z. Miller	Rozalia Project, Founder & Expedition Science Expert; Cora Ball, Founder & CEO
Dr. Ricardo Rivera-Acevedo	Cofounder, Viridis Research, Water Treatment Researchers
Katy Stevens	Head of Corporate Social Responsibility and Sustainability; European Outdoor Group
Usman Valiente	Senior Policy Analyst; Circular economy lab
Holly Wyer	California Ocean Protection Council; Marine Pollution Program Manager
Dana Zheng	Program Manager, Policy Planning and Analysis, Liquid Waste Services; Metro Vancouver
And many others who requested confidentiality	

Appendix B.

The Survey Analysis Methodology

The results presented in the study outline the findings from contingency and multiple regression analyses with respect to Metro Vancouver households' (respondents') laundry and clothing purchase behaviours, environmental concerns and attitudes, apparel sustainability attitudes, and interventions preferences. The information outlined in the charts provide insights regarding correlations between variables (demographic, attitudinal, and behavioural).

With the exception of a few multiple-choice questions, all closed-ended questions were numeric 11-point Likert scales with semantic anchors at 0, 10, and 5 as the 'neutral' position. The numeric Likert scale of 0 to 10 was employed so that, wherever necessary for analysis, the responses could be considered as continuous, enabling the use of statistical tests for continuous data. Further, the continuous nature of responses from 0 to 10 enables reliable and consistent collapsing of small categories into larger ones, in the form of categorical variables, providing ease of clear and consistent contingency analysis. The numeric scale could function as both an interval scale, in response scales ranging from 'strongly disagree = 0' to strongly agree = 10' where the units are equidistant for every pair of adjacent values, and as a ratio scale where a response of zero is a true value of zero, such as frequency of a behaviour in 'Never = 0' and 'Always = 10' (Toepoel, 2015)

Unless otherwise stated, the responses to Likert scale questions were collapsed into 3 categories: Net: 0, 1, 2, 3; Net: 4, 5, 6; Net: 7, 8 ,9, 10.

In the contingency analyses, comparisons of category proportions (percentages) for statistical significance were conducted using Z-tests, comparisons of means for open-ended numeric responses were conducted using t-tests. Means comparisons for more than two groups were done using ANOVA -type analyses. Unless otherwise stated, a significant difference found in contingency analysis is typically reported in larger size, bold, and italics type face. The multiple regression analyses were done using Ordinary Least Squares (OLS).

It is important to note that the data analyzed in this study are the self-reported perceptions, attitudes, behaviours (behaviour recall), and priorities of a representative sampling of Metro Vancouver households in 2020. The sample statistics summarized (mean, median, and sample proportions) offer reliable estimates of the population parameters for Metro Vancouver. Although consideration must be given to the limits of such a study, the data presented here are critical to addressing issues of environmental sustainability in the textile and apparel sector, especially with respect to synthetic microfibre emissions at the watershed scale.

Appendix C.

The Metro Vancouver Household Survey

The following is a brief summary of the key findings from a representative household survey study conducted in Metro Vancouver, British Columbia, Canada. At the time of writing, it is the first ever representative household-level survey and assessment of consumer behaviours, perceptions, attitudes, and preferences as they pertain to the synthetic microfibre pollution issue. Please note, the Survey questionnaire instruments singularly focused on synthetic microfibre emissions, not all microfibre types.

The survey was designed to address the following questions, among others.

- How do households' (respondents) laundry and purchase behaviours correlate with microfibres emissions?
- How do households' attitudes toward the environment (e.g., prior knowledge of the microfibre pollution issue and related concern about the environment) correlate with their policy preferences?
- How likely or unlikely are households to invest in microfibre reduction measures? Would households take advantage of rebates or subsidies for investment in abatement technologies?
- What is the potential impact of microfibre related eco-labelling on consumer purchase behaviour? What trade-offs do households make regarding their purchase decisions?
- How much value do households place on a healthy environment with less microfibre pollution? What is consumer willingness-to-pay for sustainable clothing and abatement technologies? Does willingness-to-pay vary across household groups?
- What is the potential efficiency of each potential intervention opportunity as a source-control measure?

Behavioural considerations

Laundry Facilities

Among the Metro Vancouver Household Survey respondents, 34% were renters and 60% were homeowners, **figure C.1**. Figure 3 provides the breakdown of primary laundry method[75].Shown, in **figure C.2**, nine hundred and ninety-nine respondents use either ensuite (in the home) appliances or share (common) laundry rooms available to all residents in their building. As may be expected, nearly all homeowners (93%) have access to ensuite laundry machines. Perhaps reflecting the City of Vancouver and Metro Vancouver rental housing markets' increasing reliance on high-rise condominium buildings, nearly two-thirds (58%) or 3 in 5 respondents who rent their homes use ensuite laundry machines.

A significant factor directly impacting the total mass of microfibres released from household laundries is the type of washing machine, specifically, whether it is top-loading or front-loading (Hartline et al., 2016). When controlling for garment type, age (mechanical aging from previous washes), and brand, Hartline et al. (2016) report that by mass microfibres recovered from the effluent of top-loading washers are seven times greater than those collected from front-loading washers, ranging from 220 mg of microfibres per garment recovered from front-loading machines to as much as 1906 mg from the top-loading alternative. The significant difference has been attributed to the abrasive action of the central agitator in top-loading machines versus the rotating drum in front-loading machines and the higher volume of water which wash out more fibres.

Critically, 46% of Metro Vancouver households use top-loading washing machines, figure 5. Among renters, and likely condominium-dwellers, 57% use top-loading machines, not pictured. Forty-one precent (41%) of homeowners report the same, likely also because they reside in a condominium. Based on these statistics, and the Hartline et al. (2016)

[75] Illustrated in figure 3, a very small number of respondents (total n=34) report using the services of laundromats (n=22), drycleaners (n=6), or hand washing (n=6) as their primary method of cleaning their clothing. As these are very small proportions of the total data, they are excluded from the majority of the contingency analysis and charts on laundry behaviour. In figure 4, 'other' refers to those 34 respondents

findings, for every load of laundry, nearly half of Metro Vancouver households could potentially have a synthetic microfibre footprint seven times greater than the other half.

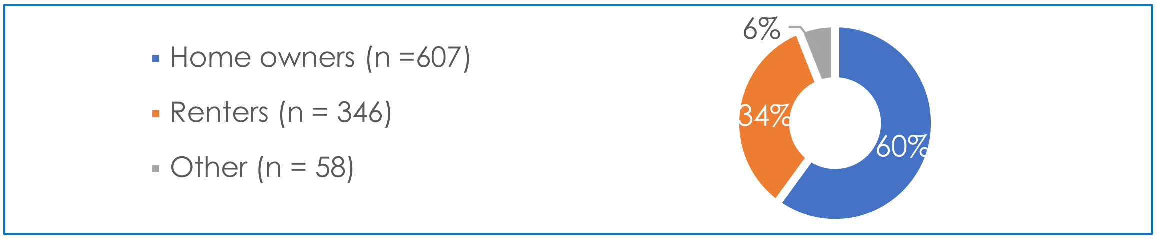

Figure C.1. Proportions of respondents who own or rent their homes, N = 1011; base excludes N/A

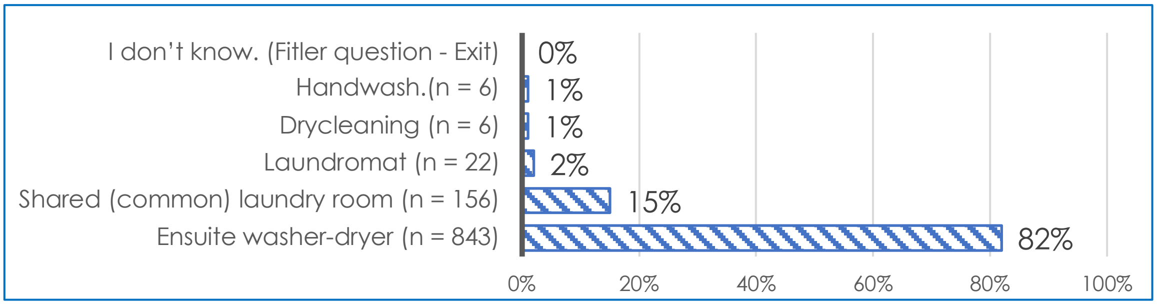

Figure C.2. Primary household laundry method; N = 1034

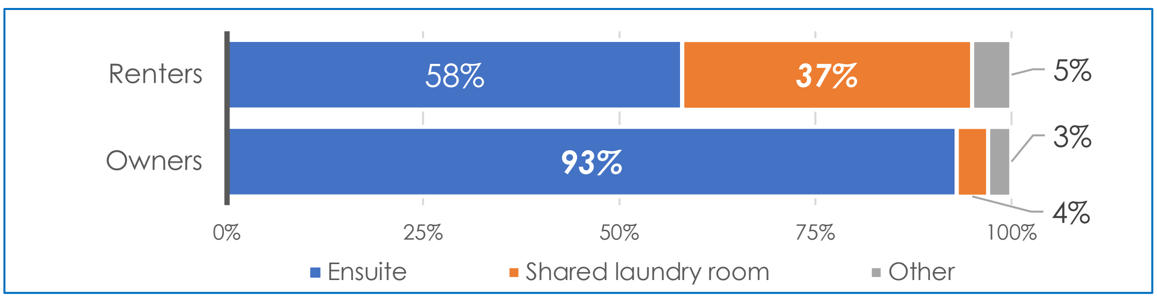

Figure C.3. Primary laundry method by home ownership

Figure C.4. The types of washing machines used by Metro Vancouver household

Laundry Behaviours

Laundry Frequency

Based on the self-reported mean of 2.5 loads of laundry per week, on average, Metro Vancouver households run 130 loads of laundry per year (assume 52 weeks/year), which is 40% less than the average of 219 loads assumed by McIlwraith et al. (2019) for Ontario households. Of course, the self-reported mean increases by household size and the number of children, see **figures C.5** and **C.6**. Comparing their means of 2.5 and 2.6, men and women, respectively, do not appear to differ significantly in laundry frequency. As their group means of 2.2 (18–34 years old), 3.0 (35-54 years old), and 2.4 (55+ year old) indicate, and is reflected in their frequency distributions 35- to 54-year-olds reported significantly higher numbers of wash loads per week, which may correspond to parenthood and/or transition from education and training to professional work. The youngest demographic reports the fewest number of wash-loads per week. The convenience of having access to ensuite laundry nearly triples the likelihood of running more than one load of laundry per week, **figure C.7**.

Care and Maintenance

Clothing care instructions are typically provided on a permeant label (wash tag) along one of the inside seams of most garments. Whether or not consumers read and follow care instructions is important for minimizing fibre damage and extending the life of garments; thereby, minimizing fibre breakage and microfibre release. Clothing made from synthetic textiles such as polyester and rayon require different laundry frequency and wash cycle settings than natural fibres or mixed fibre fabrics.

As may be expected, gender and age impact the likelihood of engaging with care instructions. However, more than half (61%) of respondents reported they often read the care instructions on individual articles of clothing before running a wash cycle. The ratio was largely driven by female respondents, the 55+ age group from both genders, and respondents from small households of only one or two persons, **figure C.8**.

In summary, it appears that the presence of children in the household, age, and access to an ensuite laundry correlate with greater laundry frequency and whether or not one follows care instructions.

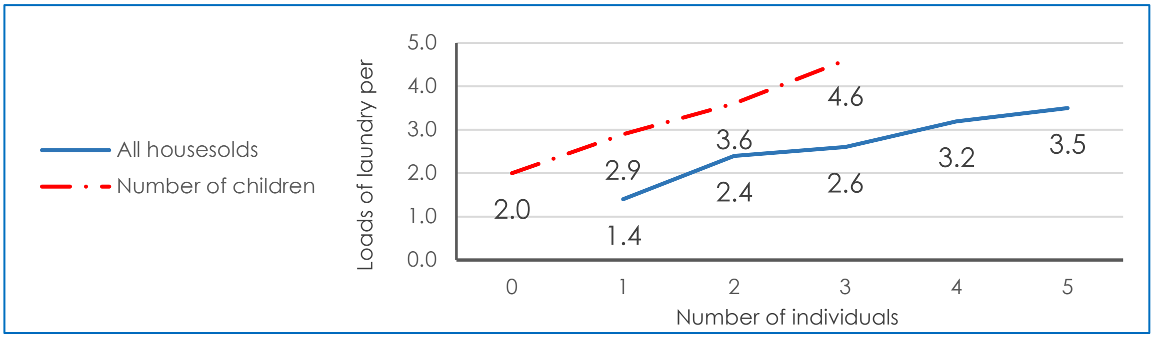

Figure C.5. Average number of loads of laundry per week by household size and number of children

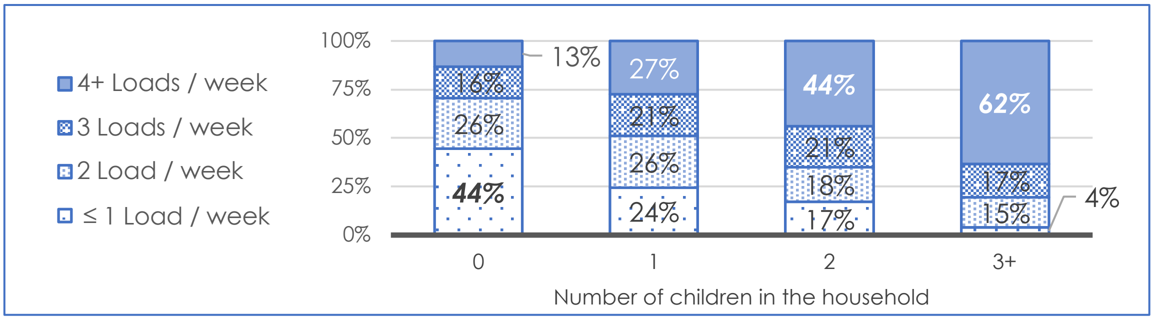

Figure C.6. Number of loads of laundry per week by the number of children in the household

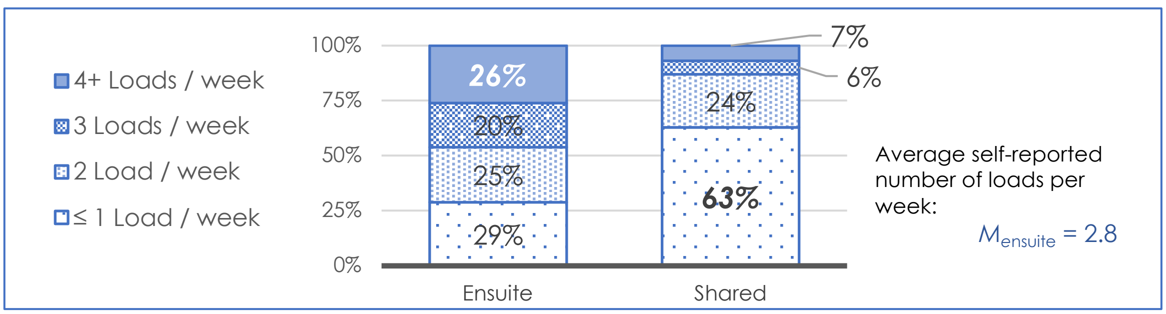

Figure C.7 Number of loads of laundry per week by laundry facility

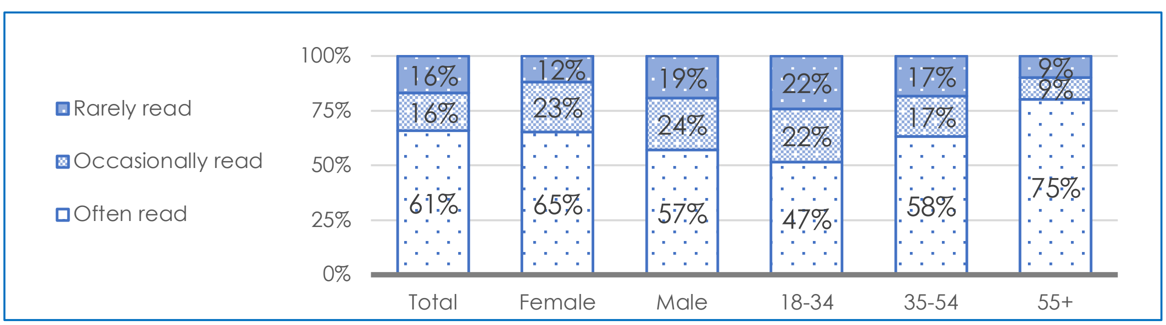

Figure C.8 Proportions of respondents who read the wash tag care instructions on individual articles of clothing, compared by gender and age

Appliance Purchase Priorities

Various reports suggest that Arçelik, a European appliance manufacturer, may have produced a washing machine with a multilayered filter that can capture 90% of microfibres from a wash cycle (Ho, 2019). According to the Arçelik website, they are currently working to develop a system that may capture 99.9% of microfibres from a wash cycle (Bulgurlu, 2020). In the absence of mandated emissions standards, microfibre reduction from household laundries will rely on voluntary action by industry and point-of-purchase information measures to motivate consumers to select the sustainable option, such as an Arçelik washing machine.

Given that washing machines with preinstalled filters are not currently available in the Canadian market, the general concept of environmental impacts was used as a proxy for microfibre capture technologies. Summarized in **figure C.9**, Metro Vancouver households do not prioritize the environmental impacts of washing machines as an important consideration in their purchases. In fact, price and product performance were rated as the top two most important criteria, followed by how well the appliance fits into the designated space in the home. Further, higher household income does not correlate with a greater likelihood of prioritizing the environmental sustainability of washing machines, see **figure C.10**. Greater household income correlates more closely with prioritizing product performance and product fit. Higher and lower income households do not differ in their point-of-purchase preferences and priorities for washing machines.

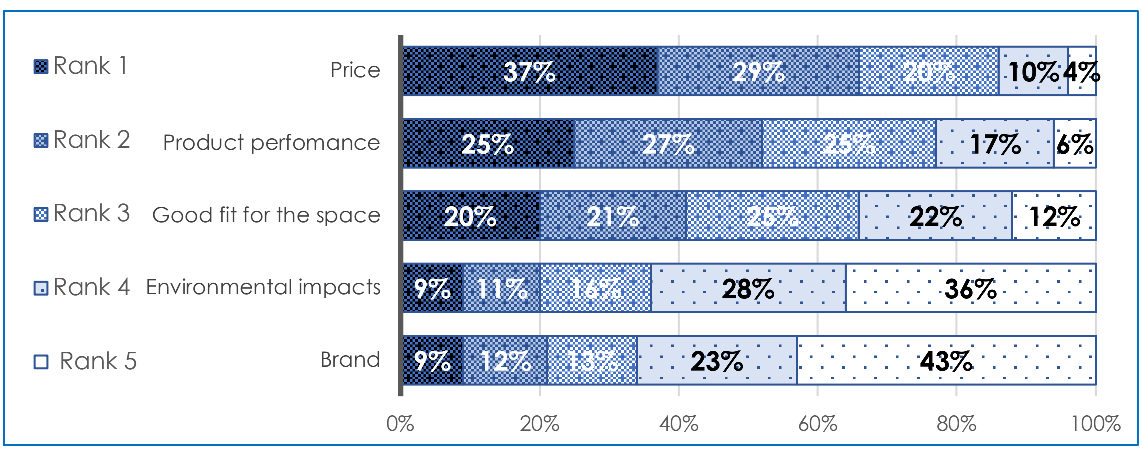

Figure C.9. Point-of-purchase priorities when buying a new washing machine
A rank of one indicates the top priority criterion.

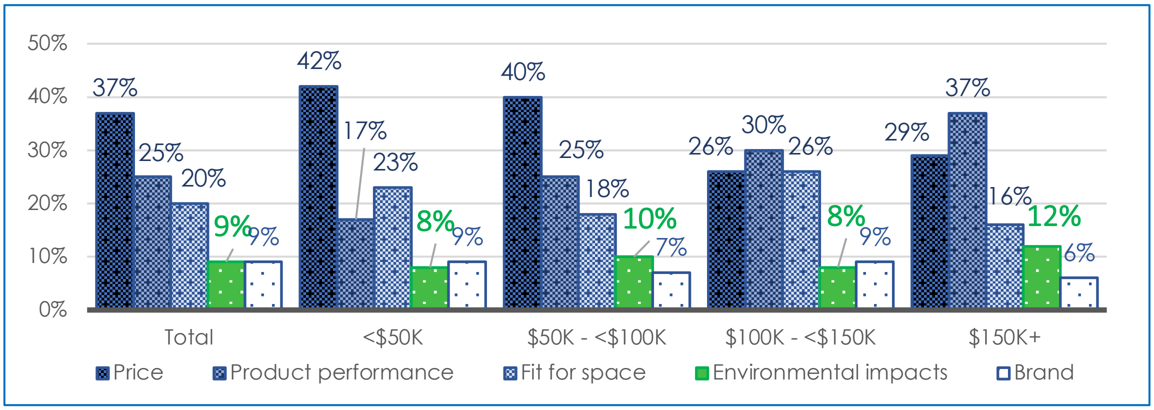

Figure C.10. Which appliance criterion is ranked first at the point of purchase? Compared by householdincome

Clothing Purchase Behaviours

Today, synthetic fibres dominate the textile market and polyester accounts for more than 60% of all garments on retail shelves (Environmental Audit Committee, 2019; Textile Exchange, 2019). The overall growth in textile production is led by synthetic fibres (Henry et al., 2019; The Fiber Year, 2017). The fashion industry's increasing reliance on synthetic fibres and the synthetic microfibres pollution problem has often been attributed to the growth in consumption of fast fashion[76] (Brodde, 2017; Cobbing & Vicaire, 2017; Environmental Audit Committee, 2019; Storry & McKenzie, 2018; Vassilenko et al., 2019). It has also been argued that fast fashion democratized the benefits of fashion for everyone, irrespective of class associations, income, or background (Environmental Audit Committee, 2019). However, whether or not this supposition has been investigated against real consumer behaviour is unclear. In order to address this potential gap in research, this section explores the relevant behavioural factors including the relationship between household income and preference for fast fashion. As described in the next section, *Outliers and Excluded Data*, extreme outliers were excluded from this section of the analysis. In the context of this study, the term clothing refers to all articles of clothing except socks and underwear.

Total volume of articles of clothing purchased over a year

As noted in **figure C.11,** it appears that on average, Metro Vancouver residents may purchase 29 articles of clothing per person per year. Of course, the average is

[76] Affordable clothing from fashion retailers carrying the latest trends is called fast fashion.

impacted by outliers, and the median of 8 may be considered a better behavioural representation. Despite the skewed nature of the data, however, when comparing the volume of clothing purchases in quartiles (each level ~ 25% of data), it is clear that more than 22% of respondent purchase an average of 25+ articles of clothing per year. That is, 22% of shoppers purchase at least two new items per month.

Although the differences are significant, women are only slightly more likely than their male counterparts to purchase 9 or more articles of clothing over a year, **figure C.12**. The oldest age group, 55+ years old, are significantly more likely than other groups to buy fewer than 9 items over the span of a year **figure C.13**. Households with children are twice as likely as others to purchase 25 or more articles of clothing in a year, **figure C.14**. The largest proportion of the 55+ age group (45%) purchase no more than 4 articles over a year, which is the comparatively smallest volume of purchases. Outlined in **Table C.1**, respondents belonging to the lower income brackets buy fewer clothing per year than those in higher income groups.

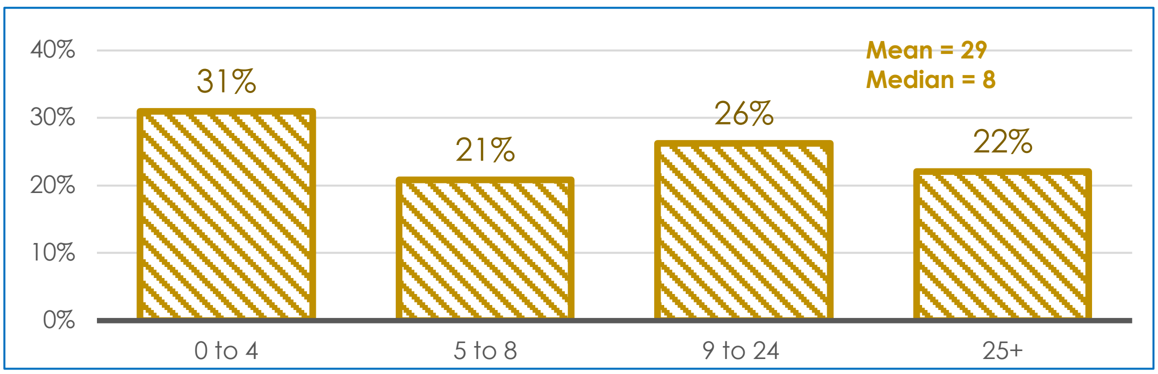

Figure C.11. Number of articles of clothing purchased over the period of one year; N = 1034

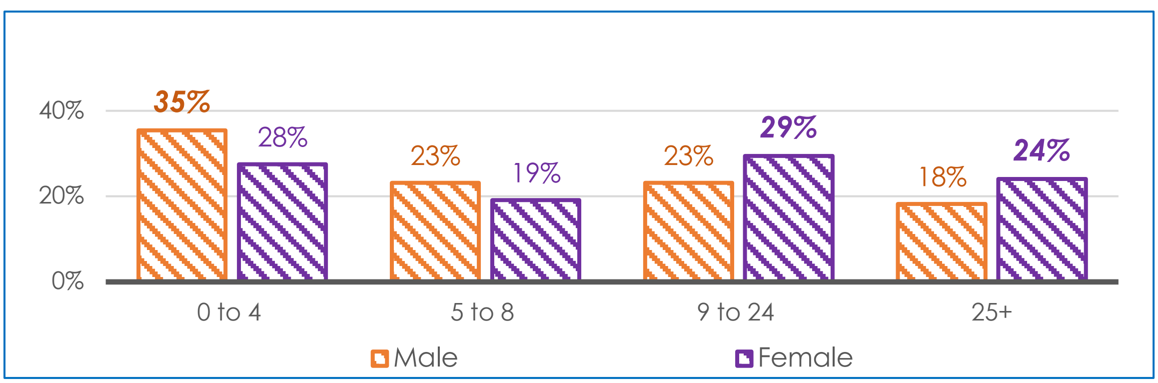

Figure C.12. Number of articles of clothing purchased over the period of a year, compared by gender; N = 1034

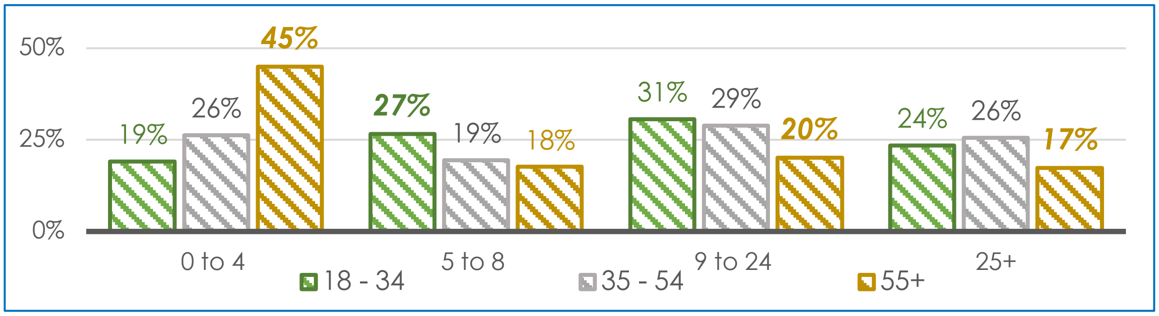

Figure C.13. Number of articles of clothing purchased over the period of a year, compared by age; N = 1034

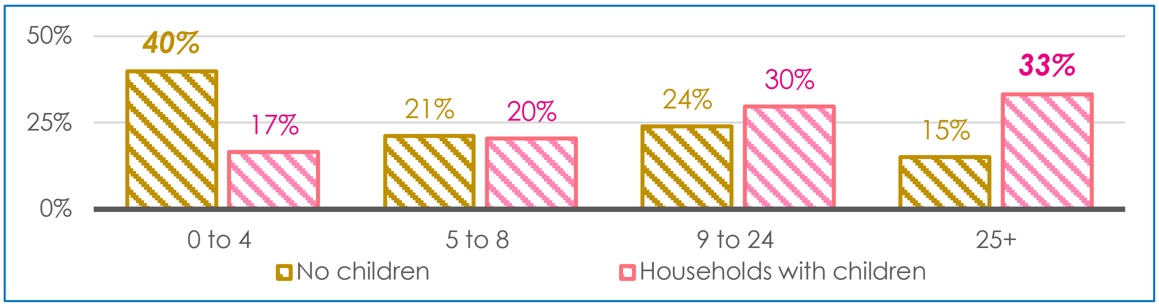

Figure C.14. Number of articles of clothing purchased over the period of a year, compared by children in the household

Table C.1. Comparing the number of articles of clothing purchased over the period of a year, by household income

	<$50K	*$50K-<$100K*	*$100K-<$150K*	*$150K+*
0 to 4 articles/year	***35%***	32%	22%	24%
5 to 8 articles/year	18%	21%	23%	25%
9 to 24 articles/ year	25%	27%	27%	27%
25+ articles/year	22%	20%	28%	24%

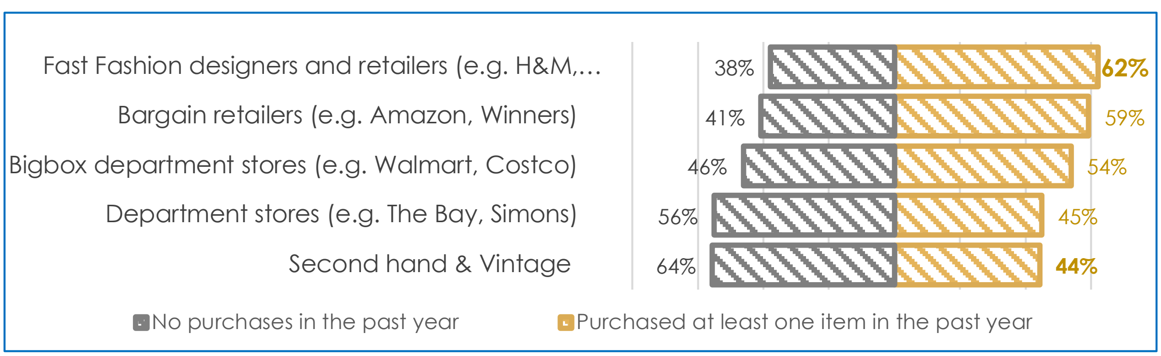

Figure C.15. Top 5 shopped clothing retailers, compared by the proportions of respondents having made at least one purchase from the retailer group in the past year

Favouring low-cost fashion above more sustainable alternatives

Based on the self-reported ratios, in the past year, two out of every three Metro Vancouver residents (62%) frequented and purchased at least one article of clothing from a fast fashion retailer, **figure C.15** and **table C.2**. Similar proportions of them shopped bargain and big box department stores. Very definitively, affordable designers and retailers are the top three types of fashion establishments that Metro Vancouverites favour, followed very closely by mid-range department stores, such as The Hudson's Bay Company, and Simons. Designers and retailers of casual and professional everyday clothing that carry environmentally sustainable collections, such as Oak & Fort and G-Star Raw, were the lowest shopped group. It should be noted that although some outdoor specialty retailers, such as Patagonia, offer environmentally sustainable selections, their collections may be niche and carry a relatively limited range of garments suitable to everyday needs. Further, purchases of seasonally appropriate clothing, such as a Patagonia winter coat, likely accounts for a much smaller percentage of respondents' annual purchases than casual garments. A promising statistic, however, is that nearly half (44%) of respondents frequent second-hand and vintage retailers, potentially reducing demand for new apparel.

Table C.2. Top-shopped fashion retailers in Metro Vancouver

Fast Fashion designers and retailers (e.g., H&M, Zara, Uniqlo)	***62%***
Bargain retailers (e.g., Amazon, Winners)	***59%***
Big box department stores (e.g., Walmart, Costco)	***54%***
Department stores (e.g., The Bay, Simons)	45%
Second-hand retailers (e.g., Mine & Yours, Value Village, Hunter & Hare)	44%
Athleticwear designers and retailers (e.g., Nike)	40%
Mid-range retailers and designers (e.g., Aritizia, Brandy Melville)	38%
Outdoor specialty designers and retailers (e.g., Patagonia, MEC)	36%
Neighbourhood boutique	34%
Professional clothing retailers (e.g., Mark's Work Warehouse)	32%
Yoga athletics (e.g., Lululemon)	20%
Upper mid-range designers and retailers (e.g., Kate Spade)	17%
High-end designers and retailers (e.g., Holt Renfrew, Vivienne Westwood)	16%
Specialty size (Mr. Big & Tall)	15%
Sustainable designer retailers (e.g., G-Star Raw, Frank & Oak)	12%

Proportions of respondents who purchased at least one item from each of the 15 retailer groups.

Investigating fast fashion shopping more closely (excluding responses of 0% fast fashion purchases in the past year), **figure 5.16**, it appears that both genders and all age groups buy fast fashion, though women and the two younger age groups are significantly more likely to do so. Respondents who purchase some, most, or all of the clothing for young children or teenagers are significantly more likely than those who do not shop for children (the N/A group) to buy fast fashion, **figure C.17**. Further, higher household income is correlated with buying fast fashion. The two highest income brackets are significantly more likely than the lower income groups to buy fast fashion apparel, **figure C.18**.

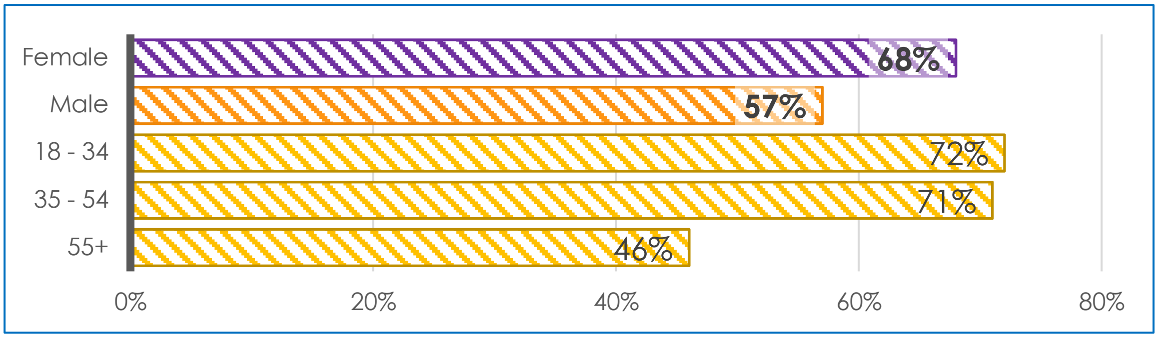

Figure C.16. Who shops fast fashion? Compared by age and gender

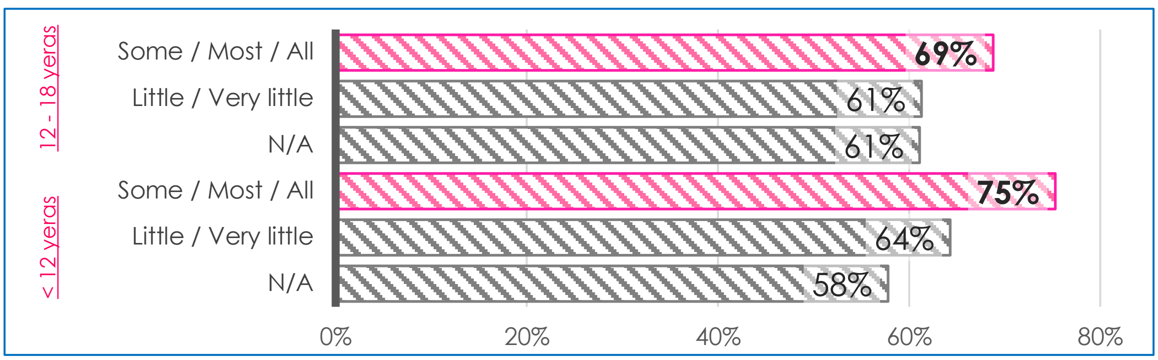

Figure C.17. Who shops fast fashion? Compared by the age group of children in the household

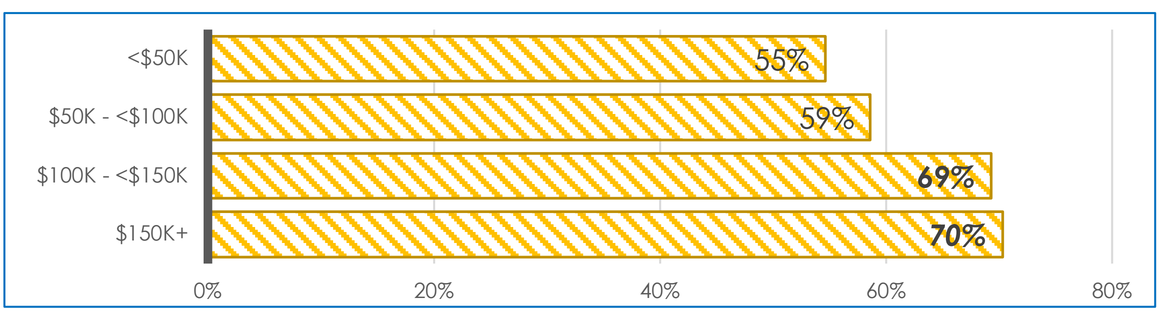

Figure C.18. Who shops fast fashion? Compared by household income

Although households in the two lower income brackets are less likely than their higher income counterparts to purchase fast fashion, they are equally likely to purchase low-cost apparel from bargain retailers and big box department stores. Manufacturers such as Wal-Mart and Target have adopted the fast fashion model of producing fashion at a lower cost and shortening new fashion product delivery times from twice a year, as was the case in the last century, to every two to three weeks, and even daily (Remy et al., 2016). The fast fashion phenomenon and the barriers it imposes on sustainability in the industry and microfibre emissions management is explained in Chapter 6. **Figure C.19** illustrates that overall, two out of three respondents from any income bracket are purchasing their apparel from low-cost clothing retailers.

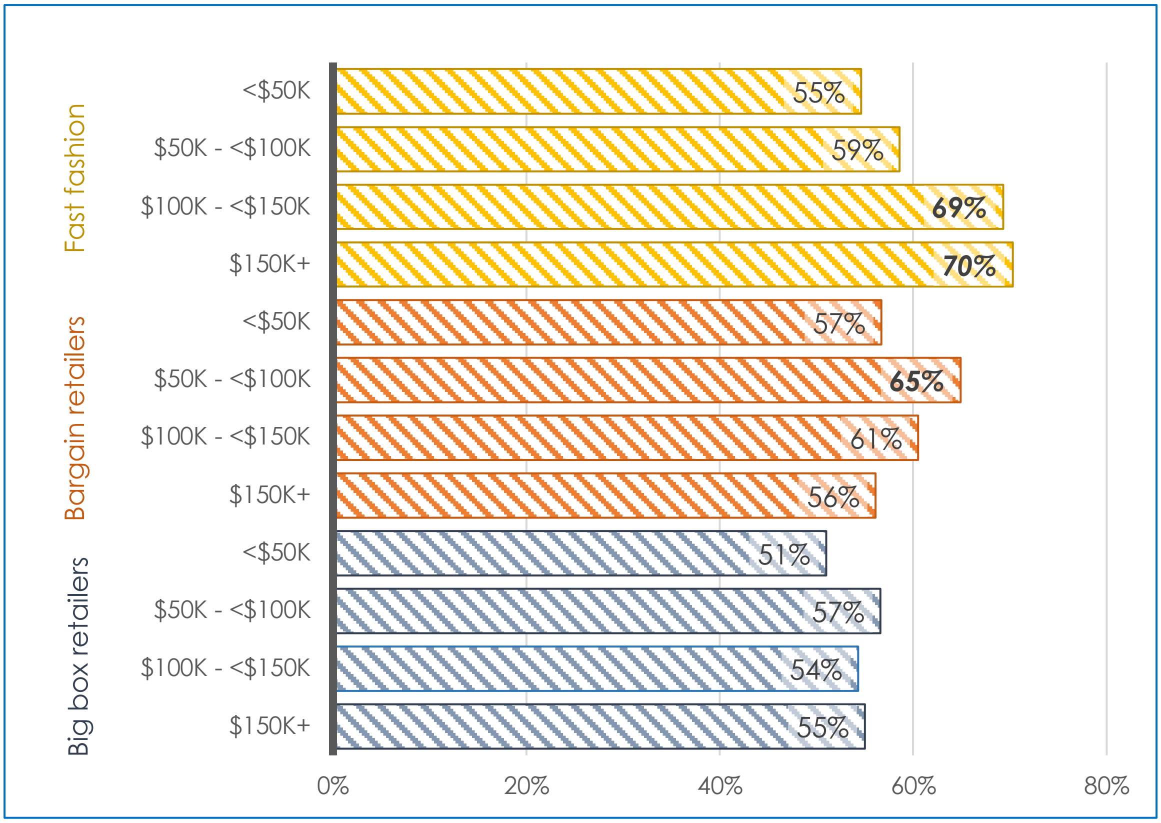

Figure C.19. Comparing the patronage of global low-cost fashion retailers by the proportion of consumers from different income brackets.

Point of purchase information measures

Designed in sharp colours and sleek multi-layer shapes, hangtags are a disclosure label applied to articles of clothing (and other apparel) accessible to consumers at the time of purchase. As noted in the previous chapter 4, some jurisdictions may mandate point-of-purchase information measures to address synthetic microfibre emissions, which are to be listed on hang tags. Findings from interviews with apparel industry representatives suggest whether or not consumers utilize hang tags in their purchase decision-making is largely unknown (Anonymous Expert #3, 2020b). Therefore, the potential impactful-ness of any informational measures at this level is an important consideration to explore and address.

Sixty five percent of Metro Vancouver shoppers report that they often read hang tags before making a purchase, **figure C.20**. Consumers likely want to know more about an article of clothing and learn about the care protocols before making a purchase decsion. However, consumer priorities are foundational to whether or not point-of-purchase informational interventions will be sufficient for reducing synthetic microfibre emissions from household laundries. More to the point, the question is whether or not information campaigns and point-of-purchase informational measures will be effective as a primary source intervention. In short, information measures may be necessary, but are they sufficient?

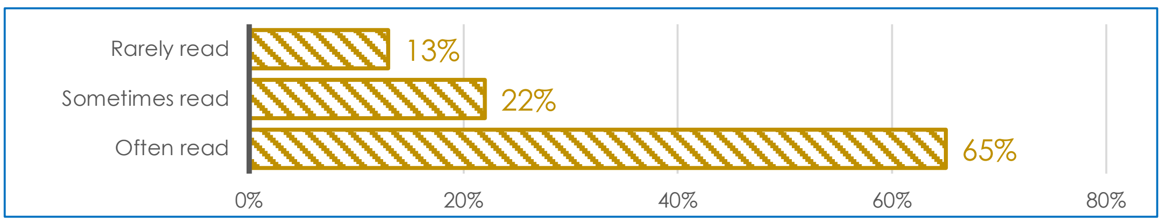

Figure C.20. How often consumers read hang tags before making a purchase?

The *Metro Vancouver Household Survey* asked respondents to rank 9 point-of-purchase clothing criteria and list their top 5 purchase decision priorities, where a rank of 1 is given to the most important criterion. The criterion of 'environmentally sustainable production process' was listed as a proxy for sustainability issues related to synthetic microfibre emissions. Very decisively, a majority, 57%, of respondents ranked price as the most important criterion guiding their purchase decision, distantly followed by fibre type, material performance, and care instructions, in second, third, and fourth place, respectively, see **figure C.21**. The fifth-place rank was a tie between 'locally produced' and 'brand name.' Sustainability ranked seventh. Critically, only 2% of all respondents ranked environmentally sustainable production as their top point of purchase priority, **table C.3.** There does not appear to be any relationship between preference for environmental sustainability and household income. That is, belonging to a higher income bracket does not improve the likelihood of ranking sustainable production as a high priority issue for purchase decision making.

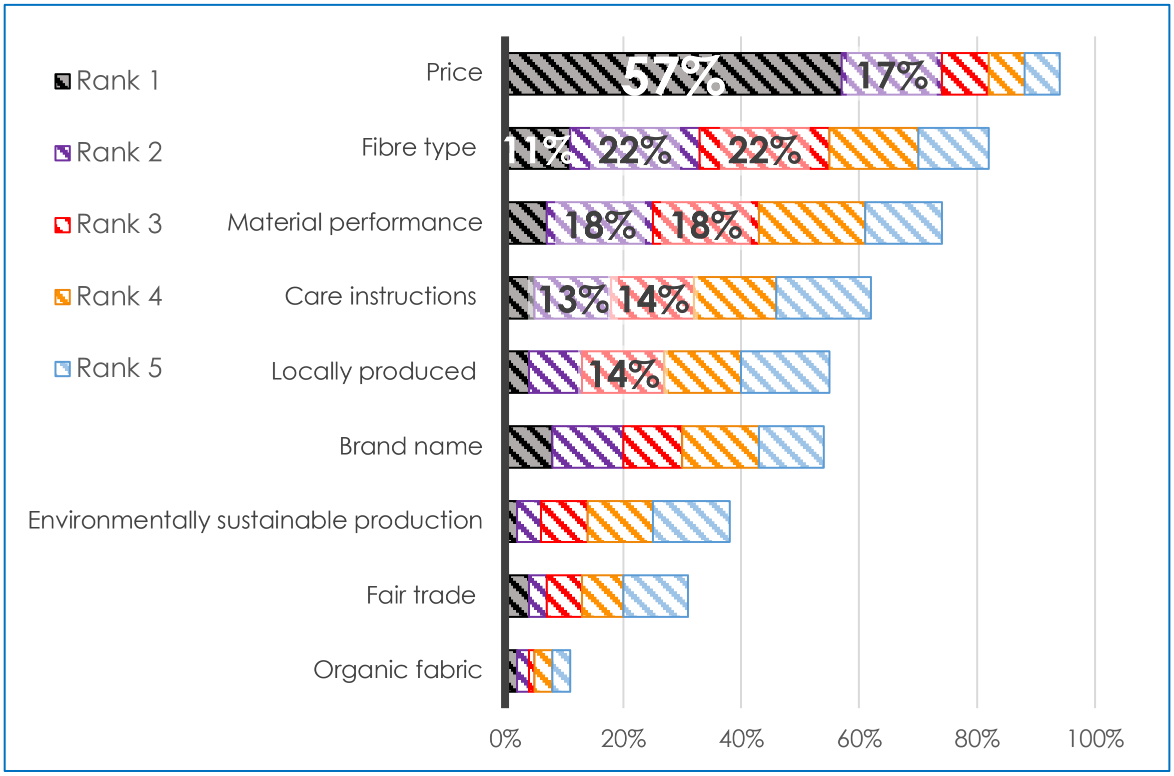

Figure C.21. Ranking consumer priorities at the point-of-purchase

Table C.3. What proportion of each income bracket rank each of the 9 point-of-purchase criteria as their primary consideration at the point-of-purchase?

Income bracket	N = 1034	<$50K	$50K-<$100K	$100K-<$150K	$150K+
Price	57%	64%	57%	54%	47%
Fibre type	11%	10%	11%	10%	13%
Brand name	8%	4%	9%	6%	12%
Material performance	7%	2%	8%	10%	10%
Care instructions	5%	5%	4%	8%	5%
Locally produced	4%	4%	3%	5%	8%
Fair trade	4%	6%	4%	3%	2%
Organic fabric	2%	3%	0%	3%	1%
Env sustainable production	2%	2%	4%	2%	3%

Factors influencing behaviour

As discussed earlier in this report, there has been a great degree of effort from the scientific community to investigate the environmental impacts of microplastics and synthetic microfibres. Accordingly, there have been efforts to identify mitigation strategies and some government action has been taken to implement various recommendations. However, public awareness and concern about plastic pollution, generally, and synthetic microfibres, specifically, has not been assessed. Indeed, public awareness (issue knowledge), environmental concern, priorities about environmental issues, and attitudes, are considered key aspects of how the public frame their views and offer support for environmental interventions and policy strategies (Fransson & Gärling, 1999; Gelcich et al., 2014; Hines et al., 1986; M. Wiernik et al., 2013; Paul et al., 2016).

Environmental Concern

Midway through the Survey, respondents were provided a paragraph of contextual information about synthetic microfibre ocean pollution. Near the end of the Survey, they were asked to rate whether or not they perceive the issue as a serious environmental concern. Illustrated in **figure C.22**, a vast majority (85%) of respondents rated synthetic microfibre ocean pollution as a serious environmental issue.

Nearly 50% of all respondents reported they had no prior knowledge of the microfibre issue ahead of completing the Survey. The provision of information about synthetic microfibres in the environment, their sources, and their potential impacts, filled that knowledge gap. Those with prior knowledge about the issue are only slightly (by 9 percentage points) more likely to rate synthetic microfibres as an issue of serious concern than their counterparts without prior knowledge, **figure C.23**. **Figures C.24** to **C.26** illustrate further that irrespective of various demographic factors and socioeconomic class considerations, the vast majority of respondents perceive synthetic microfibres as a serious environmental issue. It is worth noting that although, when compared to other groups, a smaller proportion of respondents among the Conservative Party of Canada voters rated the issue as serious, 68% constitutes a large majority, **figure C.27**. In short, environmental concern about microfibres is not a wedge issue for voters.

Overall, the synthetic microfibre issue appears to be highly salient. This may be in part attributable to the personal and relevant context of the problem as it involves the individual respondents' personal clothing consumption and laundry habits. A more in-depth discussion of environmental concern about synthetic microfibres in comparison with other environmental issues, such as air pollution and climate change, may be provided upon request from the study author.

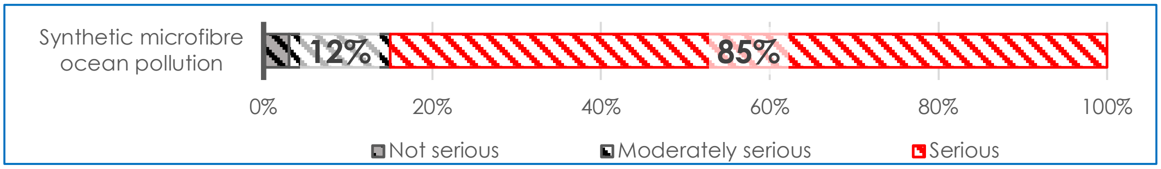

Figure C.22. The proportion of respondents that are concerned about synthetic microfibre ocean pollution, after the provision of information

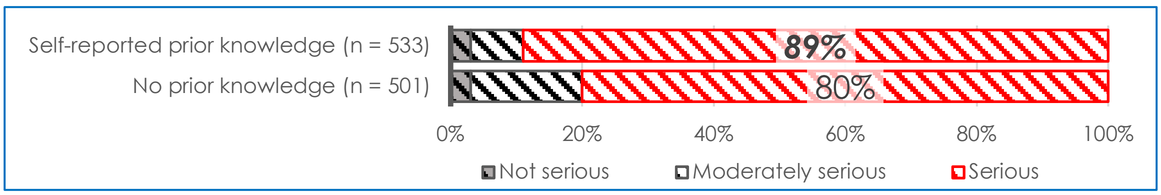

Figure C.23. Concern about synthetic microfibre ocean pollution, compared by self-reported prior knowledge about the issue

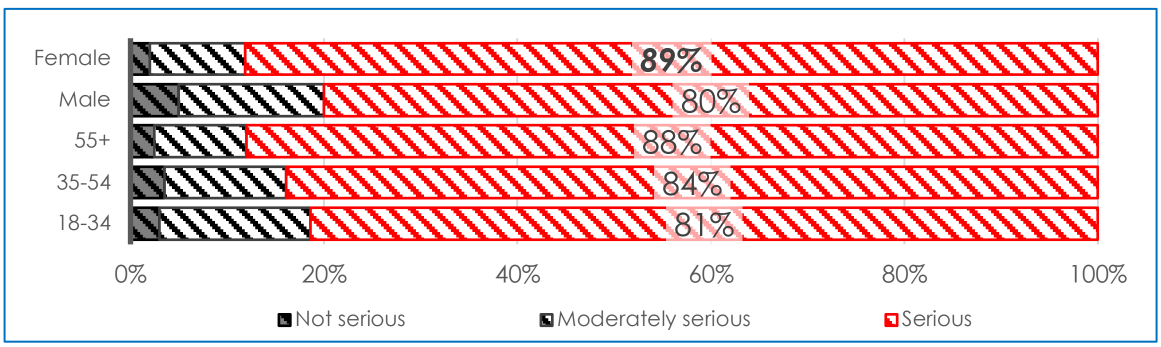

Figure C.24. Concern about synthetic microfibre ocean pollution, compared by age and gender

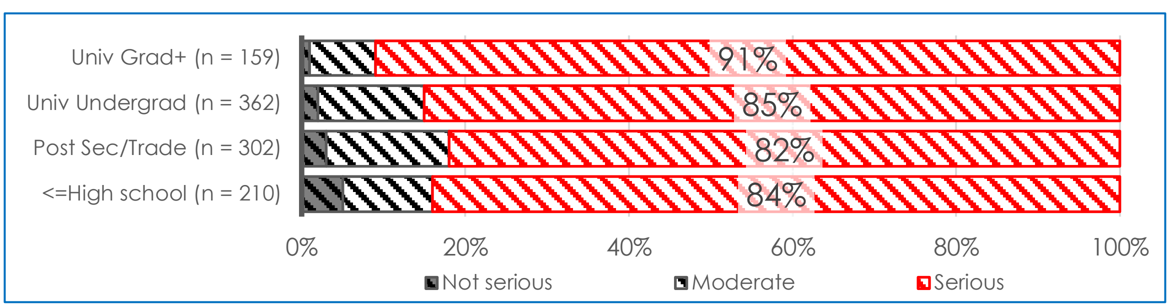

Figure C.25. Concern about synthetic microfibre ocean pollution, compared by educational degree completion

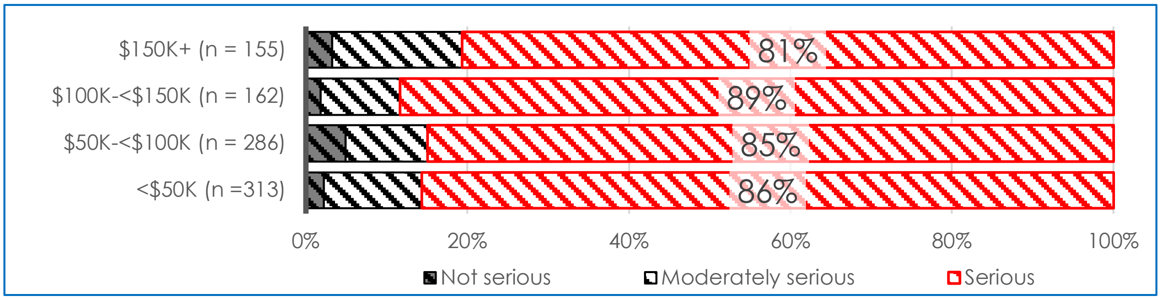

Figure C.26. Concern about synthetic microfibre ocean pollution, compared by household income

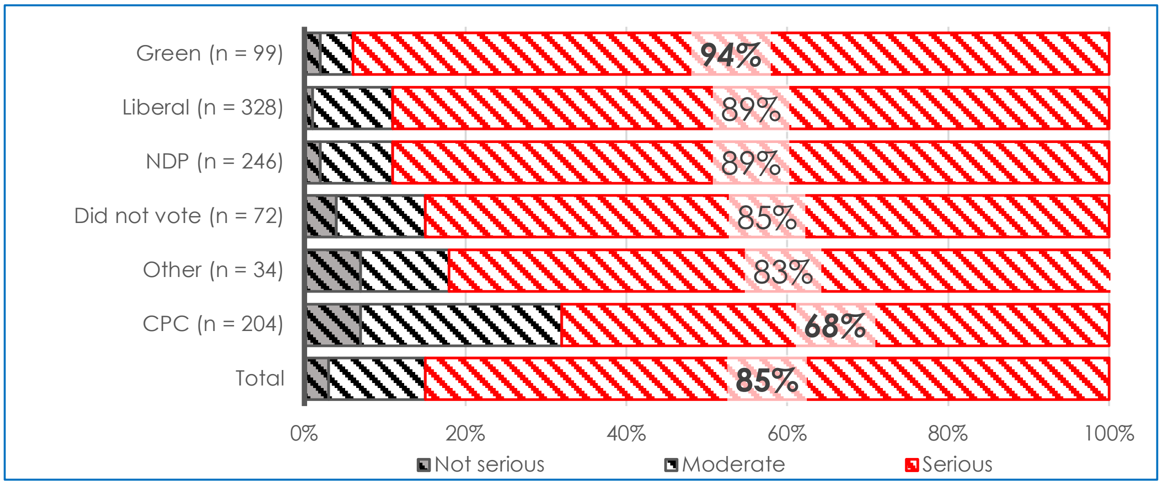

Figure C.27. Concern about synthetic microfibre ocean pollution, compared by 2019 Federal vote

Environmental Knowledge

In the *Metro Vancouver Household Survey*, consumer knowledge about the environmental impacts of microplastics was measured as accurate and concrete knowledge (or objective rather than perceived and subjective) about plastics and synthetic microfibres. Early studies investigating environmental knowledge suggest concrete knowledge about a specific issue (isolated from abstract knowledge about the state of the environment) have a stronger correlation (or moderating effect) on attitudes and intention (verbal commitment) to change behaviour, and even self-reported behaviour (Fransson & Gärling, 1999; Polonsky et al., 2012) .

The results from the knowledge test (N = 1034) were normally distributed, with a mean of 6.36, and a standard deviation of ±2.18, **figure C.28**. The respondents scores varied from 0 out of 12 to a perfect score of 12 out of 12. Summarized in **table C.4**, the vast majority of respondents, 84%, were not knowledgeable about the prevalence of synthetic microfibre in coastal BC; 79% did not know that cotton and polyester blend fabrics are not recyclable; 59% did not know that synthetic microfibres emissions from household laundries are a source of microplastic pollution. However, only 21% were entirely ignorant about the relationship between plastic pollution and environmental issues.

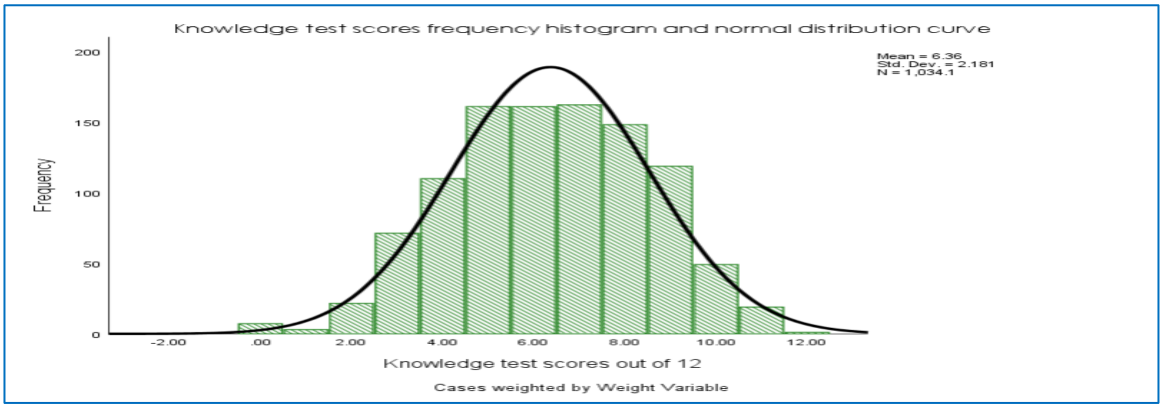

Figure C.28. Knowledge test scores histogram and normal distribution curve
Sample size N = 1034, with a mean of 6.36, and a standard deviation of ±2.18.

Table C.4. The results from the microfibre knowledge test, incorrect responses represent wrong answers and "I'm not sure."

N.	Question Concept	Correct	Incorrect
1.	Plastics and biodegradability	77%	23%
2.	Plastic waste and the environment	93%	7%
3.	Microplastics, global predominance	65%	35%
4.	Plastics accumulation	94%	6%
5.	Sources of microplastics	76%	25%
6.	Recent Canadian policy change	56%	44%
7.	Synthetic microfibres	16%	84%
8.	Wastewater treatment plants and microplastics	10%	90%
9.	Synthetic microfibres	50%	50%
10.	Fabrics and synthetic microfibres	21%	79%
11.	Wastewater treatment plants and microplastics	36%	64%
12.	Synthetic microfibres	41%	59%

Incorrect responses represent wrong answers and "I'm not sure."

In order to develop a reliable index of consumer knowledge about synthetic microfibres for use as an independent variable for examination of consumer preferences for interventions, the respondents were grouped into four knowledge levels, shown in figure C.29. Shown in figure C.30, although 84% of all respondents ranked microfibres as a serious issue, there is a 22-percentage point difference between the highest and lowest knowledge score levels. In summary, in comparison to the demographic variables explored in the previous section, knowledge about the presence, sources, and negative environmental impacts of synthetic microfibres is the single strongest predictor of environmental concern about synthetic microfibre emissions to the ocean.

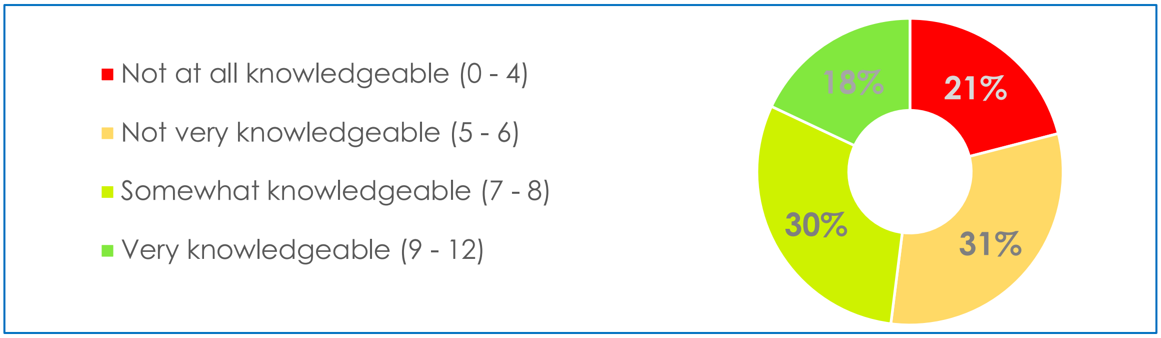

Figure C.29. An index of knowledge about microplastics and synthetic microfibres
Each category represents the proportion of respondents in each knowledge level on the 12-point knowledge test-score scale.

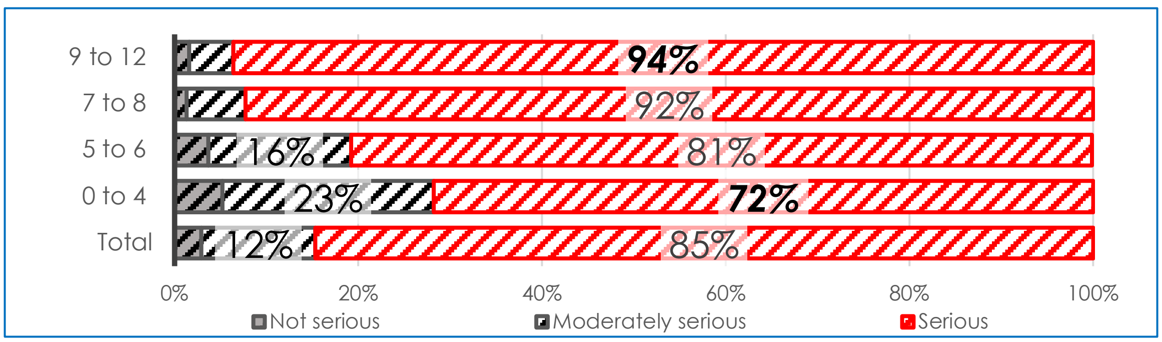

Figure C.30. Concern about synthetic microfibre ocean pollution, after the provision of information, compared by scores in the knowledge test

Valuing the ocean and reducing microfibre pollution

According to the OECD, the valuation of ecosystem services is crucial to quantifying the contribution of the environment and biodiversity to human well-being (OECD, 2018). It follows that it is crucial for policy makers to know what value citizens place upon a non-market good (the environment) to inform their policy considerations. This is especially true in cases of negative environmental externalities which are not reflected in market prices (Shaffer, 2010); as is the issue of synthetic microfibres emissions from apparel and household laundries. It can also be argued that it is difficult to measure how changes in the status quo may affect human well-being. However, in order to develop and implement appropriate interventions to improve the status quo and minimize continual environmental degradation caused by synthetic microfibres, it is imperative to understand and assess the trade-offs people make between negative environmental externalities and other priorities (Shaffer, 2010).

In the case of environmental issues such as synthetic microfibres pollution where a change is necessary to improve the current conditions or minimize further degradation, the value of improvement to the current condition is measured by a willingness to pay for a positive change (OECD, 2018, pp. 88, 89; Shaffer, 2010, p. 78).

Briefly, the elicitation method employed in the current study is a single-bounded dichotomous choice (or referendum) method, where the respondent may choose to state 'yes' or 'no' to the option of buying (hypothetically) the technology presented to them. However, each respondent was asked three willingness-to-pay (WTP) questions about three items which have considerable overlap in their functions, as follows: whether or not they would be willing to pay for two different types of microfibre capture technologies (with 80+% capture rating) and whether or not they would pay more for an article of clothing that would shed 90% less microfibres instead of buying the equivalent alternative that would shed more, all at different market price levels. Given this context, the elicitation method may be considered a double-bounded dichotomous choice, where a second and third opportunity are posed for the respondent to state their preference[77].

Overall, the dichotomous choice approach is thought to be an informative estimator of respondents' willingness-to-pay. It is a cost-effective approach with a minimal number of questions in the Survey. It is also thought to simplify the respondent's cognitive task by simulating a situation they may face in a supermarket where they decide whether or not to accept the given price (OECD, 2018, p. 98).

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[77] The dichotomous choice model estimates WTP by posing the question twice. In the second question a higher price than the first is posed if the first response were positive (yes), or a lower price is posed if the initial response were negative (OECD, 2018, p. 99). When the sample size is small, double bounded dichotomous choice is a more efficient and reliable estimator of willingness to pay. However, with a large sample size the single bounded model is warranted because the efficiency differences between the single and double bounded models tend to decrease with larger samples (Calia & Strazzera, 2000).

Willingness-to-pay for abatement technologies

The first WTP question of the Survey asked respondents whether or not they would be willing to pay $40 (plus taxes and shipping) for a wash bag that would reduce synthetic microfibres emissions from clothing into the washing machine effluent. Shown in **figure C.31**, nearly 3 out of 4 Metro Vancouver households would be willing to pay at least $40 for a technology that would reduce their microfibres emissions. When asked in the following WTP question whether or not respondents would be willing to pay $350 (including taxes, shipping, and installation) for an external filter that could capture microfibres from every load of laundry, the proportion decreased to 1 of 2 Metro Vancouver households, see **figure C.32**. In both cases, the gender and age differences in WTP are not dramatic. However, as should be the case for higher price dichotomous choice estimators, the respondents in the highest income bracket are significantly, but slightly, more likely than the other income groups to state they are willing to pay $350, **figure C.36**. Overall, respondents' willingness to pay for either of the technologies appears to be most strongly associated with their level of knowledge about microplastics and synthetic microfibres, see **figures C.37** and **C.38**. There is a 24-percentage point difference between the highest and lowest knowledge levels who state they are willing to pay at least $40 for a microfibre capture technology. More importantly, between the lowest knowledge group (0 to 4) and the next level (5 to 6) there is a 15-percentage point difference in willingness to pay $40 for pollution abatement. The difference is significant. Based on this finding, addressing consumer knowledge gaps regarding this issue can dramatically increase consumer willingness to change behaviour and/or adopt interventions.

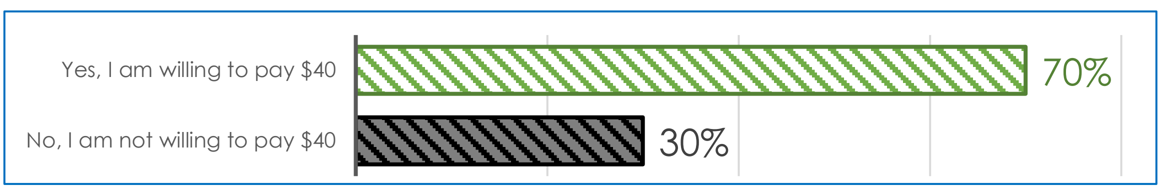

Figure C.31. The proportion of respondents willing to pay at least $40.00 for a washbag that captures synthetic microfibres

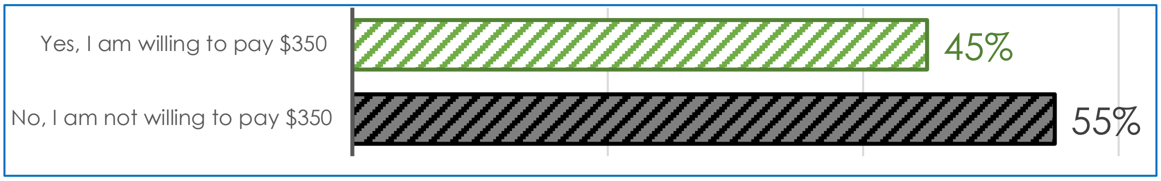

Figure C.32. The proportion of respondents willing to pay at least $350.00 for a washing machine filter attachment to capture synthetic microfibres

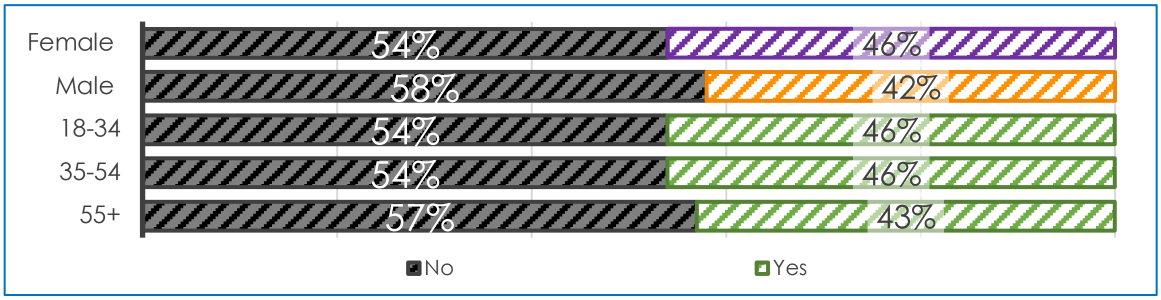

Figure C.33. Willingness to pay $40.00 for the washbag, compared by age and gender

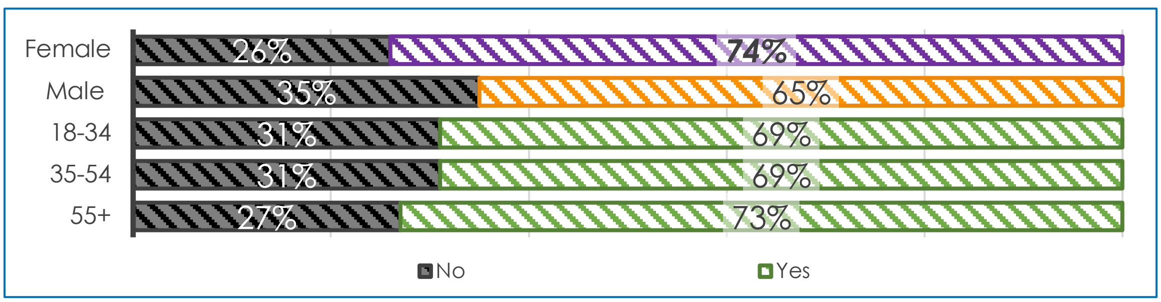

Figure C.34. Willingness to pay $350.00 for washing machine filter attachment, by gender and age

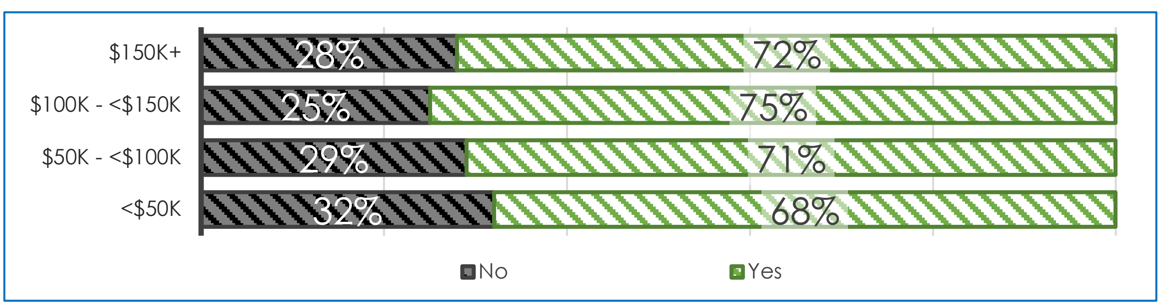

Figure C.35. Willingness to pay $40.00 for a washbag, compared by household income

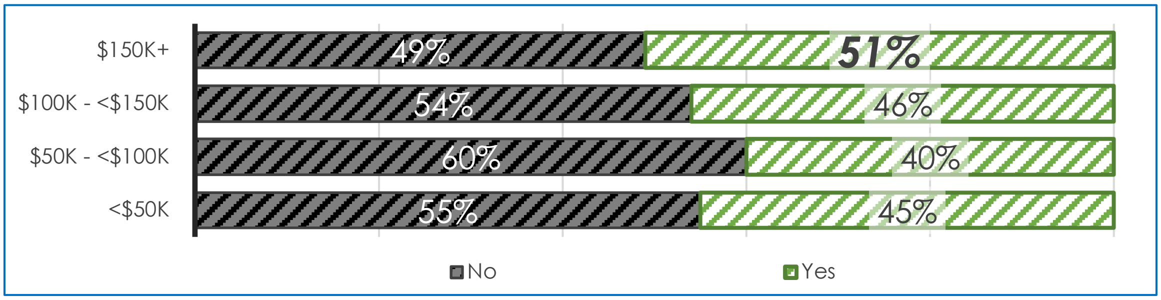

Figure C.36. Willingness to pay $250.00 for a washing machine filter attachment, compared by household income

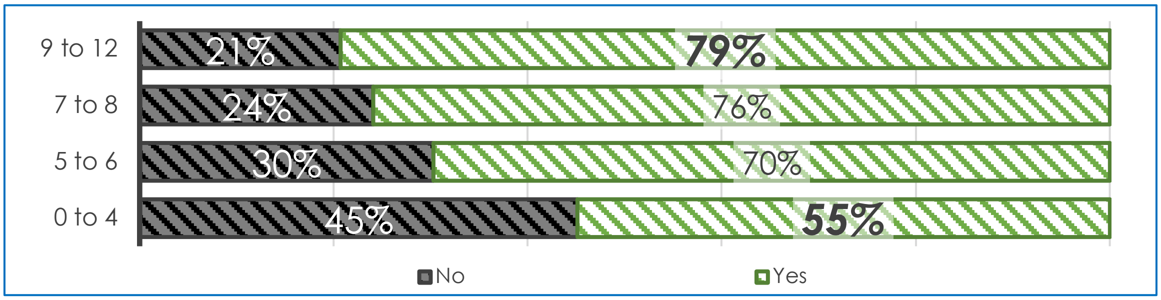

Figure C.37. Willingness to pay $40.00 for a washbag, compared by scores out of 12 in knowledge test

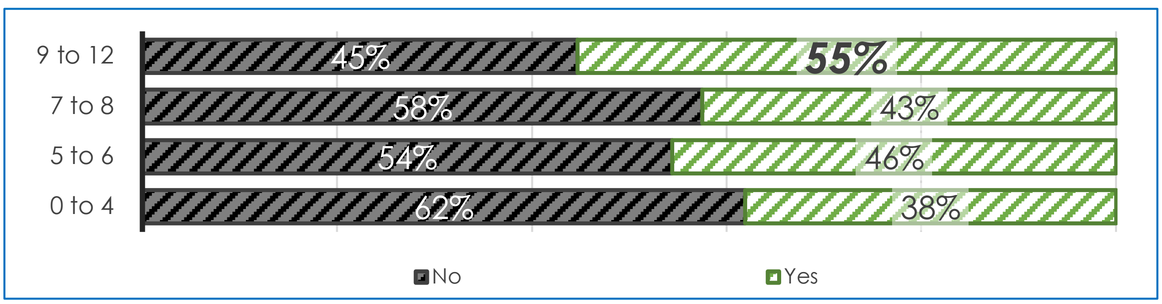

Figure C.38. Willingness to pay $350.00 for washing machine filter attachment, compared by scores out of 12 in knowledge test

Based on their willingness-to-pay for abatement technology, Metro Vancouver residents place a high value on reducing synthetic microfibre emissions into the marine environment. That is, if approximated in monetary terms, taking steps to reduce synthetic microfibre ocean pollution is worth at least $40 to 70% of households. Moreover, a high price of $350 fails to dissuade nearly half of respondents (45%) from placing a high value on microfibre pollution reduction.

Willingness-to-pay for better quality clothing

Based on expert consultation, improving fibre construction, textile engineering, and clothing design to reduce microfibre shedding by 90% may lead to a 10% price increase, at the upper margin (Mertens, 2020). Recall that for a large majority of respondents, price was the primary consideration when purchasing clothing, see **figure C.21**. For a more in-depth evaluation of consumer priorities when they purchase clothing and the value they may place on the environment, it is important to identify what trade-offs they may make when presented with a sustainable option. In order to provide a more reliable measure of consumer WTP that may change with price increase, the WTP question was presented at 5 different price levels to 5 groups of approximately equal size (n ~ 200). The base price for all groups was $50 and each group was presented with one higher price option to state whether or not they are willing to pay more for an article of clothing which is equivalent in every respect, except that it sheds 90% fewer microfibres than the $50 option. Shown in **figure C.39,** a very large majority of respondents (80% and 83% of the respondents in the 5% and 10% levels, respectively) are willing to pay at least 5% or 10% more for an article of clothing that sheds 90% less microfibres. The age and gender differences were not significant.

The key benefit of posing the WTP question in this way is that it can be reliably assumed that all the respondents who answered “yes” to the higher price level questions are equally likely to respond in the same way to lower price options. The short-coming of this approach, however, is that it cannot be known whether or not the “No” group at the price would have responded “Yes” at a lower price. Despite this, as evidenced by the decreasing trend in the proportions of respondents saying “Yes” as the price increases, the WTP approach is valid and reliably estimates the value consumers may place on environmental protection.

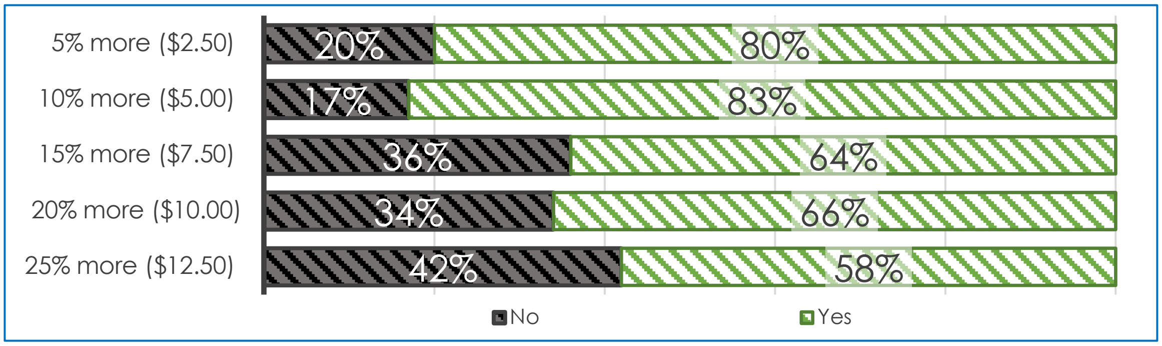

Figure C.39. Willingness to pay more for an article of clothing that sheds 90% fewer synthetic microfibres than the lower cost ($50.00) equivalent alternative which sheds more microfibres; each price level was presented to ~200 respondents

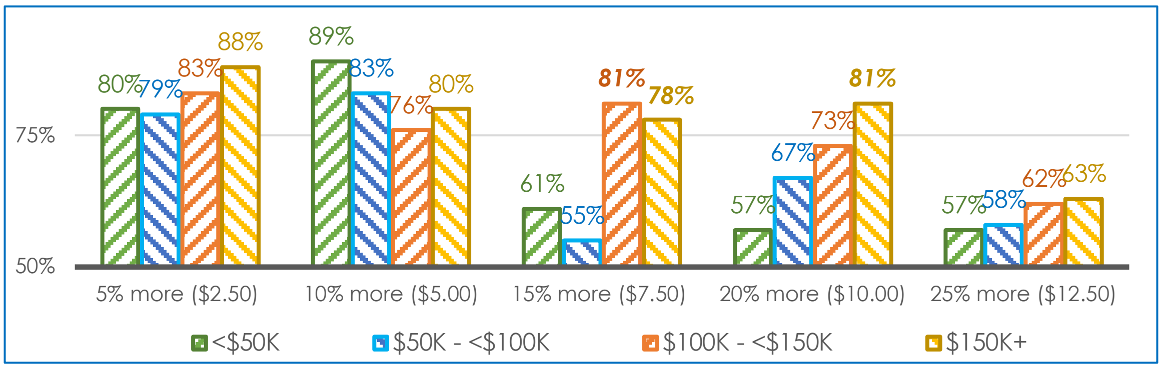

Figure C.40. Willingness to pay more for clothing that shed 90% fewer synthetic microfibres than the lower cost $50.00 alternative which may shed more
The data were compared by household income; each price level was presented to ~200 respondents

Policy Preferences

Government action on environmental issues may require the support of a wide voter base. Based on the findings reported earlier, the issue of synthetic microfibres does not appear to be polarizing (see **figure C.27**). Nearly all respondents, 85%, irrespective of various demographic factors or voter behaviour, believe ocean pollution caused by synthetic microfibres emissions from household laundries is a serious environmental issue. As evidenced by their willingness-to-pay, Metro Vancouverites place a great deal of value on reducing microfibre emissions to the marine environment. Based on these findings, the critical question, then, is whether or not voters in Metro Vancouver would support direct government action on the synthetic microfibre problem. That is, from a consumer and voter perspective, what role should the government play in tackling marine pollution caused by emissions from household consumption and related laundry behaviours? The remainder of this chapter will elucidate this question.

Support for regulatory action

When asked, “Would you support or oppose the government taking each of the following actions to reduce the amount of synthetic microfibres released into the environment from clothing?”, the representative sample of Metro Vancouver households were nearly unanimous in their support for the government setting strict product performance standards for the apparel and appliance industries. Illustrated in **figure C.41**, more than 4 out of 5 households would support regulatory action to minimize environmental degradation caused by synthetic microfibres. Of interest, even a consumer tax on apparel to reduce consumption of high microfibre shedding apparel has at least 50% support. Further, only 14% believe the government should have no role in addressing this issue.

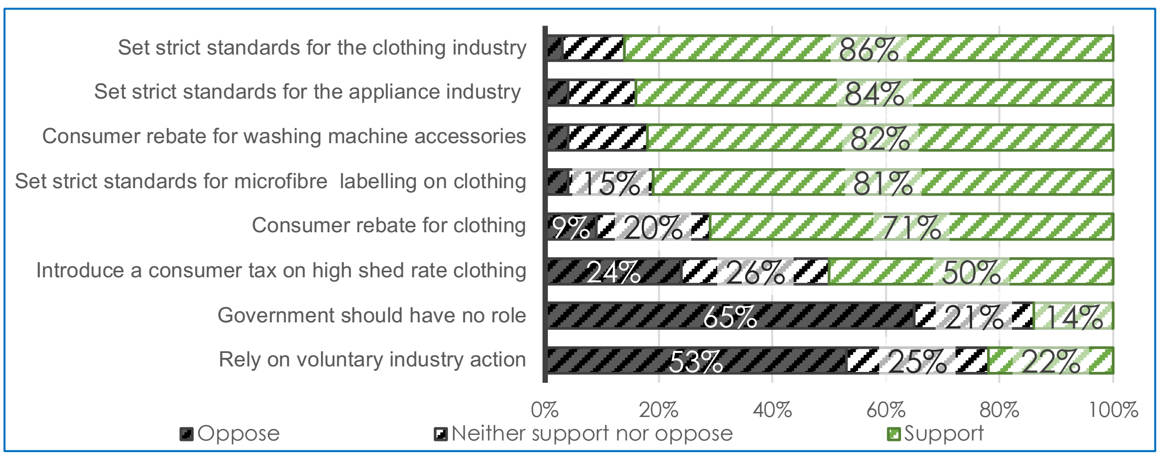

Figure C.41. Consumer support for various actions taken by the government to reduce synthetic microfibre emissions into the environment

In line with the findings in the previous sections, demographic factors such as age and gender are not strong predictors of respondents' support for various government actions. Rather, the level of knowledge about synthetic microfibres and related environmental issues is the single strongest predictor of consumer support for regulatory action by the government. As illustrated in **figures C.42** and **C.43**, when comparing the highest and lowest knowledge levels, there is more than a 20-percentage point difference in support for regulatory action on the apparel industry and a consumer tax. Moreover, in both cases, there is a 14-parentage point difference between the two lowest knowledge levels. Crucially, this indicates that a small improvement in environmental knowledge about synthetic microfibres has the potential to significantly change people's policy preferences.

Perhaps the most convincing illustration of consumers' support for direct government intervention is illustrated by the very large degree of voter support for regulatory action on the apparel industry, see **figure C.44.** Although there is a 20-percentage point difference between the Green and Conservative Party of Canada (CPC) voters, 3 out of every 4 CPC voters support government regulatory action on microfibre emissions. **Figure C.46** further confirms strong voter support for action. Nearly 1 out of 2 CPC voters and 3 out of 4 Green Party, New Democratic Party, or Liberal Party voters expect governments to take action on the issue, whatever the action may be.

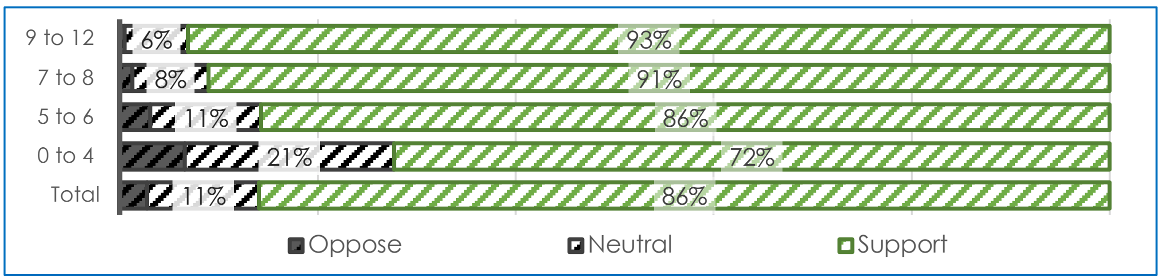

Figure C.42. Support for and opposition to strict emissions standards for the clothing industry, by scores out of 12 in knowledge test

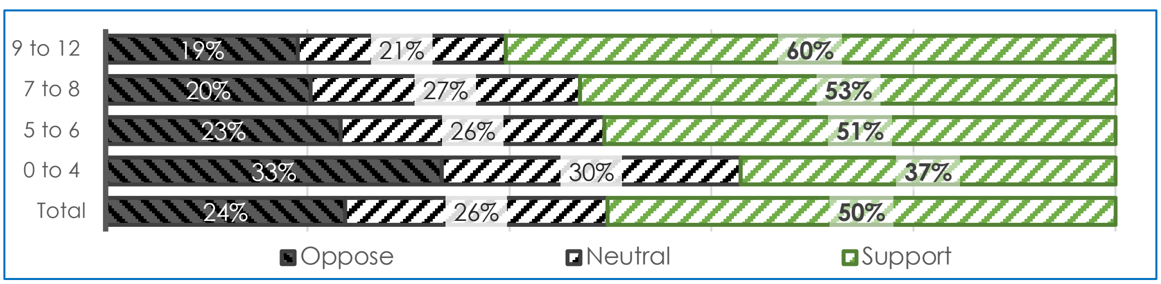

Figure C.43. Support for and opposition to a consumer tax on higher shedding clothing, by scores out of 12 in the knowledge test

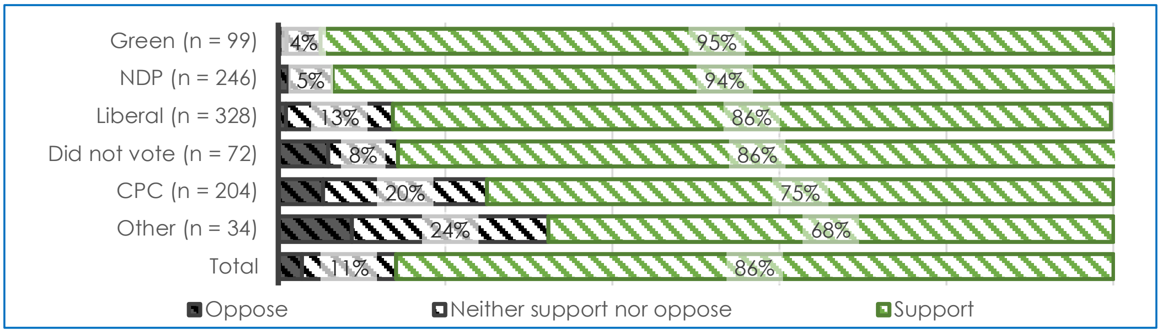

Figure C.44. Support for and opposition to strict emissions standards for the clothing industry, compared by 2019 federal vote

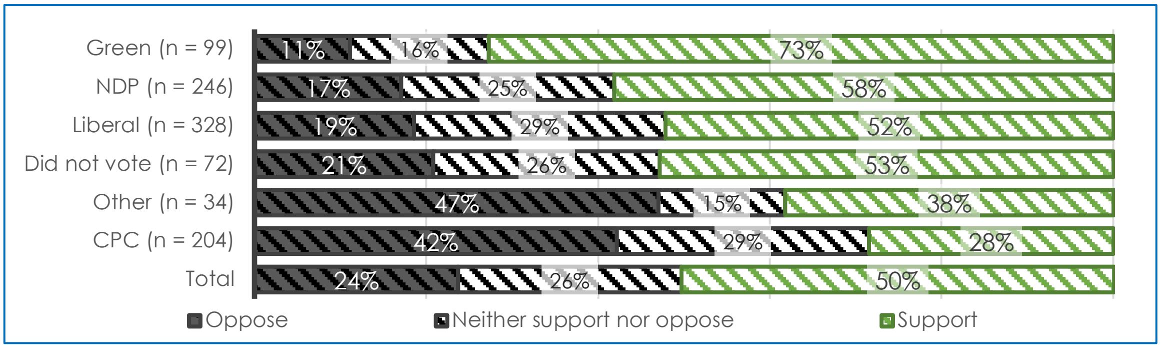

Figure C.45. Support and opposition to increasing consumer taxes for higher shedding clothing, compared by 2019 federal vote

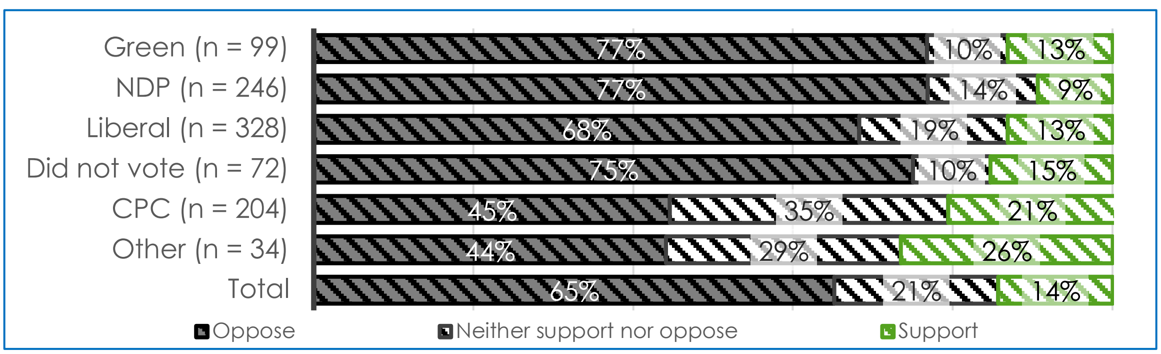

Figure C.46. Support for and opposition to "no government action" on the synthetic microfibre issue, compared by 2019 federal vote

Product disclosure & certification

As the findings in the previous section indicate, there is strong demand for mandated product disclosure that would indicate the rate of synthetic microfibre emissions per article of clothing per wash cycle. Seen in **figure C.41**, more than 4 out of 5 Metro Vancouver shoppers would like to see product performance standards for clothing and appropriate product labelling indicating environmental sustainability. With respect to product certification and labelling, consumers trust government certification bodies significantly more than industry associations or manufacturers, **figure C.47**. The very low level of trust in manufacturer and industry certification may be attributable to concerns about greenwashing (Laitala, 2020). Concerns about manufacturers' motivations and potential for greenwashing may also partly explain the strong demand for government mandated product performance standards and product disclosure requirements. However, given that nearly equal proportions of respondents report they trust independent/third-party certification and government labelling, governments can allocate the responsibility for product testing and certification to a non-governmental third-party body and minimize the potential administrative burden.

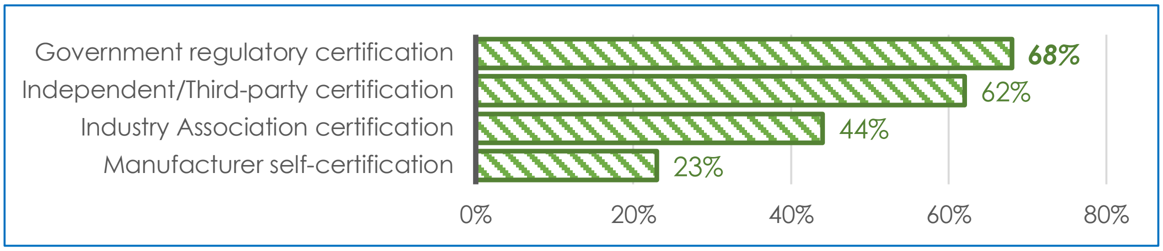

Figure C. 47. Which environmental sustainability certification bodies is most trusted by consumers?

Accountability

Although it is only in the last decade that the synthetic microfibres issue has gained the attention of marine scientists and governments concerned about environmental degradation, the pollution from synthetic microfibres emissions is not a new phenomenon (Mertens, 2020). Microfibres, synthetic or natural, are persistent in the environment (Athey, 2020). Unless action is taken by all stakeholders, global and regional population growth, and thereby, growth in consumption will lead to increasing microfibres emissions and increasing environmental degradation. Looking to the future, the Metro Vancouver Household Survey respondents were asked "if the problem persists, who should be held most accountable for the ocean pollution caused by the release of synthetic microfibres from washing clothing made from synthetic materials?" In **figure C.48**, citizen consumers rank the fashion industry as the first group to hold accountable, followed by the appliance industry. But even though they place the majority of the responsibility with industry, only 40% of all respondents ranked consumers as the last group to hold accountable.

Consumers are saying, some of the responsibility for better environmental outcomes lies with them.

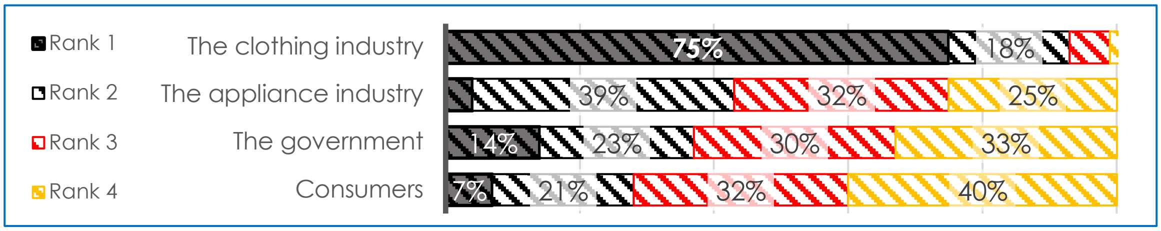

Figure C.48. Ranking which stakeholders should be held most accountable if the synthetic microfibre issue persists in the future; a rank of 1 is given to the primary group to hold accountable

Outliers and Excluded Data

Laundry behaviour

The survey question which investigated garment-specific laundry behaviour was open-ended for numerical entries. Due to the open-ended nature some responses were extreme outliers. For the purposes of visualization and analysis, a maximum cap was set at 97.5 % of the data, where only 2.5% of the data, half of a p-value of 0.05 and the equivalent of one tail, was excluded. The cap of 97.5% was equivalent to 30 wears before washing the item. The question format did not offer an option of 'never wash' or anything similar. Therefore, it is possible that by forcing respondents to enter the number of times they wear a garment before washing, respondents who rarely, if ever, wash a particular staple article would respond with an extreme value such as 100 or 1000, as was seen in the data.

Clothing purchase behaviour

Two consecutive questions in the survey were designed to estimate the volume of clothing Metro Vancouver residents purchase over the span of a year. Given the potential issues associated with behaviour recall and its increasing unreliability over larger time frames, the matter of how many articles of clothing may have been purchased by an individual was broken up into two parts. In the first question, respondents were asked to estimate, on average, how many articles of clothing (excluding socks and underwear) they purchase per purchasing event. This was followed by another question which asked to recall how frequently they purchase clothing. The questions were ordered such that respondents' recall of shopping frequency would not bias their estimate of how many articles of clothing they purchase. Further, due to the open-ended nature of the first question, which has the potential for extreme and perhaps false entries, it was necessary to devise an internal consistency measure providing a mechanism by which outliers could be reliably identified and excluded from analysis in this section. The multiple-choice design of the follow-up question was intended to serve as the internal consistency device. **Table C.5** provides the conversion factors for the purchase frequency responses in the second question. The product of the frequency factors and the number of articles purchased per purchasing event is the estimated self-reported total volume (articles of clothing per year) of clothing purchased. A benefit of this approach is that it can magnify outliers such that they can be reliably excluded from analysis. In order to retain the representative nature of the data, and given that a response of zero is meaningful, 2.5% of the extreme outliers at the upper tale of the data were removed from the analysis for this section. The resulting sample size is N = 1007

Table C.5: Purchase frequency conversion factors

Clothing purchase frequency	Times / year
More than once a week	96
Once a week	48
Once every two weeks	24
Once a month	12
Once every two months	6
Once every three months	4
Once every three (four) to six months	2
Once a year	1
Less than once a year	0.5
Never	0

Correlation Analysis

Consumer intention to change behaviour

Having controlled for personal characteristics[78], respondents who report the highest intention to take steps to reduce their microfibres footprint are likely women, are very knowledgeable about the issue, are very concerned about the impact of synthetic microfibres on the environment, believe what they do as individuals can make a meaningful difference in the health of the environment, and strongly believe that each consumer can have a positive impact on the health of the environment by purchasing environmentally sustainable products rather than buying the alternatives that may not be sustainable. Indeed, when controlling for all other factors, on average, women's intention to take pro-environmental steps is about 6% higher than their male counterparts[79]. Further, respondents who are very knowledgeable about the synthetic microfibres issue are on average 9.5% more likely than respondents who are not at all knowledgeable about the problem to say they intend to take steps to reduce their microfibre footprint.

From among the different attitudinal variables that were regressed, the belief that the individual's choice in buying environmentally sustainable products, rather than buying unsustainable alternatives, can have a positive environmental impact, had the strongest correlation with pro-environmental intention. For example, a person who strongly agrees with that statement, on average, reports an intention level that is 27% higher than respondents who are neutral about it. The other attitudinal variables do not appear to have a significant correlation with intention but add to the overall fit of the estimated relationship.

Given that 85% of all respondents said that the synthetic microfibres issue is a serious environmental concern (with a median of 9 and a mode of 10 out of 10), the groups of respondents who rated the issue as 7, 8, 9 or 10 were compared against those who rated the issue as not at all serious (Net 0 to 3). As is evident from the regression findings,

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[78] With the exception of gender, all other personal characteristics (such as age, household income, or 2019 federal vote, among others) were not statistically significant. However, controlling for them contributes to the strength of the adjusted R-squared values, which is the percent variation in the outcome variable that is explained by the model.

[79] Women's average intention is equal to the average intention of the reference category, which is the model's constant, plus women's correlation constant (ß). The proportion of women's correlation constant (the impact of gender) relative to the males is the percent difference between the two groups.

of all the variables in the model, environmental concern has the strongest correlation with intention. Compared to respondents who believe the issue of synthetic microfibres is “not at all serious,” respondents who believe the issue is moderately serious are on average 42% more likely to express they are willing to change their behaviour. Moreover, the average intention of respondents who rated the issue as extremely serious is 78% higher than the reference group. Overall, 50% of the variation in intention is explained by the model, see **table C.6**.

Consumer WTP for technology

From an attitudinal perspective and as may be expected, consumers who believe their purchase behaviour can have an impact on the environment (question 25) are significantly more likely than the reference group (neutral attitude) to state they are willing to pay at least $40 or $350 to protect the environment. Moreover, those who strongly disagree that their purchase behaviour can impact the environment are significantly more likely to refuse to pay for environmental protection, at either price levels.

Looking at the other two significant explanatory variables, knowledge about the issue and environmental concern are significant predictors of whether or not respondents were willing to pay at least $40 to protect the environment. The same relationship is not observed at the $350 level. At the higher price level, the impact of the coronavirus outbreak on finances and if respondents are ‘more worried’ about the environment is more important.

With respect to household income, counter to what may be expected, a significant relationship between household income and WTP was not observed. Respondents from higher income brackets were no more likely than their lower income counterparts to say ‘Yes’ they are willing to pay for microfibre capture technology. This finding may seem to refute the validity and reliability of WTP as an estimator of the worth or value that individuals may attribute to the environment. However, it can be argued that the issue of ocean pollution caused by the release of synthetic microfibres from household laundries is a unique environmental problem that the majority of the public are responsive to, and their concern about the problem is reflected in their stated preferences. Metro Vancouver residents are very concerned about environmental issues in general. Yet, their concern about plastic pollution exceeded all other environmental concerns. It followed that the great majority of respondents (85%) also reported they believe the synthetic microfibre problem is a serious environmental issue. As a pollutant, synthetic microfibres are unique in that they are released from the individual person's clothing that they wash. They are a very personal pollutant. It stands to reason that WTP for mitigating the environmental impacts of a "personal pollutant" may deviate from expectations. In other words, a very plausible explanation for the absence of a significant relationship between household income and WTP may be that the issue of synthetic microfibres is highly salient and personal. As shown in **table C.6**, there are clear knowledge and attitudinal trends that significantly correlate with WTP, whereas the usual potential financial limitations do not figure significantly into the respondents' accounting of the value they place on protecting the ocean.

Another consideration that may explain the strong WTP observed in this study is the issue of place attachment. It can be said that all Metro Vancouver residents may be cognisant of the fact that they reside on the Pacific Ocean, and they may interact with it in some way or another. Running a study such as the one discussed in this report in effect controls for place of residence by surveying a representative sample of the residents of the same region. However, in doing so it lacks a reference group, such as respondents who may live in an in-land region, to compare attitudes and preferences. In fact, an important limitation of this study was that it could not account for place attachment. Place attachment, which is a multidimensional attitudinal variable that reflects an individual's personal connection to the environment, is an important consideration in predicting pro-environmental intentions and behaviours (Ramkissoon et al., 2012). Place attachment may, in fact, be a strong explanatory variable for the strong intention and WTP observed in this study.

Knowledge and concern about synthetic microfibres

The strength of the correlation between environmental concern and respondents' intention and WTP necessitates a closer analysis of the predictors of environmental concern. Regressing personal characteristics against environmental concern reflects the findings from the contingency analysis. Gender and knowledge about the issue are the strongest predictors of environmental concern. On average, women's concern about synthetic microfibres is 6% higher than men. Similarly, the level of concern expressed by the groups which are somewhat knowledgeable or very knowledgeable is on average

6.1% and 6.5%, respectively, higher than the least knowledgeable group (scores of 0 to 4).

Critically, respondents' education, household income, or which Party they voted for in the 2019 Federal election are by and large not significant predictors of environmental concern. However, this seemingly "insignificant" finding is a crucial one. The key takeaway here is that background characteristics, other than gender, do not seem to matter much in predicting interventions preferences. The implication is, whereas class issues, such as household income and education, may need to be addressed first and prior to addressing a problem of interest, they need not be a priority consideration for interventions into the microfibre problem. Put a little differently, if the multiple regression results had indicated that background characteristics significantly predicted intention, WTP, or environmental concern, then improving knowledge about microfibres would do little to address the problem, at least not before addressing income or education disparities. That, however, is not the case h

Table C.6. OLS Multiple regression results, modelling correlations between respondents' intention and willingness to pay and their environmental concern, knowledge about synthetic microfibres, and attitudinal considerations

Explanatory variable	Variable level	Intention		WTP $40		WTP $350	
		ß	SE	ß	SE	ß	SE
	Regression constant	4.43***	-1.36	-0.01	0.20	0.43	0.28
Gender REF: Male	Women	0.27***	-0.10	0.03	0.03	0.02	0.04
	Prefer to self-describe	0.47	-0.38	0.24	0.10	-0.05	0.25
Score in knowledge test REF: Not at all knowledgeable (0 to 4)	Not very knowledgeable (5-6)	0.18	0.16	0.09**	0.04	-0.01	0.05
	Somewhat Knowledgeable (7-8)	0.17	0.16	0.10**	0.04	-0.05	0.05
	Very knowledgeable (9-12)	0.42**	0.17	0.11**	0.05	0.04	0.06
The impact of the COVID-19 outbreak on concern about the environment REF: No change	A lot less worried	0.22	0.61	-0.06	0.10	0.08	0.12
	Less worried	0.01	0.31	0.11	0.06	0.06	0.08
	Neutral	0.02	0.14	-0.03	0.04	0.05	0.05
	More worried	0.43***	0.15	0.04	0.04	0.11**	0.05
	A lot more worried	0.47***	0.14	0.12***	0.04	0.11*	0.06
Concern about the impact of synthetic microfibres on the environment, REF: Not at all serious (0-3)	Moderately serious (4-6)	1.85*	0.96	0.21*	0.12	0.06	0.15
	Serious	2.34**	0.97	0.29***	0.13	0.12	0.15
	Very serious (8)	2.74***	0.96	0.34***	0.14	0.16	0.15
	Dangerously serious (9)	2.84***	0.96	0.40***	0.126	0.17	0.15
	Extremely serious (10)	3.45***	0.96	0.40***	0.12	0.16	0.15
The impact of the COVID-19 outbreak on household finances REF: No impact	Very negative impact	-0.10	0.21	-0.01	0.05	-0.05	0.07
	Negative impact	0.21	0.16	0.05	0.05	0.02	0.06
	Neutral impact	-0.11	0.14	0.06	0.06	0.05	0.05
	Positive impact	-0.05	0.19	0.12**	0.05	0.18**	0.07
	Very positive impact	-0.01	0.26	-0.00	0.07	0.07	0.10
Question 3- What I do can make difference in the health of the environment REF: Neutral 4 to 6	Strongly disagree	-0.85	0.76	-0.11	0.10	-0.10	0.11
	Disagree	0.37	0.37	0.04	0.09	0.10	0.10
	Agree	0.10	0.14	-0.03	0.04	-0.03	0.05
	Strongly agree	0.29*	0.16	-0.01	0.04	-0.01	0.05
Question 9a – environmental issues will be solved with new technologies REF: Neutral 4 to 6	Strongly disagree	0.27	0.39	0.04	0.09	-0.17	0.15
	Disagree	0.03	0.28	-0.02	0.07	0.05	0.09
	Agree	-0.18	0.12	0.05	0.03	-0.03	0.04
	Strongly agree	-0.01	0.16	-0.06	0.04	-0.05	0.05
Question 9b – it is critical to take action on environmental issues now REF: Neutral 4 to 6	Strongly disagree	-1.35	1.61	0.47***	0.16	0.28	0.20
	Disagree	-0.48	0.92	0.11	0.14	-0.04	0.14
	Agree	-0.06	0.25	0.01	0.06	-0.10	0.07
	Strongly agree	0.24	0.27	0.06	0.06	-0.04	0.07
Question 25 –Buying sustainable products can have a positive effect on the environment REF: Neutral 4 to 6	Strongly disagree	-0.94	0.97	-0.20*	0.12	-0.24**	0.11
	Disagree	-0.15	0.53	-0.02	0.10	-0.02	0.10
	Agree	0 .51***	0.15	0.07*	0.04	0.05	0.05
	Strongly agree	1.19***	0.16	0.16***	0.05	0.17***	0.05

Question 8 – It is worth it for individual consumer to make efforts to protect the environment REF: Neutral 4 to 6	Strongly disagree	-0.27	1.69	-0.35**	0.17	-0.16	0.19
	Disagree	-0.27	1.05	-0.02	0.19	-0.10	0.16
	Agree	0.17	0.24	-0.02	0.06	0.13*	0.07
	Strongly agree	0.25	0.24	-0.01	0.06	0.11	0.07
No. of Observations		1034		1034		859 (excludes N/A)	
Adjusted R-square		0.503		0.182		0.109	
Controlling for:	Age			2019 Federal vote			
	Household income			Home ownership			
	Education			Type of laundry facility			
	Children in the household			Prior knowledge about microfibres			

NOTE: *** indicates statistically significant at 1%, ** indicates statistically significant at 5%, and * indicates statistically significant at 10%.

Table C.7. OLS Multiple regression results, correlations between personal characteristics and concern about the impact of synthetic microfibres on the environment (environmental concern)

Predictor Variable	**Variable level**	**ß**	**SE**
	Regression constant	4.93***	0.81
Gender REF: Male	Women	0.28***	0.10
	Prefer to self-describe	0.49	0.35
Age group, REF: 18 to 24 years old	25-30	-0.14	0.27
	30-34	-0.07	0.23
	35-39	0.12	0.26
	40-44	-0.05	0.26
	45-49	0.13	0.25
	50-54	0.44*	0.25
	55-59	0.22	0.25
	60-64	0.31	0.26
	65-69	0.17	0.26
	70-74	0.26	0.26
	75-79	0.25	0.38
	80-84	0.84*	0.41
	85-89	0.87	1.38
Household income bracket, REF: <$25K	$25K - <$50K	0.16	0.19
	$50K - <$100K	0.03	0.19
	$100 - <$150K	-0.07	0.21
	$150K - <$200K	0.07	0.26
	$200K+	-0.15	0.26
	D/K Prefer Not to answer	-0.10	0.21

Education, REF: Some high school	Completed high school	1.00	0.70
	Some college or trade training	0.97	0.69
	Completed college/trade degree	0.98	0.69
	Some undergraduate studies	0.97	0.69
	Completed undergrad degree	0.98	0.69
	Graduate degree	1.13*	0.68
2019 Federal vote, REF: "did not vote"	Conservative Party of Canada	0.08	0.24
	Liberal Party of Canada	-0.01	0.20
	New Democratic Party	-0.02	0.20
	Green Party of Canada	0.06	0.23
	Other Parties	0.47	0.33
	Prefer not to answer	-0.20	0.30
Score in knowledge test, REF: Not at all knowledgeable (0-4)	Not very knowledgeable (5-6)	0.02	0.15
	Somewhat knowledgeable (7-8)	0.30**	0.14
	Very knowledgeable (9-12)	0.32*	0.17
Number of children in the household REF: No children (0)	1	-0.12	0.14
	2	-0.05	0.17
	3+	-0.40	0.34
Prior knowledge about microfibres, REF: No	Yes	0.38	0.11
	"I'm not sure"	-0.42	0.26
No. of Observations		1034	
Adjusted R-square		0.513	
Controlling for:	Attitudinal variables	Home ownership	
	COVID-19 impact on finances	Laundry facility	
	COVID-19 impact on environmental concern		

NOTE: *** indicates statistically significant at 1%, ** indicates statistically significant at 5%, and * indicates statistically significant at 10%.

Appendix D.

Policy Analysis Tables

The policy analysis discussed in **Chapter 8** is based on the evaluative framework which was laid out in **Chapter 7**. The policy evaluation for all three options is provided in the following tables. Please note, the tables provided below are presented in the order in which the objectives were analysed, not in the order in which they are discussed in Chapters 7 and 8.

Table D.1.1. Policy Option 1 evaluation: New Appliance Legislation, Effectiveness

Objectives	Primary Criteria	Levels of criteria	Levels of intervention	Weight	Measure or Index	Score	Weighted Score
Effectiveness	Emissions reductions during the use-phase of textiles	Emissions reductions from washing machines (WMs)	Privately owned WMs	X6*	Whether or not the intervention will lead to reductions from each household group at level of intervention: 1 = Low reductions 2 = Some reductions 3 = High reductions	1	6/66
			Commercial WMs (Rentals)	X3*		1	3/66
			WMs in Commercial facilities (Laundromats)	X1		1	1/66
		Emissions reductions from dryer machines	Privately owned dryers	X6*		1	6/66
			Commercial dryers (Rentals)	X3		1	3/66
			Dryers in commercial laundry facilities	X1		1	1/66
		Emissions reductions during wear & tear	N/A	X1		1	1/66
	Emissions reductions from the production-phase	Projected impact of policy on the likelihood of emissions reduction during the textile and clothing manufacturing process	N/A	X1**	1 = Negative or no impact 2 = Some positive impact 3 = Very positive impact	1	1/66
Total Score				**66**			**22/66**
Score Percentage							**33.3/100%**
Score ratio in the final tally – The effectiveness policy objective is double weighted, accounting for 20% of total score.							**6.7/100**

* In BC, there are at least twice as many homeowners (68%) with access to privately owned appliances as there are renters (31%) .

** Interventions, such as better fibre engineering would lead to emissions reductions from the production phase and the use-phase of textiles.

Table D.1.2. Option 1 evaluation: New appliance legislation – Distributive equity

Objective	Primary Criteria	Levels of criteria	Income bracket affected	Weight	Measure or Index	Max Score
Distributive Equity	Cost Burden	Monetary cost to low-income households	<50K	X1	1 – Significant negative impact 2 – Limited negative impact 3 – No negative impact	3/24
			50 - <100K	X1		3/24
	Exposure Burden	Lifestyle cost to consumers	<50K	X1		3/24
			50 - <100K	X1		3/24
			100K – 150K<	X1		3/24
			150K+	X1		3/24
		Health exposure burden for factory workers	N/A	X1		3/24
		Lifestyle cost (enjoyment of environment) for citizens of manufacturing country	N/A	X1		3/24
Total score						**24/24**
Score ratio						**/100%**
Score ratio in the final tally of all objectives.						**10/100**

Table D.1.3. Option 1 Evaluation: New appliance legislation – Political feasibility

Objective	Primary Criterion	Stakeholder groups	Consideration measured	Weight	Measure or Index	Max Score
Political feasibility	Stakeholder acceptance	Consumers	Voter support	X1	1 – Low 2 – Med 3 – High	3/18
		Apparel industry companies	Projected support for policy	X1		3/18
		International labour in the apparel industry	Projected change in job availability	X1	1 = Decrease 2 = No change 3 = Increase	2/18
		Appliance industry	Projected support for policy	X1	1 – Low 2 – Med 3 – High	1/18
		Water utilities	Projected support for policy	X1		3/18
		Non-governmental organizations	Projected support for policy	X1		3/18
Total score						**15/18**
Score ratio						**83.3%**
Score ratio in the final tally of all objectives.						**8.3/100**

Table D.1.4. Option 1 evaluation: New appliance legislation - Accountability

Objective	Primary Criterion	Stakeholder groups	Consideration measured	Weight	Measure or Index	Max Score
Accountability	Policy visibility	Apparel industry companies	The projected strength of the signal to motivate action on reducing microfibre emissions	X4 = 12	1 – Low 2 – Med 3 – High	4/30
		Appliance industry		X2 = 6		6/30
		Governments		X3 = 9		6/30
		Consumers		X1 = 3		1/30
Total score						**17/30**
Score ratio						**56.6%**
Score ratio in the final tally of all objectives.						**5.6/100**

* The triple weighting for government accountability accounts for the degree to which a policy sends a signal for action to local/provincial government, federal governments, and the international community of policy actors.

Table D.1.5. Option 1 evaluation: New appliance legislation – Administrative ease

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Administrative ease for government	Ease of policy management	The degree to which a policy can be implemented using existing infrastructure	X2*	1 = Low 2 = Med 3 = High	4/12
		The ease of monitoring compliance	X1		2/12
		The ease of enforcement	X1		2/12
Total score					**8/12**
Score ratio					**66.6%**
Score ratio in the final tally of all objectives.					**6.6/100**
* Given that implementation is the first step in taking policy action, it can be considered the most important factor or potential hurdle impacting administrative ease					

Table D.1.6. Option 1 evaluation: New appliance legislation – Minimized Cost

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Minimized administrative cost	Impact on government budget	Estimated upfront capital costs*	X1	1 = Less than $400 million 2 = $400 to $1,200 million 2 = more than $1,200 million	3
Total score					**3/3**
Score ratio					**10/100%**
Score ratio in the final tally of all objectives.					**10/100**

* Given that implementation is the first step in taking policy action, upfront capital costs can be considered the more important cost factor or potential hurdle impacting policy adoption

Table D.1.7. Option 1 evaluation: New appliance legislation – Progress toward circularity

Objective	Primary Criterion	Level or stage in lifecycle	Consideration measured	Weight	Measure or Index	Max Score
Progress toward circularity	Policy contribution to initiating transition toward a circular economy	Production phase	Product design	X1	Projected level of impact on progress: 1 = Low 2 = Med 3 = High	1
		Use-phase	Product durability	X1		1
		End-of-life recyclability	Contribution to establishing infrastructure	X1		1
		Industry transparency	Supply-chain transparency about product lifecycle	X1		1
Total score						**4/12**
Score ratio						**33.3/100%**
Score ratio in the final tally of all objectives.						**3.3/100**

* The lack of supply chain transparency is one of the most important barriers to environmental and social sustainability in the garment and footwear sector. Improvements in transparency at any stage of product lifecycle can have the potential to motivate industry toward transparency in other stages and ultimately circularity.

Table D.1.8. Option 1 evaluation: New Appliance Legislation – Policy efficiency

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Policy efficiency	Time factor of policy efficiency	Time (in years) to maximal emissions reduction from the phase in textile lifecycle which is targeted by the policy	X1	3 = 1 to 5 years 2 = 6 to 10 years 1 = more than 10 years	1
Total score					**1/3**
Score ratio					**33.3/100%**
Score ratio in the final tally of all objectives.					**3.3/100**

Table D.1.9. Option 1 evaluation: Policy Option 1 Score Summary

Objective	Score	Max Score
Effectiveness	6.7	20
Distributive equity	10	10
Political feasibility	8.3	10
Accountability	5.7	10
Administrative ease	6.7	10
Minimized cost to government	10	10
Progress toward circularity	3.3	10
Immediacy of reductions	3.3	10
Total	**54.0**	**100**

Table D.2.1. Policy Option 2 evaluation: CleanBC Subsidy – Effectiveness

Objectives	Primary Criteria	Levels of criteria	Levels of intervention	Weight	Measure or Index	Score	Weighted Score
Effectiveness	Emissions reductions during the use-phase of textiles	Emissions reductions from washing machines (WMs)	Privately owned WMs	X6*	Whether or not the intervention will lead to reductions from each household group at level of intervention: 1 = Low reductions 2 = Some reductions 3 = High reductions	3	18/66
			Commercial WMs (Rentals)	X3*		3	9/66
			WMs in Commercial facilities	X1		3	3/66
		Emissions reductions from dryer machines	Privately owned dryers	X6*		3	18/66
			Commercial dryers (Rentals)	X3		3	9/66
			Dryers in commercial laundry facilities	X1		3	3/66
		Emissions reductions during wear & tear	N/A	X1		1	1/66
	Emissions reductions from the production-phase	Projected impact of policy on the likelihood of emissions reduction during the textile and clothing manufacturing process	N/A	X1**	1 = Negative or no impact 2 = Some positive impact 3 = Very positive impact	1	1/66
Total Score				**66**			**62/66**
Score Percentage							**93.9/100%**
Score ratio in the final tally – The effectiveness policy objective is double weighted, accounting for 20% of total score.							**18.8/100**

* In BC, there are at least twice as many homeowners (68%) with access to privately owned appliances as there are renters (31%).

** Interventions, such as better fibre engineering would lead to emissions reductions from the production phase and the use-phase of textiles.

Table D.2.2. Option 2 evaluation: CleanBC – Distributive equity

Objective	Primary Criteria	Levels of criteria	Income bracket affected	Weight	Measure or Index	Max Score
Distributive Equity	Cost Burden	Monetary cost to low-income households	<50K	X1	1 – Significant negative impact 2 – Limited negative impact 3 – No negative impact	1/24
			50 - <100K	X1		1/24
	Exposure Burden	Lifestyle cost to consumers	<50K	X1		3/24
			50 - <100K	X1		3/24
			100K – 150K<	X1		3/24
			150K+	X1		3/24
		Health exposure burden for factory workers	N/A	X1		3/24
		Lifestyle cost (enjoyment of environment) for citizens of manufacturing country	N/A	X1		3/24
Total score						**20/24**
Score ratio						**83.3/100%**
Score ratio in the final tally of all objectives.						**8.3/100**

Table D.2.3. Option 2 evaluation: CleanBC – Political feasibility

Objective	Primary Criterion	Stakeholder groups	Consideration measured	Weight	Measure or Index	Max Score
Political feasibility	Stakeholder acceptance	Consumers	Voter support	X1	1 – Low 2 – Med 3 – High	3/18
		Apparel industry companies	Projected support for policy	X1		3/18
		International community	Projected change in job availability for international labour	X1	1 = Decrease 2 = No change 3 = Increase	2/18
		Appliance industry	Projected support for policy	X1	1 – Low 2 – Med 3 – High	1/18
		Water utilities	Projected support for policy	X1		3/18
		Non-governmental organizations	Projected support for policy	X1		3/18
Total score						**15/18**
Score ratio						**83.3%**
Score ratio in the final tally of all objectives.						**8.3/100**

Table D.2.4. Option 2 evaluation: CleanBC - Accountability

Objective	Primary Criterion	Stakeholder groups	Consideration measured	Weight	Measure or Index	Max Score
Accountability	Policy visibility	Apparel industry companies	The projected strength of the signal to motivate action on reducing microfibre emissions	X4 = 12	1 – Low 2 – Med 3 – High	4/30
		Appliance industry		X2 = 6		6/30
		Governments		X3 = 9		9/30
		Consumers		X1 = 3		1/30
Total score						**20/30**
Score ratio						**66.6%**
Score ratio in the final tally of all objectives.						**6.7/100**

* The triple weighting for government accountability accounts for the degree to which a policy sends a signal for action to local/provincial government, federal governments, and the international community of policy actors.

Table D.2.5. Option 2evaluation: CleanBC – Administrative ease

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Administrative ease for government	Ease of policy management	The degree to which a policy can be implemented using existing infrastructure	X2*	1 = Low 2 = Med 3 = High	6/12
		The ease of monitoring compliance	X1		1/12
		The ease of enforcement	X1		1/12
Total score					**8/12**
Score ratio					**66.6%**
Score ratio in the final tally of all objectives.					**6.7/100**
* Given that implementation is the first step in taking policy action, it can be considered the most important factor or potential hurdle impacting administrative ease					

Table D.2.6. Option 2evaluation: CleanBC – Minimized Cost to Government

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Minimized administrative cost	Impact on government budget	Estimated upfront capital costs*	X1	3 = Less than $400 million 2 = $400 to $1,200 million 1 = more than $1,200 million	3
Total score					**3/3**
Score ratio					**10/100%**
Score ratio in the final tally of all objectives.					**10/100**

* Given that implementation is the first step in taking policy action, upfront capital costs can be considered the more important cost factor or potential hurdle impacting policy adoption

Table D.2.7. Option 2 evaluation: CleanBC – Progress toward circularity

Objective	Primary Criterion	Level or stage in lifecycle	Consideration measured	Weight	Measure or Index	Max Score
Progress toward circularity	Policy contribution to initiating transition toward a circular economy	Production phase	Product design	X1	Projected level of impact on progress: 1 = Low 2 = Med 3 = High	1/3
		Use-phase	Product durability	X1		1/3
		End-of-life recyclability	Contribution to establishing infrastructure	X1		1/3
		Industry transparency	Supply-chain transparency about product lifecycle	X1		1/3
Total score						**4/12**
Score ratio						**33.3%**
Score ratio in the final tally of all objectives.						**3.3/100**

The lack of supply chain transparency is one of the most important barriers to environmental and social sustainability in the garment and footwear sector. Improvements in transparency at any stage of product lifecycle can have the potential to motivate industry toward transparency in other stages and ultimately circularity.

Table D.2.8. Option 2 evaluation: CleanBC – Policy efficiency

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Policy efficiency	Time factor of policy efficiency	Time (in years) to maximal emissions reduction from the phase in textile lifecycle which is targeted by the policy	X1	1 to 5 years = 3 6 to 10 years = 2 More than 10 years = 1	3
Total score					**3/3**
Score ratio					**100%**
Score ratio in the final tally of all objectives.					**10/100**

Table D.2.9. Option 2evaluation: CleanBC Score Summary

Objective	Score	Max Score
Effectiveness	18.8	20
Distributive equity	8.3	10
Political feasibility	8.3	10
Accountability	6.7	10
Administrative ease	6.7	10
Minimized cost to government	10	10
Progress toward circularity	3.3	10
Immediacy of reductions	10	10
Total	**72.1**	**100**

Table D.3.1. Option 3 evaluation: modified EPR - Effectiveness

Objectives	Primary Criteria	Levels of criteria	Levels of intervention	Weight	Measure or Index	Score	Weighted Score
Effectiveness	Emissions reductions during the use-phase of textiles	Emissions reductions from washing machines (WMs)	Privately owned WMs	X6*	Whether or not the intervention will lead to reductions from each household group at level of intervention: 1 = Low reductions 2 = Some reductions 3 = High reductions	1	6/66
			Commercial WMs (Rentals)	X3*		1	3/66
			WMs in Commercial facilities (Laundromats)	X1		1	1/66
		Emissions reductions from dryer machines	Privately owned dryers	X6*		1	6/66
			Commercial dryers (Rentals)	X3		1	3/66
			Dryers in commercial laundry facilities	X1		1	1/66
		Emissions reductions during wear & tear	N/A	X1		1	1/66
	Emissions reductions from the production-phase	Projected impact of policy on the likelihood of emissions reduction during the textile and clothing manufacturing process	N/A	X1**	1 = Negative or no impact 2 = Some positive impact 3 = Very positive impact	1	1/66
Total Score				**66**			**22/66**
Score Percentage							**33.3/100%**
Score ratio in the final tally – The effectiveness policy objective is double weighted, accounting for 20% of total score.							**6.7/100**

* In BC, there are at least twice as many homeowners (68%) with access to privately owned appliances as there are renters (31%).

** Interventions, such as better fibre engineering would lead to emissions reductions from the production phase and the use-phase of textiles.

Table D.3.2. Option 3 evaluation: Modified EPR – Distributive Equity

Objective	Primary Criteria	Levels of criteria	Level of intervention	Weight	Measure or Index	Max Score
Distributive Equity	Cost Burden	Monetary cost to low-income households	<50K	X1	1 – Significant negative impact 2 – Limited negative impact 3 – No negative impact	1/3
			50 - <100K	X1		1/3
	Exposure Burden	Lifestyle cost to consumers	<50K	X1		3/3
			50 - <100K	X1		3/3
			100K – 150K<	X1		3/3
			150K+	X1		3/3
		Health exposure burden for factory workers	N/A	X1		3/3
		Lifestyle cost (enjoyment of environment) for citizens of manufacturing country	N/A	X1		3/3
Total score						**20 /24**
Score ratio						**83.3%**
Score ratio in the final tally of all objectives.						**8.3/100**

Table D.3.3. Option 3 evaluation: Modified EPR – Political feasibility

Objective	Primary Criterion	Stakeholder groups	Consideration measured	Weight	Measure or Index	Max Score
Political feasibility	Stakeholder acceptance	Consumers	Voter support	X1	1 – Low 2 – Med 3 – High	2/18
		Apparel industry companies	Projected support for policy	X1		1/18
		International community	Projected change in job availability for international labour	X1	1 = Decrease 2 = No change 3 = Increase	2/18
		Appliance industry	Projected support for policy	X1	1 – Low 2 – Med 3 – High	3/18
		Water utilities	Projected support for policy	X1		3 /18
		Non-governmental organizations	Projected support for policy	X1		3/18
Total score						**14/18**
Score ratio						**77.7%**
Score ratio in the final tally of all objectives.						**7.8/100**

Table D.3.4. Option 3 evaluation: Modified EPR - Accountability

Objective	Primary Criterion	Stakeholder groups	Consideration measured	Weight	Measure or Index	Max Score
Accountability	Policy visibility	Apparel industry	The projected strength of the signal to motivate action on reducing microfibre emissions	X4 = 12	1 – Low 2 – Med 3 – High	8/30
		Appliance industry		X2 = 6		2/30
		Governments		X3 = 9		9/30
		Consumers		X1 = 3		2/30
Total score						**21/30**
Score ratio						**70.0%**
Score ratio in the final tally of all objectives.						**7/100**

* The triple weighting for government accountability accounts for the degree to which a policy sends a signal for action to local/provincial government, federal governments, and the international community of policy actors.

Table D.3.5. Option 3 evaluation: Modified EPR – Administrative ease

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Administrative ease for government	Ease of policy management	The degree to which a policy can be implemented using existing infrastructure	X2*	1 = Low 2 = Med 3 = High	4/12
		The ease of monitoring compliance	X1		3/12
		The ease of enforcement	X1		3/12
Total score					**10/12**
Score ratio					**83.3%**
Score ratio in the final tally of all objectives.					**8.3/100**
* Given that implementation is the first step in taking policy action, it can be considered the most important factor or potential hurdle impacting administrative ease					

Table D.3.6. Option 3 evaluation: Modified EPR – Administrative cost

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Minimized administrative cost	Impact on government budget	Estimated upfront capital costs*	X1	3 = Less than $400 million 2 = $400 to $1,200 million 1 = more than $1,200 million	3
Total score					**3/3**
Score ratio					**100%**
Score ratio in the final tally of all objectives.					**10/100**

* Given that implementation is the first step in taking policy action, upfront capital costs can be considered the more important cost factor or potential hurdle impacting policy adoption

Table D.3.7. Option 3 evaluation: Progress toward circularity

Objective	Primary Criterion	Level or stage in lifecycle	Consideration measured	Weight	Measure or Index	Max Score
Progress toward circularity	Policy contribution to initiating transition toward a circular economy	Production phase	Product design	X1	Projected level of impact on progress: 1 = Low 2 = Med 3 = High	2/12
		Use-phase	Product durability	X1		1/12
		End-of-life recyclability	Contribution to establishing infrastructure	X1		3/12
		Industry transparency	Supply-chain transparency about product lifecycle	X1		2/12
Total score						**8/12**
Score ratio						**66.6%**
Score ratio in the final tally of all objectives.						**6.7/100**

The lack of supply chain transparency is one of the most important barriers to environmental and social sustainability in the garment and footwear sector. Improvements in transparency at any stage of product lifecycle can have the potential to motivate industry toward transparency in other stages and ultimately circularity.

Table D.3.8. Option 3 evaluation: Modified EPR – Policy efficiency

Objective	Primary Criterion	Consideration measured	Weight	Measure or Index	Max Score
Policy efficiency	Time factor of policy efficiency	Time (in years) to maximal emissions reduction from the phase in textile lifecycle which is targeted by the policy	X1	1 to 5 years = 3 5 to 10 years = 2 More than 10 years = 1	2
Total score					**2/3**
Score ratio					**66.6%**
Score ratio in the final tally of all objectives.					**6.7/100**

Table D.3. 9. Option 3 evaluation: mEPR Score Summary

Objective	Score	Max Score
Effectiveness	6.7	20
Distributive equity	8.3	10
Political feasibility	7.8	10
Accountability	7	10
Administrative ease	8.3	10
Minimized cost to government	10	10
Progress toward circularity	6.7	10
Immediacy of reductions	6.7	10
Total	**61.5**	**100**