Eco-Wearables: Merging Art and Technology for Environmental Crisis Awareness

By

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Abstract

Eco-Wearables focuses on global warming, the ways that the fashion industry contributes to climate change, and the ways that fashion can also help consumers to have environmental awareness. The contemporary environmental crisis poses significant threats to global ecosystems, necessitating proactive measures to mitigate its undesirable effects. The fast fashion trend plays a significant role in Earth's warming. According to some estimates, the fashion industry is responsible for 10% of humanity's carbon emissions, water consumption, and waste production, leading to unprecedented temperature rises (UNECE, 2018). The aim of this research is to explore the potential use of wearable technology as a medium for visualizing the intensity of environmental crises and depicting temperature fluctuations. This project designs and creates an interactive garment centered on Canada, one of the significant contributors to Earth's warming, and victim to its effects, through forest fires. By designing a garment with precise laser-cut patterns inspired by Canadian provinces, it endeavors to dynamically visualize data that represents the challenges of a warming planet. The garment statistically shows the wildfire data in different Canadian provinces, transforming them into visual and wearable cues, that is a number of LED displays and colour changes based on equal intervals. Heating pads warm the garment, and these are driven by temperature increases in each province, making the climate crises tangible. By exploring global warming and its effects like Canadian wildfires and the impact of the fashion industry I intend to provide a comprehensive and holistic perspective on the complex web of issues surrounding climate change.

Keywords: Environmental Crisis, Global Warming, Wearable Technology, Climate Change, wildfire, Data Visualization, Fast Fashion

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1. Introduction

1.1 Motivation

In recent years, the Earth's surface temperature has experienced a significant increase, leading to changes across the globe, such as droughts, polar ice melt, and widespread wildfires (Dahlman, 2024). This temperature rise is attributed to various factors including the emission of greenhouse gases, industrial activities, governmental policies, and human actions. There is a growing concern on the part of those who analyze the sources of climate change about the significant contribution of the fashion industry to the pervasive environmental crisis, with the rapid emergence of awareness that fashion is a major contributor to greenhouse gas emissions. As the fashion industry grows, so does its carbon footprint, water consumption, and waste generation, perpetuating unsustainable consumption patterns in the production cycle, which have environmental consequences. Current design and production systems, alongside prevailing economic models, promote unsustainable fashion consumption, presenting a multifaceted problem that requires creative problem-solving, bold design thinking, and critical re-evaluation of existing practices (Niinimäki, 2013).

In my project, *Eco-Wearables: Merging Art and Technology for Environmental Crisis Awareness*, I illuminate the links between fast fashion practices and their impact on climate change and leverage wearable technology to design clothing that portrays and raises awareness about the effects of global warming. The motivation behind this study stems from the necessity to increase awareness of global warming and its multifaceted factors, particularly emphasizing its impact on various geographical regions, in this case Canada, where the increasing prevalence of forest wildfires serves as a poignant indicator of environmental shifts. The outset of my research on this topic coincided with the early months of my recent immigration to Canada. I began hearing about forest wildfires, and the significant volume of burning and its increasing occurrence at different times of the year, which was truly startling. This prompted me to focus my attention on this aspect of global warming and its impact on Canada.

1.2 Scope and limitations

The issue of global warming today has worldwide effects. Every point on the globe is impacted, each in its own way, such as rising sea levels in Bangladesh, melting glaciers and polar ice caps in Greenland and extreme weather events such as hurricanes in the Unites States. Comprehensively understanding all aspects of global warming is not feasible in a project of this scope. Successful representation requires examining the data of each location over the years separately and portraying the impact of global warming in a way that is impactful and conducive to thinking about its implications. Nonetheless, a focus on one location and one aspect of global warming can still contribute to a better understanding of this phenomenon.

Since my research is motivated by the environmental issues and impacts of fast fashion, I look to create wearable technology that is carbon-conscious by using recycled materials and striving for minimal energy consumption in its design. However, this does not mean that this environmental awareness project is entirely environmentally friendly.

1.3 Research Summary

This research aims to explore the potential of using technology in clothing to visually represent the intensity of environmental crises and visualize temperature fluctuations. Additionally, it seeks to highlight the risks associated with climate change by transforming wearable devices into impactful tools to increase awareness and provide a platform for environmental issues. By designing a jacket inspired by Canadian geography, the garment can interpret temperature and wildfire data in different Canadian provinces, transforming these data into visual cues as expressed by arrangements of LED lights and colour changes. The garment warms the wearer through heating pads driven by wildfire data, making temperature increase and weather crises tangible. This technology is designed in the form of clothing to signify the importance of fashion in combating the effects of fast fashion on global warming. The thesis project was divided into three separate sections: global warming, fashion and mass production, wearable technology, visualizing and displaying digital data in tangible forms. Studies conducted in each of these sections provided the groundwork for my research, and I found the Research Through Design (RTD) process particularly useful in methodology, integrating design into the research process and creating a primary prototype through data collection and visualization.

1.4 Research Questions

This thesis explores the following research question:

How can wearable technology raise awareness about the environmental crisis by merging design and technology?

How can wearable technology effectively apply data visualization, adapting colour schemes or movement patterns to represent selected environmental datasets while working accurately and meaningfully within the limitations of wearable devices?

1.5 Goal & Outcome

Eco-Wearables involved studying relevant sources on global warming, temperature changes in Canada, and statistics on wildfires in various provinces. To visualize this data creatively, sketches were drawn to integrate technology in an effective manner. All relevant information was gathered and analyzed, with particular attention to discrepancies in statistics and their distribution and important values like areas burned during forest fires in different decades. Similar projects focusing on environmental issues and raising awareness were examined. Texts related to wearable design and wearable technologies aided in determining the most suitable materials and electronic components for the project. This was crucial for achieving a suitable design. Consequently, several initial prototypes were designed and constructed using an eco-friendly approach, emphasizing material sustainability and a final prototype was built and user tested.

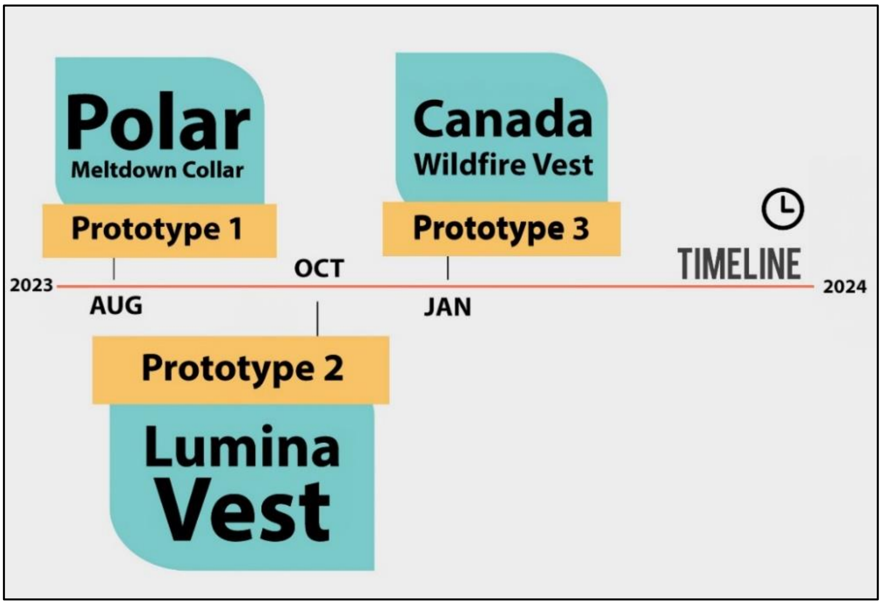

Figure 1. Timeline for making and processing thesis prototypes

Polar Meltdown Collar

This prototype is not a complete garment but rather a standing collar. It was designed using recycled materials and natural fabrics. It visually represents rising sea levels and serves as a symbol of drowning. Pockets at the top of the collar can be opened and raised, visually indicating future sea level rise. The fabric was dyed using an indigo plant- based method. No electronic components were included in this prototype; the focus was on material and conceptual design.

Lumina Vest

This prototype focused solely on Canadian data derived from regional wildfires. It was designed using recycled fabrics, with volumes separated by simplified shapes representing each province's geographical location. LED strips were used to illuminate these volumes, with Arduino programming dividing them into different sections. Colours changed from yellow to orange to red as they moved upward, indicating increasing warmth. The prototype promoted data visualization and replacement of the LED strips due to their inflexibility and difficulty in arranging them between provinces.

“The Canada Wildfire Vest”

The design of this garment represents the culmination of prototypes for the thesis, utilizing more precise design and data. Laser-cut patterns of Canada's provincial regions on the front of the vest depict vegetation cover, with small holes for placing LEDs underneath. Natural leather was used in this section. The back of the vest displays the melting ice of northern Canada using denim fabric and using recycled denim fabric shaped to represent melting ice caps. A standing collar at the top, inspired by the first prototype, symbolizes drowning as extreme water events intensify with global warming. A significant feature of this prototype is the interactive zipper on the front. Lifting the zipper illuminates LEDs that show a gradated intensity of warm colours graduated from yellows to oranges, to reds. Heating pads sewn into the lining warm as the zipper is lifted allow users to feel the temperature increase more vividly.

2. Literature Review

In this section, I will examine the literature that supports my thesis, framing the scope of my research, which is aimed at developing wearable technology to enhance environmental awareness. My research is structured into four distinct sections, each contributing to a holistic understanding of the issues at hand: global warming, fashion and mass production, wearable technology, digital to material data visualization and representation.

2.1 Global Warming

The first theme of the literature review is the broad topic of global warming and its implications on a global scale. I then address its specific consequences in the context of Canada, where destructive wildfires continue to plague the nation. According to Goughton (2005), "Global warming is an impending environmental crisis that demands immediate and coordinated global action across scientific, technological, economic, and political domains." A comprehensive historical perspective is vital for understanding this phenomenon.

Hutton's work presents a meticulous examination of temperature changes over the past century, millennia, and millions of years. The 20th century is a period of significant temperature escalation, mainly attributed to human activities. Proxy data and ice core analyses elucidate natural climate changes, such as the "Medieval Warm Period" and the "Little Ice Age," underscoring the unprecedented nature of recent temperature increases. Hutton's analysis serves as a clarion call for urgent action in the face of the profound challenges posed by climate change.

To better understand the complex interplay of environmental factors, it is essential to consider other ecological aspects of global warming. In recent decades, there has been a continuous increase in greenhouse gas concentrations within the Earth's atmosphere. According to Stocks (1993), this rise is expected to double compared to pre-industrial levels in the next century. Consequently, it could lead to a global temperature surge ranging from 1 to 4 degrees Celsius. The higher concentration of these gases is likely to affect global circulation patterns, resulting in noteworthy changes in regional climates. While tropical regions may encounter relatively minor temperature fluctuations, polar areas are estimated to experience a considerable increase in temperature, ranging from 7 to 10 degrees Celsius (Dai, 2023). For instance, the forest fires in Canada offer a striking illustration of how global warming exacerbates pre-existing challenges. The twentieth century witnessed an upsurge in Canadian forest use for various purposes, leading to an increase in forest fires. Human activities, such as forest industrial operations, agricultural expansion, urbanization, and mining are instances that yield significant impacts on climate change. Despite advanced fire management systems, forest fires continue to affect Canada's forest resources. The situation is compounded by short periods of extreme fire leading to the accumulation of flammable materials in mature forests.

Shifting focus to the local implications of global warming, Stewart et al. (2023) contribute insights in their study examining near 0°C surface air temperatures in southern Canada. Their research encompasses data from 39 stations using high-resolution climate models. Their findings reveal a 5.1% increase in average annual occurrences of near 0°C conditions in the future climate. This occurrence varies across southern Canada and is significantly influenced by precipitation, with implications for freezing, thawing, and precipitation types. The study also identifies distinctive temperature distributions around 0°C in both current and future climates, shaped by latent heat exchanges linked to precipitation and snow cover.

This regional perspective on climate change leads to considerations of one of its significant consequences. Sea level rise is poised to bring about permanent flooding, primarily in low-lying areas, with just a few meters of increase potentially inundating regions, along with marshes and floodplains (Titus et al., 1984). The regions face the threat of losing thousands of square miles of land, exacerbated by subsidence at a rate of roughly one meter per century. These developments have implications for land use, environmental sustainability, and economic concerns. Global warming can exacerbate the frequency and intensity of wildfires, leading to increased vegetation loss and soil degradation. Subsequently, these factors can contribute to higher runoff levels during precipitation events, amplifying the risk of flash floods in affected regions.

2.2 Fashion and Mass Production

The second aspect of the literature review focuses on the role of fashion and mass production as one of the principal culprits contributing to global warming. This section sheds light on the environmental implications of fast fashion, a term synonymous with the rapid production and disposal of clothing (UNECE, 2018). By analyzing the impact of the fashion industry on greenhouse gas emissions, water consumption, and waste generation, this research seeks to justify the choice of wearables as a canvas to visually represent the impact of global warming on the planet.

In creating *Eco-Wearables*, I am aware of the environmental impact associated with wearable technology, particularly its carbon-intensive nature. Recognizing the significance of this concern, I am committed to mitigating the ecological footprint of my garment. I prioritized the use of recycled materials in the construction of my design. I incorporated energy-efficient components and design strategies to minimize the overall energy consumption of the wearable.

Fast fashion, known for its rapid production cycles and inexpensive clothing, contributes substantially to greenhouse gas emissions. The manufacturing of synthetic fibers like polyester and nylon, often used in fast fashion, consumes substantial energy, thus releasing vast amounts of carbon dioxide (CO2) into the atmosphere. In addition to emissions, the industry encourages a culture of disposability with many garments designed for short lifespans and consequently quick disposal. Regrettably, discarded textiles often find their way to landfills, where they decompose and release methane, a potent greenhouse gas. The consequences of fast fashion extend further, as it places enormous pressure on water resources. The dyeing and finishing processes for textiles involve extensive water usage, contributing to water pollution and the reduction of clean water availability (Lynda et al, 2012).

Amid these challenges, sustainable fashion practices offer a beacon of hope. By prioritizing organic and recycled materials and reducing the environmental footprint of textile production, sustainable fashion minimizes the carbon emissions associated with fast fashion. Furthermore, sustainable fashion encourages consumers to make fewer, high-quality clothing purchases, thus extending the lifespan of garments and reducing the need for constant production and the associated emissions (Blackburn, 2012).

Organizations like Fashion Revolution play an integral role in advocating for systematic change within the fashion industry. Through campaigns, research, education, and mobilization, they aim to promote transparency and environmentally conscious practices within the industry. Fashion Revolution's commitment to a cultural shift that prioritizes both people and the planet represents a powerful step towards a more sustainable future (Fashion Revolution Impact Report, 2019).

I emphasize sustainability by incorporating recycled and repurposed materials into my prototype. By adopting these environmentally conscious practices and advocating for transparency within the fashion industry, we can collectively tackle the extensive consequences of fast fashion and global warming, ultimately working towards a more sustainable and climate-resilient planet.

2.3 Wearable Technology

The final section of the literature review centers on wearable technology and its role in raising environmental awareness. I will explore how global warming data can be translated into visual feedback on the garment, creating a connection between the wearer and the Earth by simulating the effects of climate change.

Wearable technology has transformed attire into interactive interfaces, blurring the lines between clothing and technology. Wearables are described as a versatile and multifunctional addition to the garments by Iztok Hrga, serving as a form of body architecture, a second skin, or even an emotional garment that can emphasize and visualize ideas (Hrga, 2019). Hrga categorizes various examples of wearable technology based on their technological concepts and functions related to both external and internal stimuli, including movement, light, sound, touch, sight, biometrics, and emotions. The central conclusion drawn is that the wearable technology augmented clothes act as bridges, providing wearers and observers with sensory and experiential connections through visual, physical, and perceptual dimensions, offering kinesthetic, proxemic, and haptic experiences (Hrga, 2019).

Wearable technology design entails many facets, including functional, technical, and social dimensions. Clint Zeagler’s work on BodyMaps (Zeagler, 2017) offers quantitative data related to wearables and approximate sizes and ideal locations for weight distribution for wearable technology. The article argues for the development of practical and user-friendly wearable technology, thoughtfully considering user needs and expectations. Zeagler delves into the multifaceted landscape of wearable technology design, encompassing functional, technical, and social aspects. By striving to create garments that empower viewers to interact with various elements like colour alterations and patterns, Eco-Wearables aligns with the considerations outlined in Zeagler's work.

Recognizing the importance of garment design, including construction, safety and even sustainability becomes crucial for incorporating wearable technology into clothing. The process of transforming climate or wildfire raw data into data visualization on the cloth using different visualization techniques started from data collection and extended to the design of wearable garments. This involves careful considerations for sensor placement, wired connections, and encouraging the incorporation of wires into seams, all aligning with body movements (Zeagler, 2017).

Zeagler's BodyMaps approach served as inspiration for designing electronic textile fabric interfaces and sensors that seamlessly blend with garments. The design encourages a cohesive fusion of technology and clothing by integrating wires into seams and favoring vertical orientations that align with body movements.

2.4 From Digital to Material Data Representation

Design researchers like Howell (2018) assert that there is a noticeable shift from digital data representations to material data representations, with the aim of enhancing the depth and contextuality of data interpretation (Howell et al., 2018). This strategy creates physical artifacts and tangible displays to provide distinctive perspectives on data interpretation. By interpreting raw data into visualizations that take different forms such as LED lights on garments or fiber optic textiles, these representations bridge the gap between abstract raw data and embodied understanding. Data materialization encourages diverse associations and meanings to be accommodated within specific social and cultural contexts.

Representations align with the concept of contextually situated interpretation, offering a pragmatic and effective approach to achieving more profound and contextually grounded understandings of emotional biosensory data. According to Howell (2018), Emotional biosensing refers to the use of technology to detect and interpret human emotions in daily life. It involves collecting data and categorizing emotions to understand how people feel and suggesting potential actions based on this information. Consequently, data visualization and physicalization fosters nuanced insights into the influence of affect, feeling, and emotion within various social, cultural, or other relevant contexts (Howell et al., 2018). Bio-sensing isn't just about visualizing data; it's about tapping into the very essence of human experience. This project explored how bio-sensing within wearable technology becomes attuned to our feelings, simulating the rising temperature. It's not merely about awareness; it's about feeling, experiencing, understanding. This project offers different avenues for engagement, whether it's through interactive installations that respond to data or wearable technology that becomes an extension of the self.

3. Contextual Review

3.1 "Amphibio" by Jun Kame

"Amphibio," a 3D-printed amphibious garment designed by Jun Kame addresses the challenges posed by rising sea levels due to climate change. Kamei's 3D-printed wearable device, inspired by water-diving insects, offers users the ability to extend their underwater breath-holding capacity, reducing the reliance on costly scuba-diving equipment. Notably, he goes beyond mere conceptualization by providing a functional prototype, emphasizing a solution-oriented approach. However, the device's purpose isn't to enable people to permanently reside underwater. The accompanying visual representations depict wearers exploring submerged cities and chapels, painting a vision of a future where delving into the mysteries of submerged civilizations is a common leisure activity for survivors. The project has been a source of inspiration due to its innovative approach in tackling the challenges presented by rising sea levels. It draws inspiration from water-diving insects while the visual representations conjure a future where submerged exploration is a common leisure activity. One of the reasons I was inspired by this project is how climate change can lead to the design of wearables whose concern is no longer following fashion. It exemplifies speculative design, proposing a solution for a hypothetical future and I want to address current environmental issues rather than a future scenario.

Figure 2. Amphibio. Jun Kamei. (n.d.). https://www.junkamei.com/amphibio

3.2 “From Green to Red” by Beatie Wolfe

In a different realm of artistic expression, “From Green to Red”, a visual installation designed by Wolfe, serves to fuse art and climate awareness (Beatie Wolfe, 2006). This interactive video installation is not merely a visually captivating experience but also a means of translating complex climate data into a relatable and emotionally resonant narrative. By offering viewers the opportunity to engage with atmospheric carbon level data across millennia through a digital timeline, this project effectively communicates the evolution of our planet's climate. "From Green to Red" highlights the power of art and technology in conveying the urgent message of climate change, bridging the gap between scientific understanding and public awareness. Wolfe (2006) realized that data is cold and impenetrable to people. This gave her the idea to combine her song with an easy-to-understand visualization of the data.

Figure 3. From Green to Red. Beatie Wolfe. (n.d.). https://beatiewolfe.com/our-planet

3.3 “Human Sensor LDN” by Kasia Molga

Kasia Molga's project, "Human Sensor LDN," takes a different route, creatively intertwining environmental data with human interactions. This art installation utilizes wearable technology to detect air pollution levels in London, transforming this data into visual and sensory experiences. Participants don sensor-equipped garments that change colours and emit sounds based on air quality, making the invisible issue of urban air pollution visible through artistic expression. In “Human Sensor LDN” (2016), breathing with biosensors becomes an interface between the environment and the body, highlighting how our own bodies may become sensors for diagnosing the condition of the air and thus the health of our surroundings. The performance can be described as “a story of the air written by our breath, translated by these wearable costumes worn by people whose health is affected by climate change” (Molga, 2016). Kasia Molga's work is a testament to the capacity of art to engage audiences in environmental consciousness while creatively incorporating technology into the conversation.

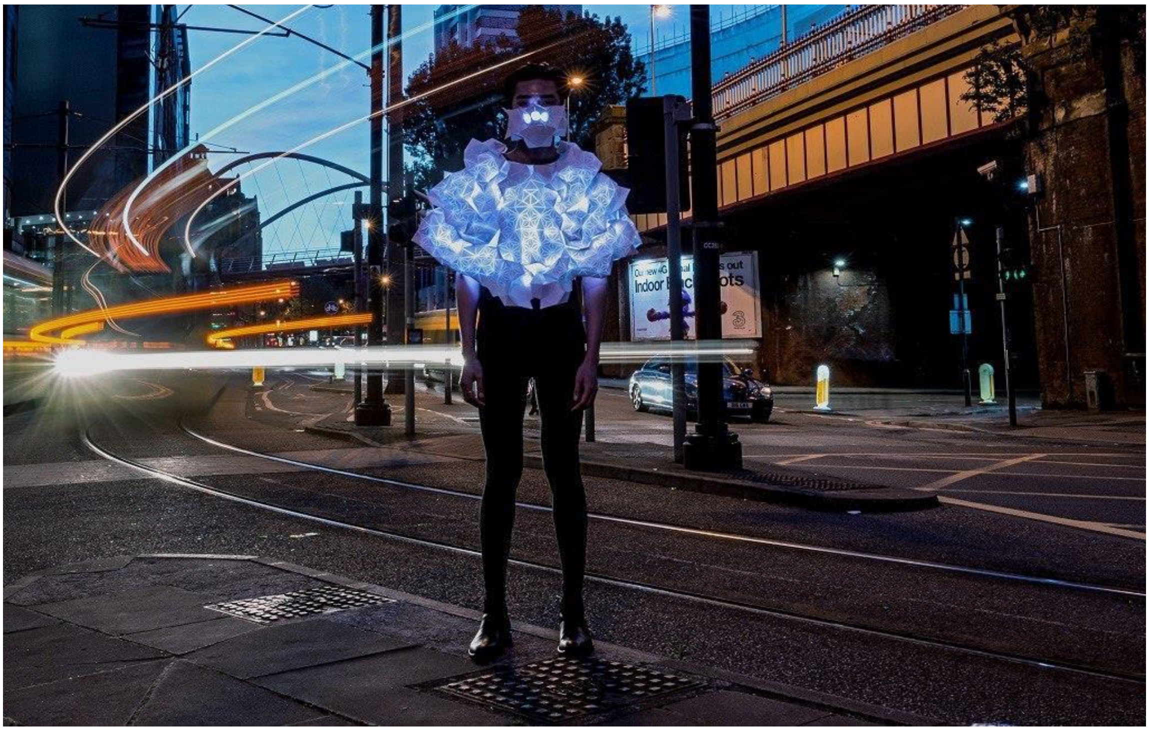

Figure 4. Kasia Molga - human sensor LDN. Invisible Dust. (2019, December 3).
https://invisibledust.com/projects/human-sensor-ldn/

These projects collectively exemplify the ways in which art and technology can serve as vehicles for raising awareness about our environment condition, offering innovative solutions, and fostering a collective sense of responsibility towards a more sustainable future. I learned the power of functional prototypes in effectively conveying ideas, as each project offered insights into the iterative process of prototyping, enabling different approaches to be applied to *Eco-Wearables*. Exploring these projects allowed me to find the ways that colour can serve as a potent tool for visualizing data. Whether it's through vibrant hues or subtle gradients, each project showcased the design and art of leveraging colour to convey information effectively within wearable technology. While not every project aligned precisely with *Eco-Wearables,* I extracted sections from each, piecing together a mosaic of inspiration. Through analyzing these projects, I was able to triangulate the dataset I aspire to work with and gain clarity on the type of wearable I aim to create.

4. Research Methodology

Eco-wearables aim to build awareness among individuals and societies about the pressing issues related to climate change. Each approach or methodology adds a different value to my existing creative practice which helped me focus on answering my research questions and building my thesis project.

4.1 Research Through Design

The Research through Design (RtD) methodology leverages the insights acquired from design practices to gain a more profound understanding of complex issues within the design industry (Zimmerman & Forlizzi, 2014). RtD involves crafting experimental solutions, often in prototype form, aiming to address existing problems or explore novel opportunities across products, software, services, or systems (Stappers & Giaccardi, 2017).

Given that the initial idea of this research was designing a wearable with the aim of environmental awareness, the first step was iterative design processes, leading to design changes and numerous diagrams and sketches before building the prototype. Overall, there is a close relationship between research and design in my project. The type of knowledge gained through this study, through research for design, leads to knowledge for designing and constructing the prototype.

Conducting the design for this research is equivalent to conducting research since the wearable being designed is a data display, and its interactive aspect is one of my main goals, dynamically visualizing weather-related data. Hence, the value of design and research in this project is equal, and they should be carried out side by side. The act of designing requires the designer to confront several challenges: between competing or conflicting background knowledge, between theory and technology, and between dream and reality. Making provokes a particular cognitive activity, one which can be used to make people aware of tacit values and latent needs (Stappers & Giaccardi, 2017). This study embraces RtD by creating a dynamic wearable technology prototype for data visualization, serving as a proof of concept.

4.2 Data Collection

By examining historical temperature data in conjunction with records of wildfire occurrences, I gained insight into how forest fires' timing and locations are influenced by shifts in climate conditions. Fires can play an important role in combustible environments, such as shrublands, grasslands, and forests, and contribute to climate change. Forest fires emit substantial amounts of greenhouse gases and particulate matter into the atmosphere, more than assumed in state climate targets. Thus, forest fire, and climate change are intertwined concepts (Swati Singh, 2022).

Satellite remote sensing is a powerful tool, offering precise and timely data on terrestrial changes, and has been extensively utilized for wildfire identification, tracking, and impact assessment at both local and regional levels. The Canada Centre for Mapping and Earth Observation and National Forestry Database[1], in collaboration with the Canadian Forest Service, has developed a comprehensive National Burned Area Composite (NBAC). This composite serves as a benchmark for curating a bi-temporal multi-source satellite image dataset for change detection, compiled from the archives of Sentinel-2, Sentinel-1, and ALOS-2 PALSAR-2.

This dataset is the inaugural large- scale, multi-source, and multi-frequency satellite image dataset with high spatial resolution for wildfire mapping, monitoring, and evaluation (Zhang et al. 2024). A comparison of fire intensity was made by The Disaster Lab of Carleton University between the wildfire disaster of July 2011 (left) and June 2023 (right) forest fires in Canada. The side-by-side comparison allows viewers to see that while hundreds of simultaneous wildfires have occurred in the past, their scale of intensity and propensity is a wholly new phenomenon.

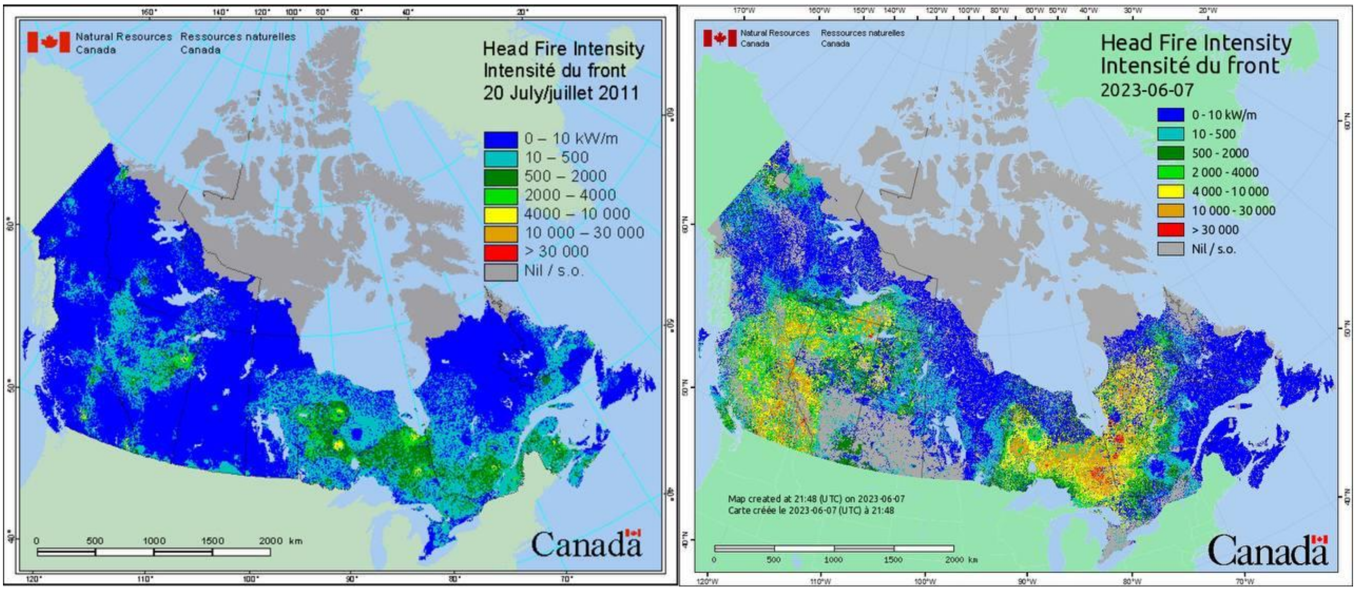

Figure 5. Forest fire intensity comparison between 2011 and 2023. (https://carleton.ca/thedisasterlab/2023/the-canadian-wildfires-of-2023/

From their dataset, which encompasses major wildfire events in Canada, I gathered decade-long time intervals of data to attain a better understanding of forest fire changes, categorized by Canadian provinces. At this stage, it was necessary to procure initial data in a format suitable for processing. Data are available in graphs, Excel files, and as vector layers (shapefile) in Geographic Information System (GIS) software.

These data include the location of wildfires categorized by province, year, and month, and the number and area of wildfires in each province. Following preliminary reviews and observation of the available charts on the website, it can be noted that information for all provinces and territories except Nunavut is available. Therefore, at this stage, I decided to exclude Nunavut from the study. Another important consideration is that the criterion for analysis should focus on the area affected by wildfires in each province. This is because the number of wildfires can lead to confusion in studies, and there are many wildfires that burn very small areas, but including the numbers of wildfire occurrence in the analysis would introduce errors. Consequently, the criterion for future investigations will be the area burned.

In the chart below, it is evident that while the number of wildfires in the province of British Columbia is decreasing, the extent of wildfires is markedly increasing, with each fire affecting larger areas.

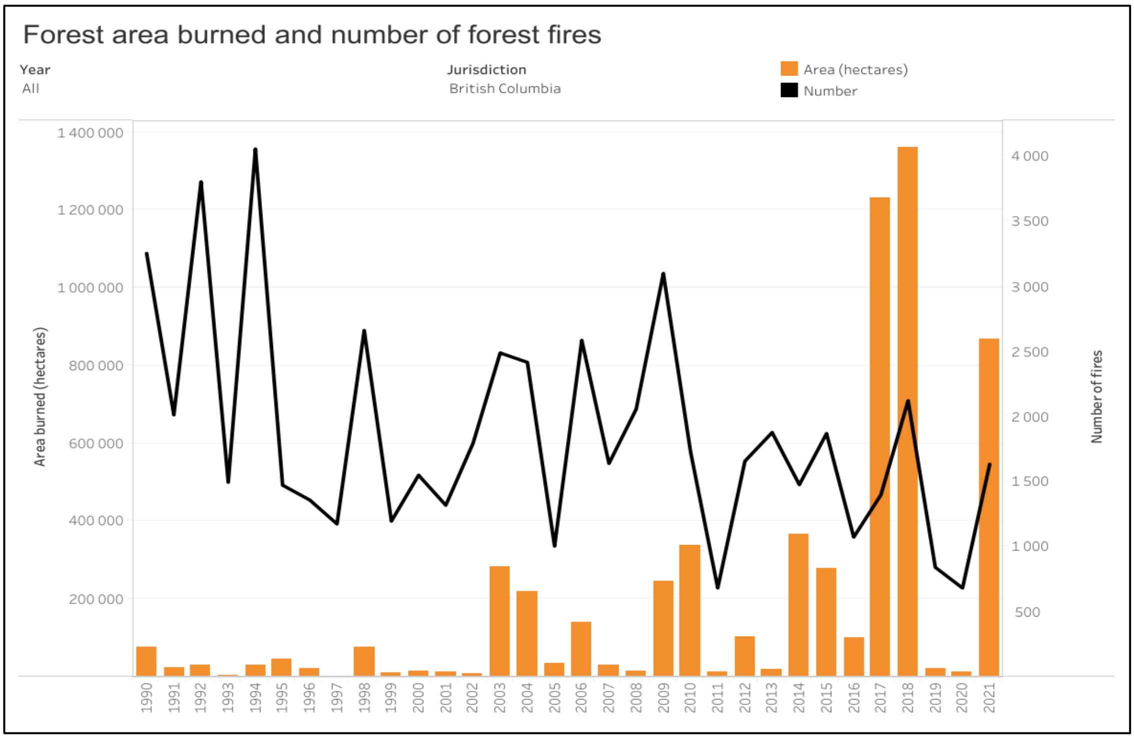

Figure 6. Chart of forest area burned from 1990–2021 in British Columbia (Canada's National Forestry Database)

Initial data points representing the locations of wildfires were imported into geographic data processing software to not only visualize the wildfire locations but also collect statistical information in tabular form. Since all data were available by year, conducting year-by-year analyses risked losing significant information. For instance, as seen in Chart 7, there were significantly more wildfires and larger affected areas in Alberta in 2003 compared to 2020. Considering the recurrence of this pattern, it was more sensible to use the total area burned per decade instead of selecting specific years as indicators, thus yielding results closer to reality. Therefore, it was necessary to calculate the total area burned for each decade separately, categorized by provinces.

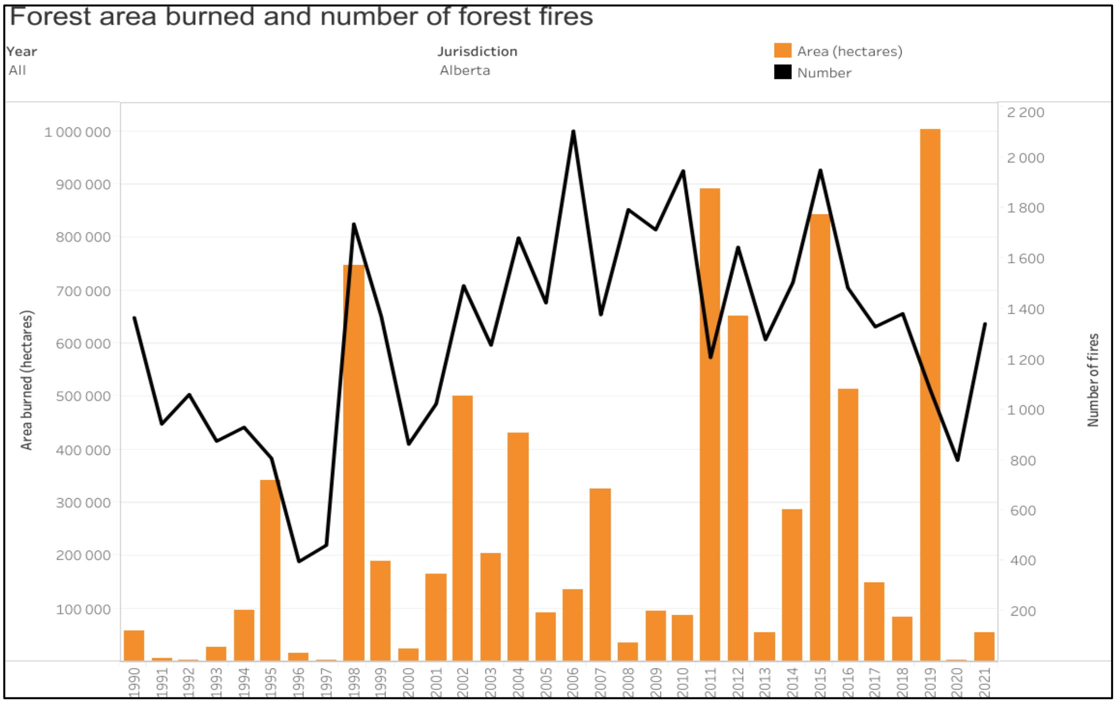

Figure 7. Chart of forest area burned from 1990 – 2021 in Alberta (Canada's National Forestry Database)

To accomplish this task, descriptive tables, and tools from GIS and QGIS software were employed. These software tools not only facilitated statistical calculations but also enabled the visualization of results in graphical and spatial formats, allowing us to represent statistical components using colour spectrum on maps.

The transformation of the initial dataset into a structured, processable format was essential prior to commencing the visualization of data, allowing the construction of a comprehensive statistical table. This table categorized fires by provinces and systematically segmented data into ten-year intervals, facilitating the calculation of cumulative burned areas attributable to wildfires across diverse regions. This table not only afforded a perspective of wildfire dynamics but also enabled the discernment of temporal trends and spatial patterns (Chart 1).

Provinces	Abbreviations	Area Burned 1990_2000	Area Burned 2000_2010	Area Burned 2010_2020
Alberta	AB	1,460,024	1,986,564	4,540,745
British Columbia	BC	277,274	955,728	3,790,542
Manitoba	MB	3,671,076	1,961,025	2,334,105
New Brunswick	NB	15,688	24,457	1,253
Newfoundland & Labrador	NL	387,658	194,787	86,651
Northwest Territories	NT	9,593,697	2,010,648	7,087,417
Nova Scotia	NS	2,465	5,000	916
Ontario	ON	2,403,537	747,701	1,618,122
Prince Edward Island	PE	8,441	9,624	4,790
Québec	QC	3,089,653	2,528,688	2,541,034
Saskatchewan	SK	4,819,080	4,383,848	5,696,522
Yukon	YT	1,768,580	2,386,249	1,366,740

Chart 1. Statistics of area burned in Canada divided by decades

4.3 Data Visualization

The objective of this thesis project is to transform raw data into visually impactful representations. These visualizations served as powerful tools for discerning relationships and patterns within the dataset. Moreover, they played a pivotal role in effectively communicating the research findings to others. By presenting quantitative insights through visually graphical displays, *Eco-Wearables* endeavored to provide a portrayal of the spatial extent and temporal evolution of wildfires. This not only sought to facilitate a deeper understanding of the phenomena under investigation but also to inform evidence-based decision-making processes aimed at enhancing wildfire management and mitigation strategies.

In this section of research, the focus shifts towards visually representing the extensive dataset compiled in Chart 1 highlighting the fluctuations in burned regions. Leveraging the capabilities of Excel graphs and Geographic Information System (GIS) software, the raw numerical data was transformed into symbolized graphs and maps, enabling a more intuitive understanding of the spatial distribution of wildfires over time.

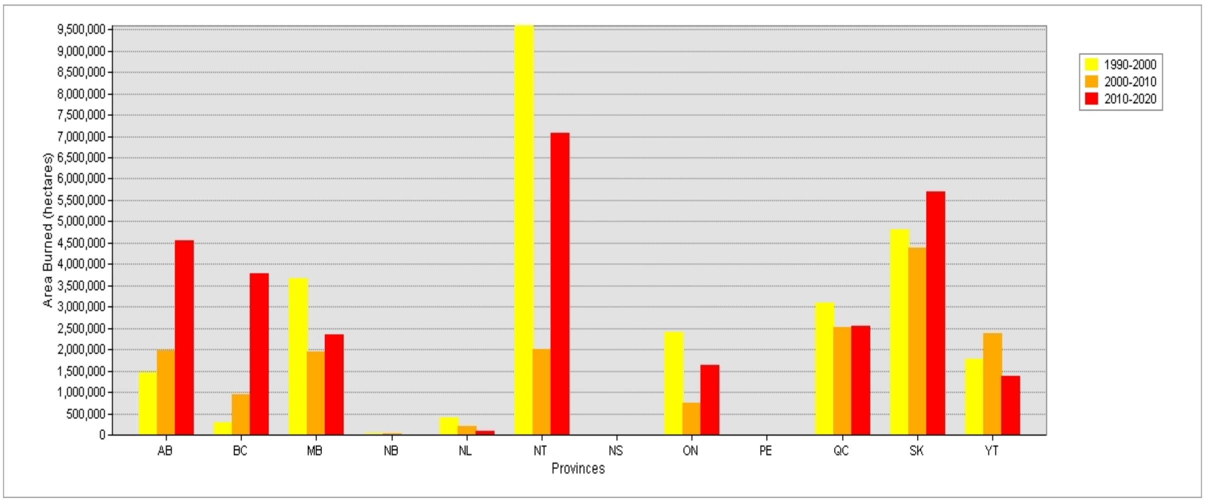

Figure 8. Spatial distribution of wildfires over time in different provinces

The resulting graph in Figure 8, derived from Chart 1, portrays the cumulative area of burned regions along the vertical axis, while province names are in abbreviated form along the horizontal axis. A colour-coded scheme was used to present three decades of data, with columns corresponding to each decade vividly distinguished. Yellow colours represent data from the 1990s to 2000, orange signifies the 2000s to 2010, and red denotes the years spanning 2010 to 2020.

The total area of burned regions has varied significantly across different decades in certain provinces. For instance, provinces like Alberta and British Columbia exhibit a discernible upward trend, indicative of a progressive increase in the extent of wildfires over consecutive decades. In contrast, provinces such as Quebec display a more uniform pattern, with fewer fluctuations in wildfire activity observed over time. These visual insights offer perspectives on the evolving wildfire dynamics within Canada's diverse geographic regions as indicators for understanding such trends.

The maps below depict distinct maps for each decade, delineating the changes in burned areas resulting from wildfires across various provinces and territories of Canada. These maps aim to provide a better understanding of the distribution of wildfires. Displaying the data in graph and symbolized map formats allows for a more accurate comprehension of this patterns of wildfires across Canada's diverse landscapes.

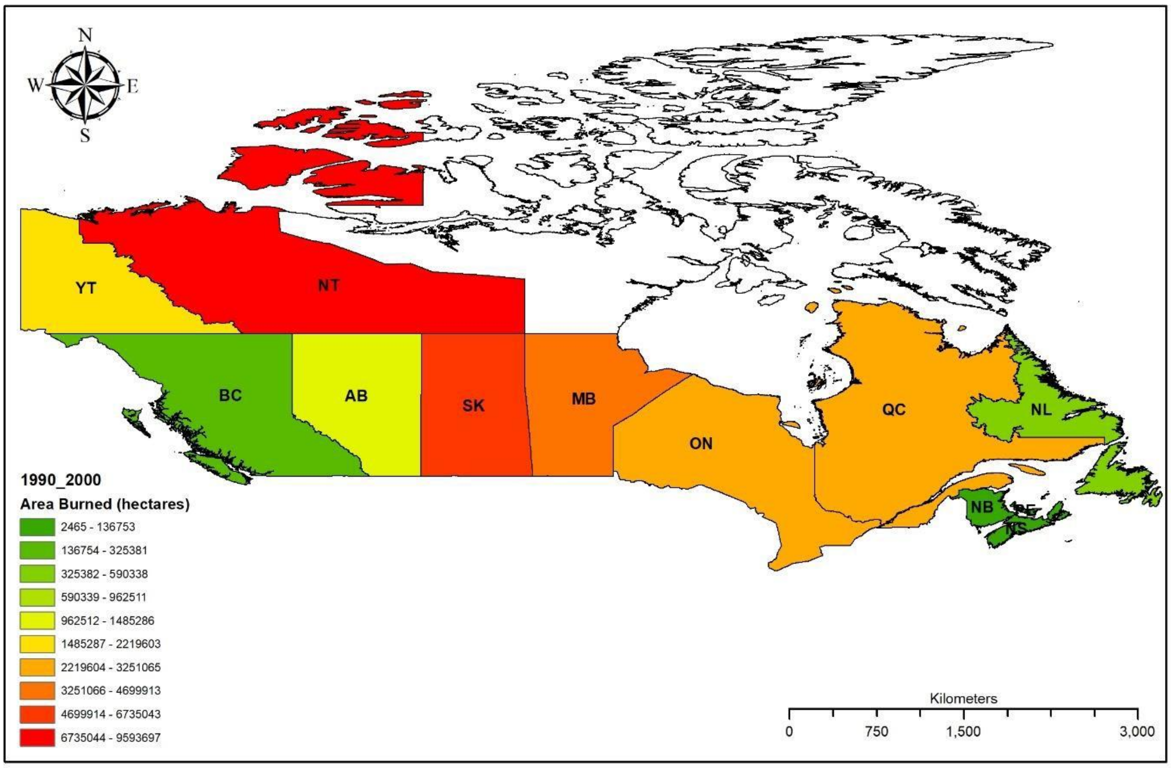

Figure 9. Symbolized map of burned area in Canada in 1990-2000

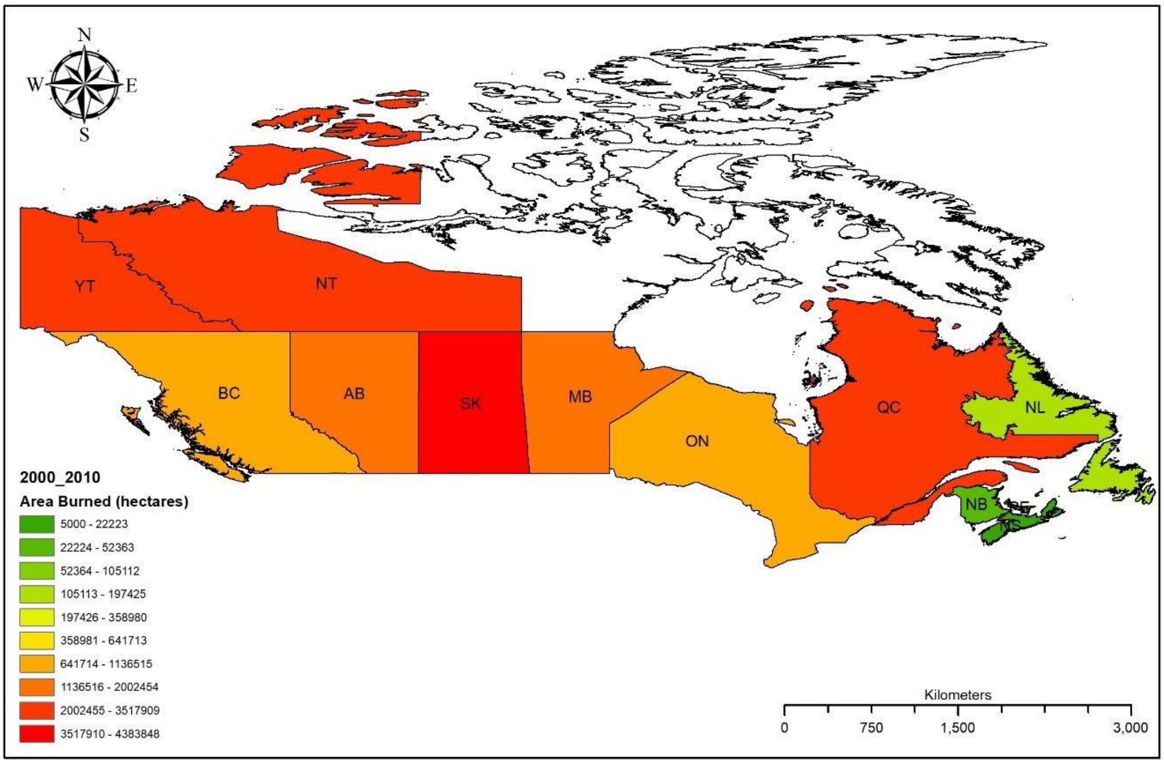

Figure 10. Symbolized map of burned area in Canada in 2000-2010

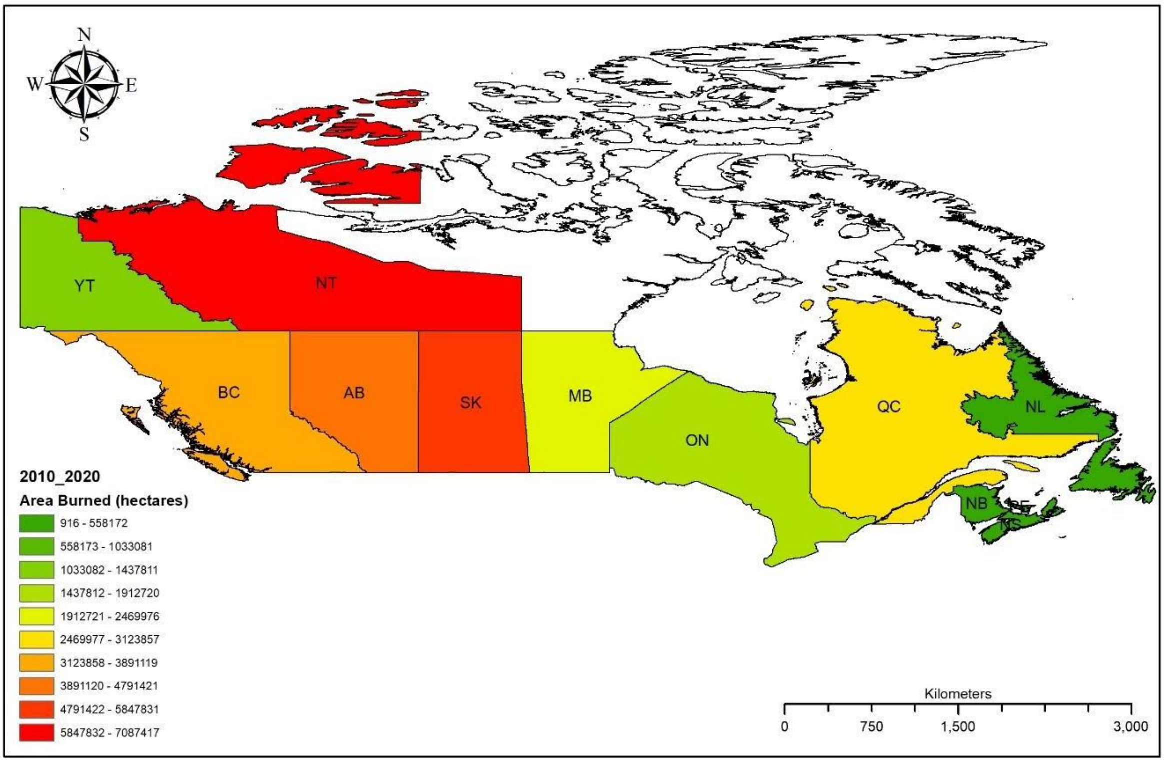

Figure 11. Symbolized map of burned area in Canada in 2010-2020

The data collection, analysis and mapping process ensured that all necessary data were available to display these changes using LED displays sewn on maps sewn onto maps on the clothing. Precise adjustments were made to the number and intensity of colours displayed on the LEDs for each decade and province. Access to processed and displayable data for the audience, devoid of the need for complex statistical knowledge, and presenting environmental concepts and concerns in their simplest form is another objective of this research.

4.4 Presenting Visualizations on Fabric

After preparing the maps and the statistics in the previous section, I transferred the visualizations onto the fabric and decided on the method to display them on the garment.

Another aspect to address in the visualization section was how to display data in the form of LED lights on clothing. It was necessary to utilize LEDs with higher flexibility compared to other strip LEDs, enabling easy placement on various parts of clothing. The challenge lay in how to project a map of different provinces and territories of Canada onto the garment. To tackle this, I initially sourced maps from geographical websites and data-providing platforms like DivaGIS, obtaining administrative area maps that depict various divisions and subdivisions within the country (Figure 12). These maps, available as vector layers, are viewable in most Geographic Information System (GIS) software.

Figure 12. Administrative provincial map of Canada

This delineation allowed for easier placement of each piece on the clothing. Upon completing the designs in Adobe Illustrator, the drawn polygons were prepared for laser cutting. By configuring settings suitable for cutting and designing patterns on materials like leather, the prepared vector drawings were transformed into output. In this way, the desired provinces were constructed to showcase the specifics of the ways that data will be displayed on the garment. The following Figure 13 depicts the laser-cut design. Tree designs indicating evergreen trees were incorporated onto these provinces, with cavities carved into many of them to accommodate LED installation. After installing the LEDs onto the clothing and placing the provinces on it, the illuminated lights from the LEDs were easily observed. This is meant to signify the impression that these trees are the ones ablaze.

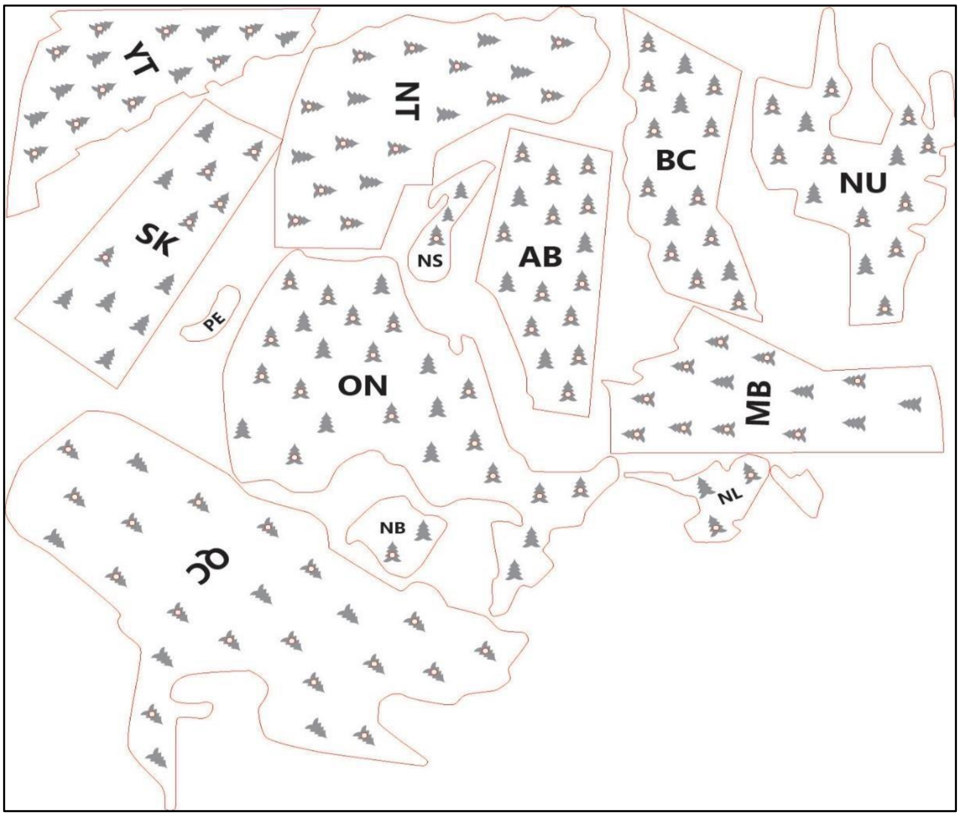

Figure 13. Provincials of Canada made by Adobe illustration

4.5 User Testing

User testing two prototypes, the Polar meltdown collar, and the Lumina vest, played a crucial role in evaluating and refining the effectiveness of “The Canada Wildfire Vest” in raising awareness about global warming and its impact. Research Ethics Board approval was received to undertake user surveys and engage in dialogue when works were exhibited. The user testing process involved multiple steps, from setting clear goals, designing a survey, and recruiting participants to preparing the testing environment and analyzing user feedback through observation and surveys.

I observed user behavior during their interactions, including navigation patterns, areas of confusion, and attention paid to data visualization elements. I encouraged participants to verbalize their thoughts while interacting with the vest, providing valuable insights into their thought processes and decision-making. Like other user-based evaluations, this approach offered the advantage of uncovering unforeseen issues. Users might encounter problems that developers or designers might not have anticipated, like difficulties manipulating the zipper or interpreting data visualizations.

By directly observing user interaction, I was able to identify these challenges and use this feedback to refine the design for future iterations. Overall, user-based evaluations proved to be a powerful tool for user-centered design, ensuring that “The Canada Wildfire Vest” was not only functional but also intuitive and effective in raising awareness about global warming. This approach aligns with the core principle of user-based evaluations, as described by Bastien (2010), where users take center stage and their interactions with the technology become the primary source of data for design improvement.

5. Prototypes

5.1 Design Process

Lim, Stolterman and Tenenberg (2008) state that prototypes and the development of ideas are greatly interwoven during the “design process”. They also explain that the importance of prototyping lies in the idea of intensive reflections that help the researcher structure, enhance, and uncover potential in the design (Lim, Stolterman & Tenenberg, 2008).

The act of wearing or witnessing garments conveying information through artistic expression and design serves as a powerful visual communication tool. Interactive functionalities enhance the sensory connection with the audience, ultimately fostering heightened environmental awareness (Zeagler, 2017).

Eco-Wearables is intended to be a wearable technology that addresses and represents climate change and seeks to be an effective communication medium. The prototyping process was divided into two parts: a low fidelity prototyping stage and a high-fidelity stage. A low-fidelity stage was designed and evaluated for general designs and sketches and aimed to depict different aspects of global warming effects in the design of a wearable. After identifying and refining the key design elements, I moved on to the second high fidelity phase, focusing on details, materials, and functions. The goal of this design process was to develop an interactive garment centered around a specific location and one of the primary contributors to global warming, namely Canada and its forest fires.

5.2 Low Fidelity Prototypes

5.2.1 Global Warming Exploration

In this section, I will describe the first stage of the design process, focusing on the construction and visualization of two low-fidelity prototypes. I will explain the Research Through Design (RtD) process behind the idea and transformation of conceptual ideas into tangible prototypes, clarifying the criteria used to evaluate and iterate the design. Moreover, I will examine the user experience of wearing, limitations encountered during the prototyping phase, and highlighting the ways that these factors influenced the conceptualization and development of the final prototype.

Research was started regarding the impacts of global warming in various locations. A list of locations and their respective impacts of global warming was compiled, accompanied by a summary of information including floods in Europe, food scarcity in Africa, wildfires in America and Canada, rising sea levels due to polar ice melt, droughts in the Middle East.

All these examples led to my concerns about the future. In response to the question I had raised at the beginning of the research, *how can wearable technology raise awareness about environmental crisis by merging art and technology?* numerous sketches were created to depict these hazards and enhance awareness. Sketches of clothing designs led to the concept of creating a collection entitled “Earth," where each garment symbolized a disaster in a specific location on Earth. However, due to the time constraints of the project and the necessity for detailed information, data, and research, it was not feasible for me to implement and construct a collection as vast as the Earth.

My location selection coincided with the initial months of my migration to Canada in 2022. The research aimed to examine the impact of global warming on Canada, with a specific focus on two main disasters: forest wildfires and rising sea levels due to polar ice melt in the construction and design of my prototypes.

5.2.2 Conceptual Design

Initial sketches proposed parts of garments, focusing on collars. Two designs were suggested for the collars. One drew inspiration from the theme of burning, where colouring and fabric manipulation on the shoulder area were intended to simulate fire, and black threads woven around a wire created a standing shape resembling burnt trees at the top of the collar (Figure 14). The second design also featured a standing collar, but this time focused on rising sea levels (Figure 15). In this design, the upper part of the collar was scalloped and pleated in a way that allowed movement, creating a staircase-like effect where the collar could ascend, simulating the drowning state for the wearer. The fabric was patterned with a combination of blue hues to simulate an oceanic theme.

Figure 14. Inspiration from the theme of burning

Figure 15. Standing collar idea focused on rising sea levels

Considering that Canada is more deeply affected by wildfires, I decided to incorporate the theme of rising sea levels into the collar and address the wildfire’s theme in the main body section of the garment. The collar, entitled "Polar Meltdown Collar," progressed to the stitching and execution stage. For the garment's body, a sketch of a unisex jacket was proposed, featuring a simplified map of Canada with geometrically shaped provinces. These shapes were completely separated by borders, allowing LED lights to be placed between them and illuminated from bottom to top with a warm colour combination. Two designs, the "Polar Meltdown Collar" and the "Lumina Vest," have progressed to the execution and stitching stage.

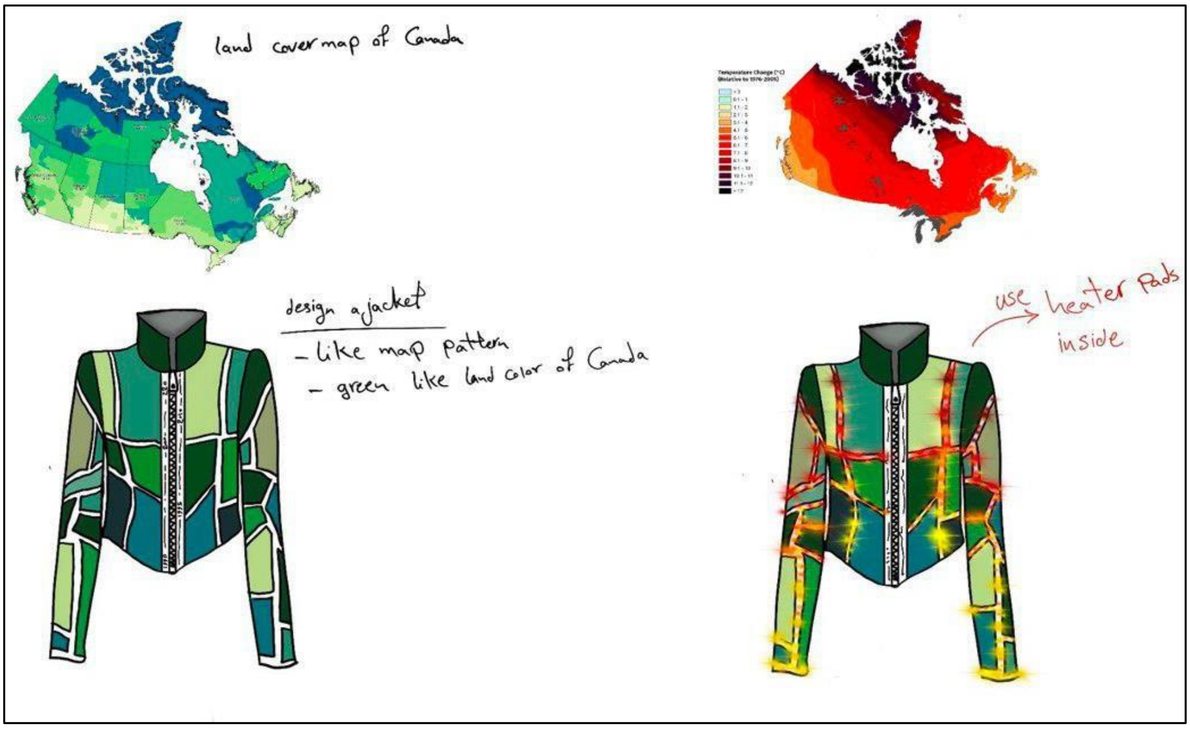

Figure 16. LED lights placed between sections illuminated from bottom to top with a warm colour combination

5.2.3 Wearable Making Process

In the execution stage of each design, the choice of materials and fabrics used is of paramount importance. The fashion industry's water-intensive processes, including dyeing and finishing textiles, strain freshwater resources and contribute to water pollution, impacting both local and global ecosystems. Therefore, for creating these prototypes, I prioritized the use of natural and recycled fabrics. I began collecting recycled fabrics, with denim scraps being the most prevalent. Given that denim is one of the most water-intensive fabrics in the fashion industry and is constantly subject to significant criticism, I decided to use this fabric to illustrate the theme of rising sea levels. In the stitching stage of the collar as the first prototype, I utilized eco-friendly and indigo dyeing methods for colouring, which are highly sustainable as all water used in the dye extraction process can be returned to agricultural products, and even indigo, after composting, provides some fertilizers.

Figure 17. First prototype: Transforming Denim Scraps into Eco-Friendly Couture

In the second prototype, pieces of recycled fabrics were used, with a combination of green colours that harmonized with Canada's vegetation cover. For this prototype attempts were made to embroider prominent volumes on the vest's collar using simplified shapes of Canada's provinces, and different LED lights were used to illuminate their borders with a range of warm colours. However, after stitching the provinces onto the collar, their shapes were not clear to observers, leading to questions about what these patched volumes represent on the garment. Thus, this design element required redesign and enhancement.

As a first step, by applying electronic components on the vest's collar with the help of Arduino and LED strips, the lighting strategy was implemented. LEDs were divided into three distinct groups based on their placement in specific provinces and territories, according to the statistics presented in the data collection section, representing three decades from 1990 to 2020 with different colours: green, yellow, and red.

Figure 18. Second prototype: The Lumina vest

5.3 High fidelity prototype

Each prototype aimed to prioritize the concept, design aesthetics and technical execution. The main objective of developing prototypes in the early stages of a design process is to detect problems or find alternative directions for new results. This means that even if the prototype is not developed to a final product, some elements are filtered out (Lim, Stolterman & Tenenberg, 2008). Therefore, each of my prototypes had strengths and weaknesses, and by understanding them, one can make the right decision for the final prototype.

5.3.1 “The Canada Wildfire Vest”: Front

Considering the feedback and discussions regarding the previous prototype, several aspects needed more attention. It was necessary to create a clearer design of the map of Canada on the garment to strengthen visual aesthetics and ensure the conceptual clarity of the final prototype. The high-fidelity prototype map of Canada is depicted with more detailed and vertically oriented representations of each province, despite the map itself being horizontally designed (Figure 17). These representations were placed vertically alongside each other in the dimensions of the garment. Hence, they were arranged from the top left in sequence and descended row by row, designing the front part of the garment with the map of Canada.

The shape of Canada's map and each of its provinces could not easily be created through stitching fabric. I decided to use a laser cutting machine for precise cutting. The designs of each province were drawn on the body pattern of the garment, so their sizes were calculated relative to their areas and drawn in Illustrator. Secondly, illuminating the LED lights in the previous sample was another issue. The edges between the provinces were illuminated, which didn't seem logical considering the aim was to represent wildfires within each land. Hence, small holes for LEDs needed to be cut inside each province so that LEDs could be placed underneath them. A pattern of evergreen trees representing Canada's vegetation was densely added in each province. Among these trees, some had small holes for LED placement, the number of which varied depending on the extent of wildfires in each province.

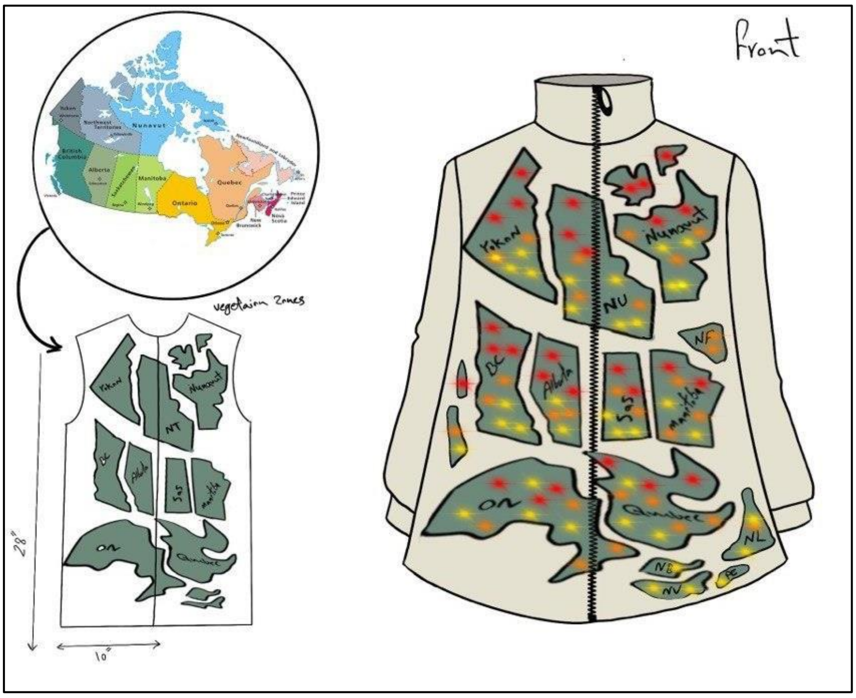

Figure 19. Redesigning Canada's Map on garment

5.3.2 "The Canada Wildfire Vest": Back

A design of ice pieces and their melting was created for the back of the vest using denim and recycled fabrics (Figure 20). Pieces of denim fabric were used, recycled from discarded denim clothing. Denim production involves several stages, each of which consumes substantial amounts of water, leading to water scarcity issues, pollution, and environmental degradation.

Steps such as spinning, dyeing, and finishing require vast quantities of water to wash and treat the fabric. Indigo dyeing, in particular, which gives denim its iconic blue hue, involves multiple dyeing and rinsing cycles, each of which requires significant water input (Periyasamy et al. 2023) Recycled denim was used to underscore little known problem of denim production.

Due to the blue colour of denim fabric and its relationship with water usage in its production, the denim design was installed on the back of the garment to represent watery areas. This signifies the surrounding waters of Canada and aims to symbolize the melting of polar ice caps due to global warming by placing white fabric pieces as polar regions and separating them from each other. One of the effects of this phenomenon on the environment could be forest wildfires.

Figure 20. Illustration the back of the garment

Figure 21. Designing the back of the garment

5.3.3 Technical Development

In this stage, the technical features of the garment, its performance, and user interaction were enhanced. The primary function of the project, focusing on the impact of global warming on Canada and forest fires, is executed using LEDs. This method utilizes data collected from the extent of wildfires in each province over different years, displaying varying degrees of warmth using colours displayed on the LEDs. For instance, the colour red represents more intense wildfires, while yellow is used for the least extent of wildfires. The previous prototype used Neopixel LED strips which, although adjustable and bendable, were not flexible enough due to the high number of bends and curves in each province, a more suitable option for the final prototype was chosen the flexible wire Neopixel strand. The next step was to attach the LEDs to the underside of each province. Their wiring on the garment needed to be done in a way that remained invisible from the outside to maintain the garment's appearance. Thus, the wiring was transferred from underneath each piece to the back of the garment and then brought back to the next piece. The Arduino Nano 33 microcontroller was used to provide logic for colour changes and timing.

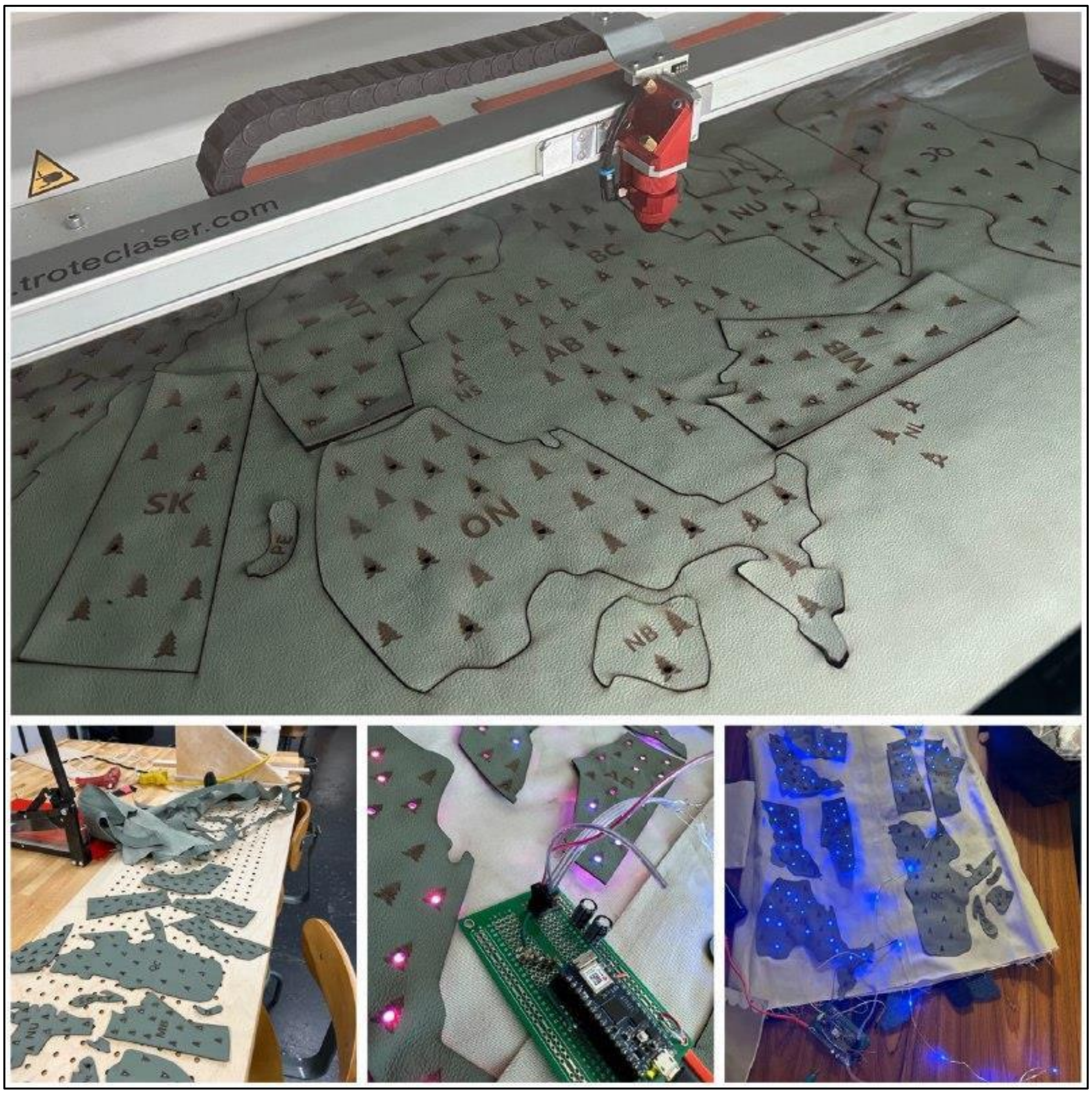

Figure 22. Laser cutting process

After thorough research, I opted for a type of NeoPixels that offered sufficient flexibility to be integrated into clothing layers. One of the key advantages of soft flexible wire NeoPixels strands lies in their flexibility. The soft wire construction enables easy bending, twisting, and shaping of the strands, facilitating seamless integration into various lighting setups. Additionally, the durable coating of the strands ensures longevity and resilience, even in challenging environments (Adafruit website).

Another notable benefit of these NeoPixel strands is their ease of installation. The flexible wire construction allows for effortless manipulation and securing of the strands, whether using clips, adhesive, or other mounting methods. This simplifies the installation process, reducing the time and effort required to set up intricate lighting configurations. Moreover, the ability to cut the strands to custom lengths further enhances their versatility, accommodating diverse project requirements. Flexible NeoPixel strands are useful for their high-quality lighting output. Utilizing NeoPixel technology, each LED within the strands can be individually controlled, enabling dynamic lighting effects and patterns. The vibrant colours and excellent colour accuracy of the LEDs ensure visually stunning illumination, making them ideal for functional lighting applications.

Figure 23. Flexible NeoPixel strands used in the layers of the garment

A zipper as a switch mechanism was proposed to facilitate user interaction with the garment’s data. When the user pulls the zipper up while wearing the garment, they can observe changes in provinces with different colours and varying numbers of illuminated LEDs, reflecting the gathered fire ￼ A conductive metal zipper acted as a switch at three points, with connections made using conductive thread sewn alongside the zipper. A connection was established at the lowest part of the zipper for readjustment purposes, ensuring that when the user unzips, the lights turn off (Switch & Sensor Workshop Advanced Wearables, 2023)

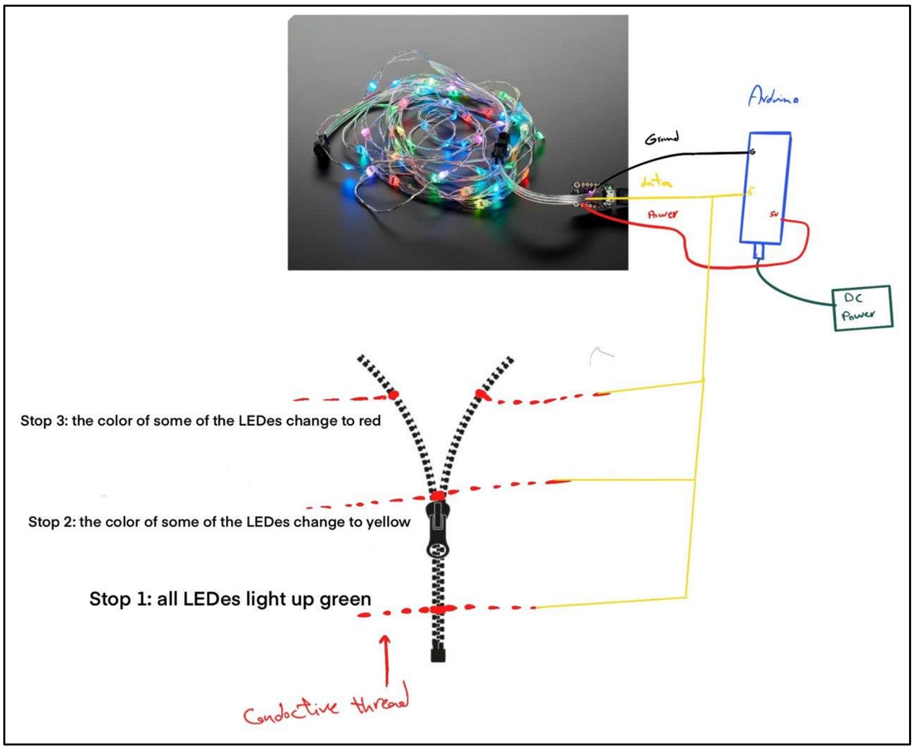

Figure 24. Designing the zipper as a switch to control mechanism

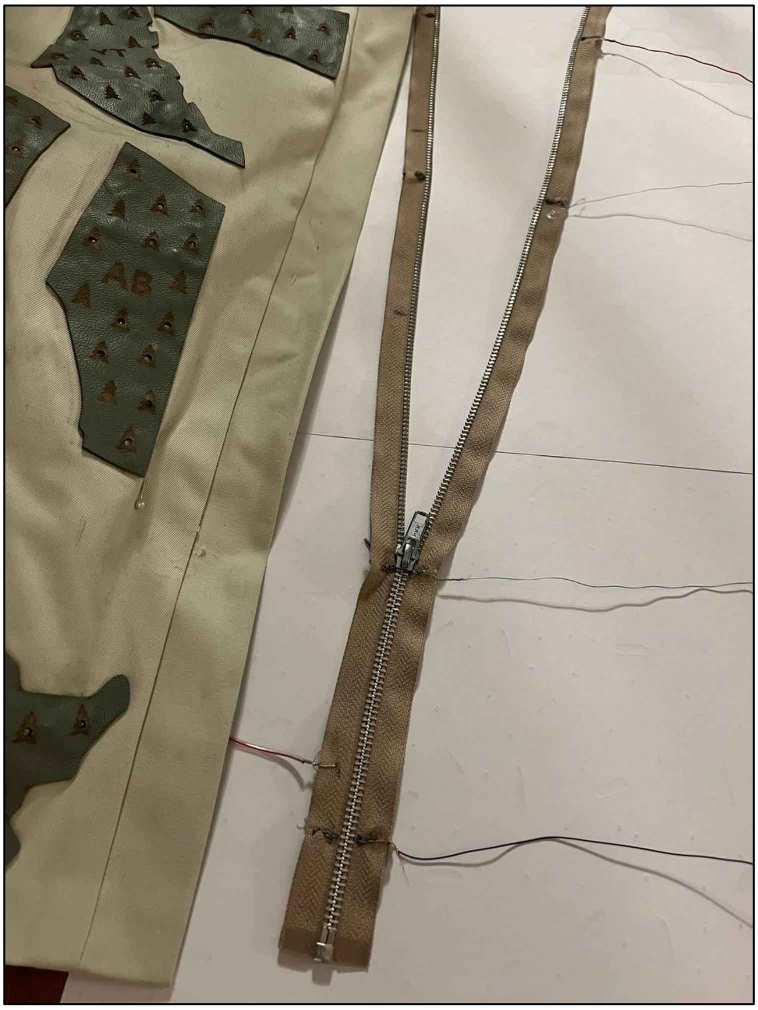

Figure 25. Making the zipper as a switch to control mechanism

Connecting LEDs to an Arduino to illuminate the LEDs on a garment involved several steps to ensure proper functionality and control. The circuit diagram details the connections between the Arduino board and the LED strip. The circuit diagram in Figure 26 illustrates the wiring layout, including how power is supplied to the LED strip and how data signals are transmitted from the Arduino to control individual LEDs. This visual representation served as a guide for assembling the physical connections accurately.

After establishing the physical connections, programming the Arduino board to control the illumination of the LEDs effectively was the next step (Appendix F: Arduino Source Code). This involved writing code that dictates how the LEDs behave, such as their color, brightness, and patterns. Addressable LED strips typically require specific libraries and functions within the Arduino IDE to communicate with individual LEDs.

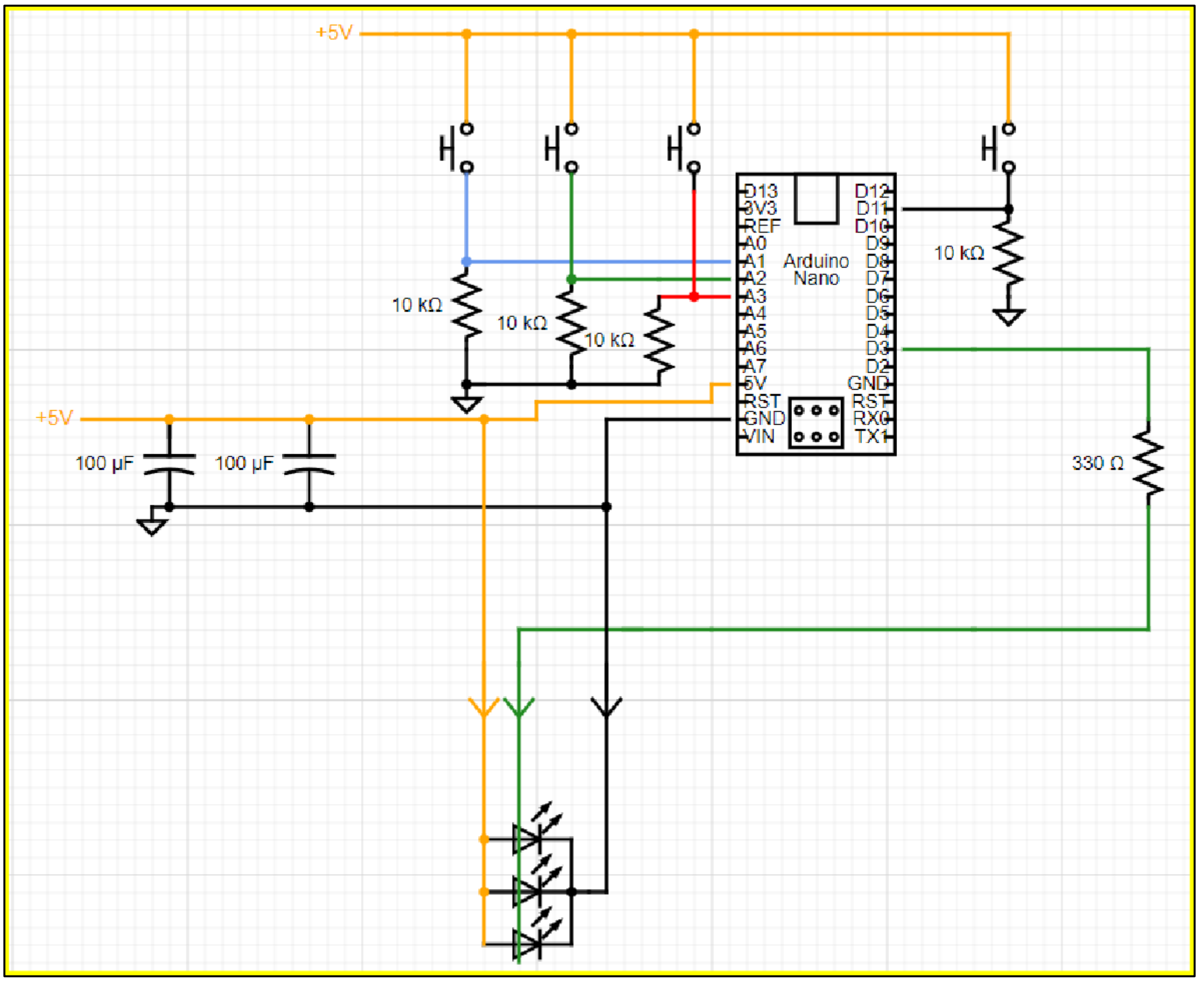

Figure 26. Circuit diagram of the project

Once the Arduino is programmed and the LED strip is connected, testing, and debugging the setup are crucial steps to ensure everything works as intended. This involved uploading the code to the Arduino board and observing the LED strip's behavior. If any issues arise, such as LEDs not lighting up or displaying incorrect colors, troubleshooting techniques such as checking wiring connections or revising the code are necessary. Through testing and refinement, the LED illumination was fine-tuned to achieve the desired visual lighting on the garment.

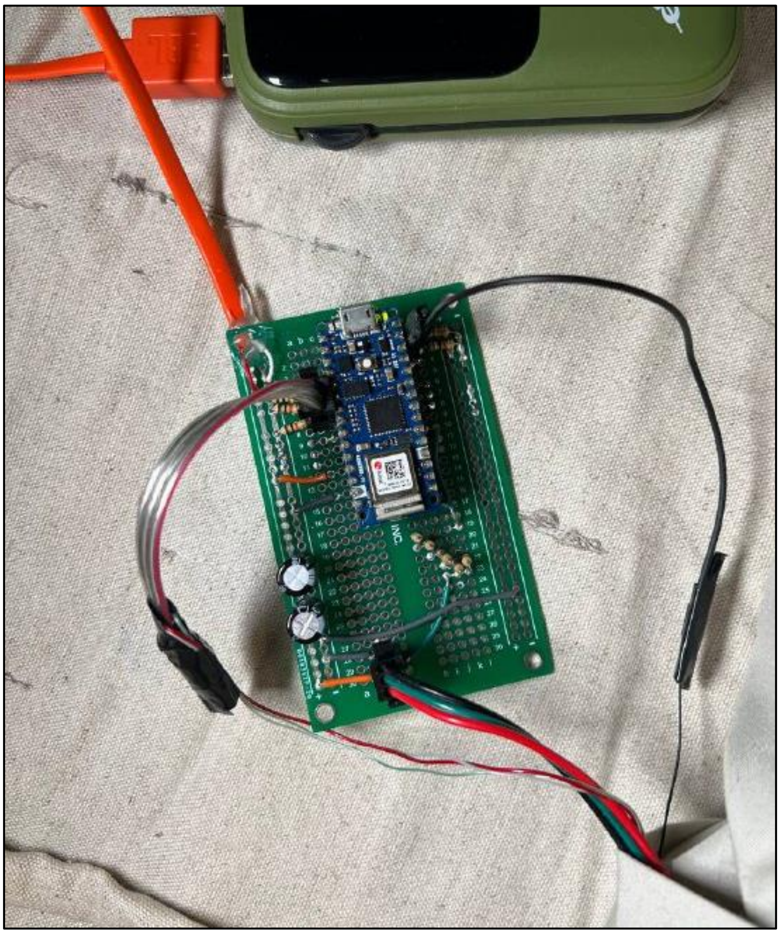

Figure 27. Circuit diagram of the project

Four states were defined in the coding to enable control of the LEDs through the zipper, ensuring interactive user engagement. In designing the illuminated zipper to symbolize three decades from 1990 to 2020 in Canada, I devised a three-step approach to visually represent each period. The first stop on the zipper corresponds to the decade between 1990 and 2000, where LEDs embedded on the provinces will illuminate with a vibrant green color. This color signifies this era, creating a distinct visual marker for the corresponding time frame. Moving along the zipper, the second stop represents the decade between 2000 and 2010, characterized by the glowing LEDs emitting a warm yellow. This transition in LED color indicates the progression in time and marks the subsequent period in Canada wildfire. Finally, the third and last stop on the zipper signifies the decade between 2010 and 2020, with the LEDs illuminating in a striking red color. This final color change serves as a visual representation of the most recent era, completing the chronological through the decades. Additionally, the number of lit LEDs in each province and territory is determined based on the ratio provided in the data collection section and Chart 1.

Figure 28. Canada wildfire vest in three different phases shows three different decades

Lastly, as another functionality of the garment, heating pads were added between the garment's layers, providing warmth to the user, enhancing the experience of temperature increase, and furthering awareness and understanding of the effects of global warming. thesis project A combination of light and heat technologies is integrated to provide a more impactful user experience. This project aims to provide individuals with a wearable prototype to closely experience the disaster of global warming.

The current initial prototype features separate connections for the LED display (representing wildfire data) and heating pads (representing the increase in ground temperature). This decision has been made for several main reasons: Combining LED and heating pad connections into a single data-centric unit not only significantly increased the technical complexity of the project but also because the intensity of the heating pad I used was uncontrollable and could only be turned on and off. On the other hand, the primary focus of the project was on the LED display, which needed to be placed in different locations and display specific data related to forest wildfires at different times. Combining these two functions could potentially cause confusion or disruptions in connections, whereas maintaining separate systems allows for independent control and monitoring of each. However, in future iterations, exploration into more advanced connections and control systems, considering safety measures, can potentially facilitate the integration of both functions.

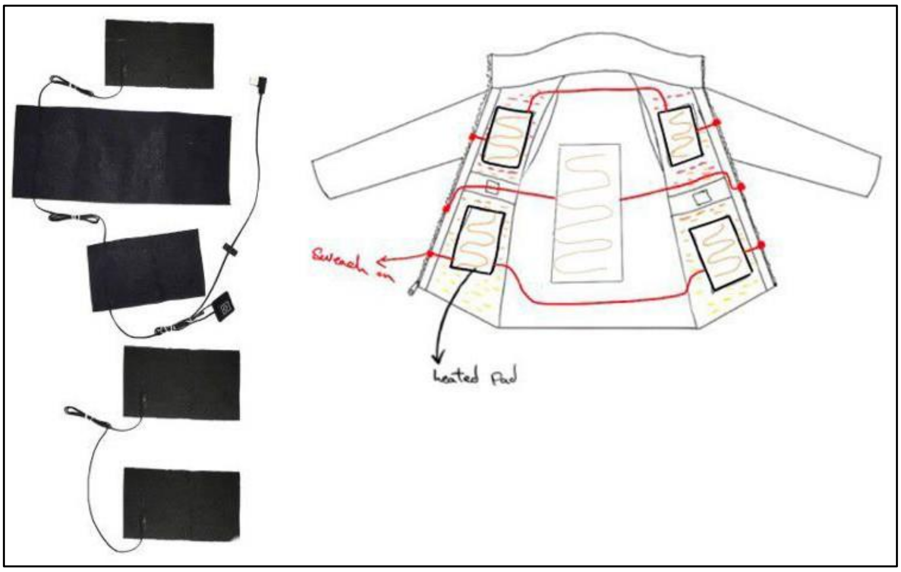

Figure 29. Heating pads were added between the garment's layers

5.3.4 Designing 3D Model for Exhibition

In recent years, especially during the pandemic, several fashion brands have used online and digital platforms to showcase their runway collections; these digital runway shows draw attention from the younger generation and provide new approaches for the future fashion industry. This trend has been further amplified by the increasing popularity of digital fashion shows and the simulation of clothing in a 3D and hyper-realistic manner. However, my aim in using 3D design for my thesis project, facilitated by Marvelous Designer software, was to integrate it into a digital display on screen for my exhibition. This digital show featured my prototype within the context of a burnt forest, symbolizing the devastating effects of global warming. The exhibition underscored the interconnectedness between fashion and its impact on the environment. The co-founder of The Fabricant, Amber Jae Slooten, observed that digital fashion allows people to live their fantasies online and avoid the waste and pollution related to traditional fashion (Fairs, 2020). Waste and pollution in the fashion industry have always been an ongoing issue that requires solutions. This approach to digital fashion could be one of the answers to help reduce waste in the mass production of fast fashion. Moreover, the nature of the digital display is expected to enhance audience engagement and facilitate a better understanding of the project's themes.

The video presentation aimed to contribute to the overarching goal of raising awareness about environmental issues and global warming. I enhanced audience comprehension by not only showcasing the created garment and its wearability but also by displaying a three-dimensional model on the screen to provide a 3D representation. By creating a 3D runway and incorporating elements of forest wildfires, I aimed to enhance the impact of environmental awareness.

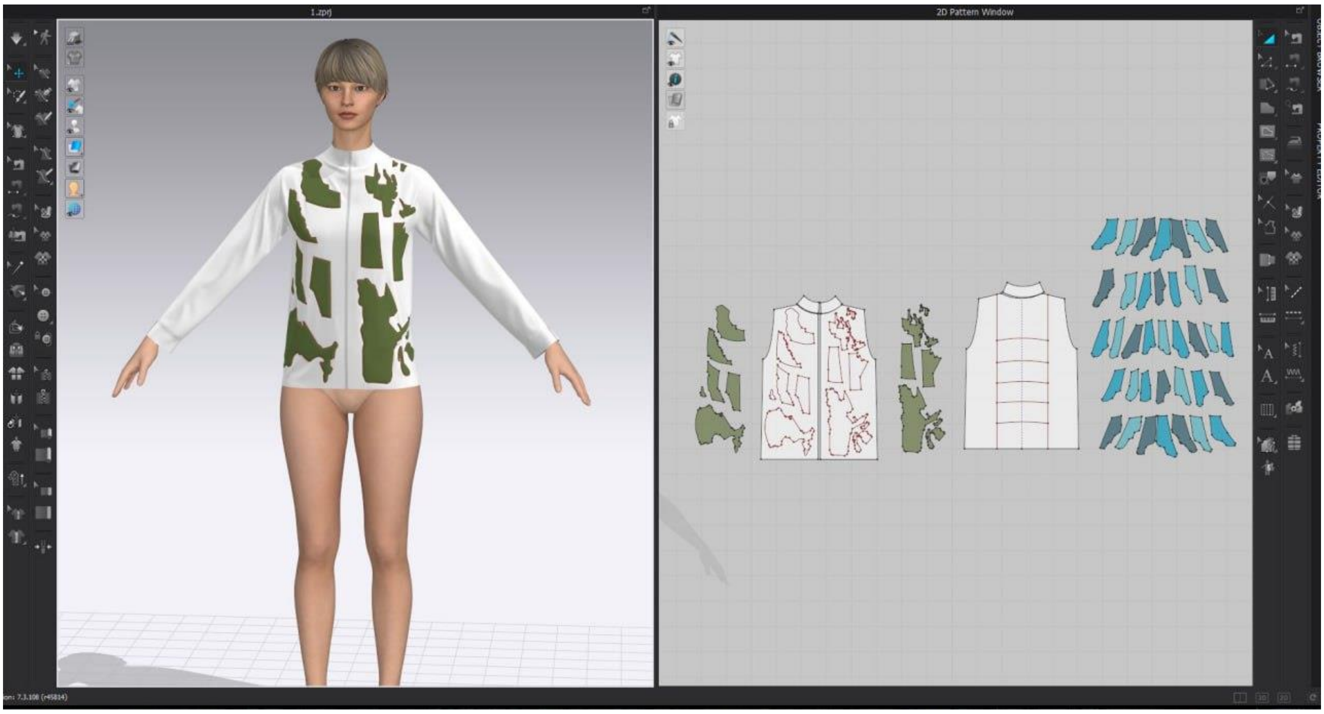

Figure 30. 3D model of the garment in Marvelous Designer software

Figure 31. Final 3D render of garment

5.3.5 Material Choices

To execute this project, special attention was required regarding the use of materials. Throughout the stages from ideation to project execution, the chosen material underwent several considerations and adjustments. Parameters such as wearability, eco-related principles, flexibility, light intensity, power source for illumination, and wiring underneath the clothing were among the issues that posed significant challenges in previous prototypes. In this project, various wearable criteria have been carefully considered to ensure the effectiveness and user acceptance of wearable technology garments (Hartman et al, 2023).

Wearable Criteria	Descriptions
Comfort and Portability	The comfort of the garment is prioritized through considerations such as fabric selection, fit, and weight distribution. Sleeveless design enhances comfort and ease of wearing, while gender-neutral design ensures inclusivity and accessibility for all users. Portability is also emphasized to facilitate easy use.
Aesthetics	Aesthetic considerations play a crucial role in garment design, aligning it with the concept of global warming and enhancing the user experience. The design of the map of Canada on the garment is meticulously crafted to effectively convey environmental awareness messages. By prioritizing aesthetics, the garment transforms from a mere practical tool into an attractive and impactful visual piece of wearable technology.
Functionality	Garment functionality is carefully designed to prioritize key features such as LED activation, color change visualization, data display, interaction, and heating pad activation. Assurance is also sought to ensure that these functions operate correctly and in a timely manner.
Interaction	Interaction design elements, such as zipper design and responsive feedback mechanisms, enhance user interaction with the garment. The zipper control via the cover facilitates user interaction and engagement with wearable technology. This design approach enhances the garment's communication and effectiveness in conveying its message about global warming

Chart 2. Wearable criteria used in “The Canada Wildfire Vest” design

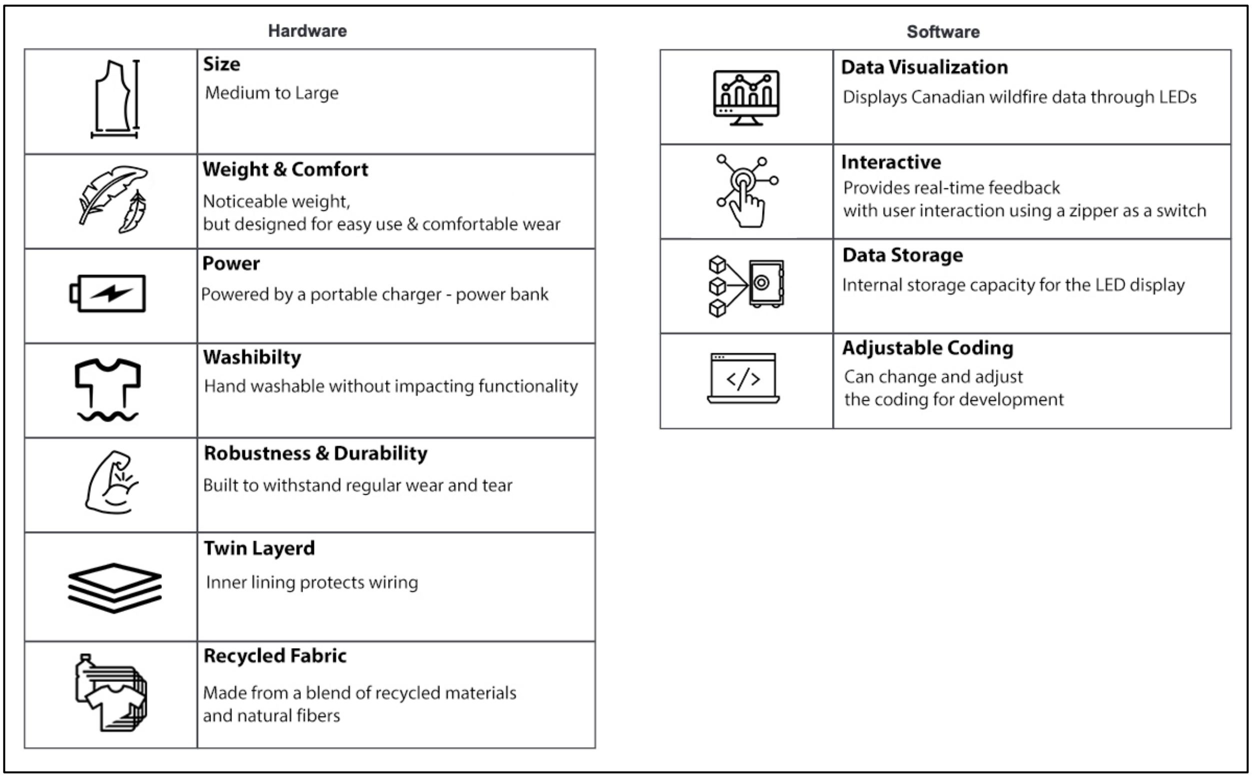

Figure 32. Design criteria used in “The Canada Wildfire Vest” (icons from www.thenounproject.com)

The type of material used in the garment can be divided into several parts. The first part is the base of the garment, which was made of cotton fabric. Integrating cotton lining into cloth design not only enhances comfort and functionality but also aligns with sustainability objectives in the fashion industry. Cotton, as a natural and biodegradable fiber, offers numerous benefits that contribute to environmental preservation. By choosing cotton lining, designers and consumers support the use of renewable resources and reduce reliance on synthetic materials derived from fossil fuels. Cotton's breathability and moisture-wicking properties enhance garment comfort while minimizing the need for chemical treatments, thus reducing environmental impact throughout the textile production process. Cotton lining promotes garment longevity and durability, reducing the frequency of replacements and ultimately decreasing waste generation.

Cotton lining supports sustainable farming practices when sourced from responsibly managed farms. Organic cotton cultivation, for instance, prioritizes soil health and biodiversity while minimizing the use of synthetic pesticides and fertilizers. By selecting garments with cotton lining sourced from sustainable farms, consumers can contribute to the preservation of ecosystems and the well-being of agricultural communities. Overall, the integration of cotton lining into cloth design not only benefits wearer comfort and garment durability but also reflects a commitment to sustainability by promoting the use of renewable resources and supporting environmentally friendly practices throughout the supply chain (Zhang, 2023).

In the front section of the garment, natural leather was used to cut out pieces representing Canadian provinces. The use of natural leather served several purposes. One of them is related to sustainability and can be considered a byproduct of the meat industry, as it is primarily derived from animal hides that would otherwise go to waste. Utilizing these byproducts helps maximize resource efficiency and reduce environmental impact by minimizing waste. The relationship between natural leather and sustainability requires a holistic approach that considers environmental, social, and ethical considerations. Through responsible sourcing, production, and consumption practices, natural leather can be part of a sustainable and ethical fashion and lifestyle ecosystem, offering durable, high-quality products with minimal environmental impact and positive social outcomes (Mahmud, 2017).

Another reason for choosing natural leather relates to technical issues regarding its use as a material in laser cutting. Along this path, we could have also utilized synthetic leather. Natural leather exhibits several properties that make it highly suitable for laser cutting techniques. Firstly, natural leather tends to possess a uniform thickness throughout the material, ensuring consistent cutting results with precise and clean edges. This characteristic is essential for achieving intricate designs and detailed cuts, as variations in thickness or density can compromise the cutting accuracy. The relatively low melting point of leather compared to synthetic materials allows for efficient vaporization by the laser, resulting in smooth edges without excessive charring or melting. This property facilitates the creation of intricate and delicate designs while minimizing damage to the material. The combination of natural leather's properties and the precision of laser cutting techniques offers significant potential for creating high-quality, intricately detailed products with minimal waste and maximum efficiency.

Figure 33. Back and front view of the garment

6. Evaluation and Discussion

The goal of this section is to provide a comprehensive analysis of the design process, the topic of global warming, the user testing, and the evaluation results using predefined criteria. This section's main objective is to review the project topic, the strengths, and limitations of the design, and to identify areas for further awareness and improvement for future work. This section presents the evaluation criteria used for the wearable and its impact on environmental awareness in the user testing process and its results. By experiencing, analyzing, and discussing the results, this section aims to inform future design iterations and highlight the successes and limitations of the design. Through this design process, I can gain a better understanding of how users interact with the wearable and its impact in relation to the main concept of global warming and identify areas that need further attention.

6.1 User Testing Process

The user testing process is an important part of the evaluation process that takes place after the prototype is completed. This process obtains accurate feedback on the comprehensibility, meaningfulness, and effectiveness of the data visualization in the context of global warming and Canadian wildfires. This involved inviting and recruiting participants who include individuals with a medium to high level of technical literacy, as well as artists who have worked in various fields.

To ensure cost-effective user testing, research suggests an "optimal sample size" of around ten participants, though this can be influenced by factors like evaluation methods and desired discovery rate (Hwang & Salvendy, 2010). The user testing method involved participants interacting with the prototype while observations were made to record their reactions, behaviors, and comments. Participants were first asked to interact with the prototype to test its functionality and usability. Participants were encouraged to share their thoughts throughout the process, ask questions, and offer creative ideas and solutions.

After they wore the garment participants were given a survey form to evaluate the project and collect quick feedback from the participants. This survey includes questions about their opinions and concerns about various aspects of global warming, particularly Canadian wildfires, as well as the impact of the wearable on raising awareness of this issue. The testing process, semi-structured interview, and survey were conducted separately and took approximately twenty minutes each. The test was conducted in front of a mirror for better observation and understanding. Participants signed a consent form before the test began, and their anonymity was preserved throughout the data and opinion collection process. All feedback and data collected is presented anonymously. To evaluate the effectiveness and usability of the prototype, ten participants were invited to the user testing session.

6.2 Result and Feedback

This section presents the results obtained from the user testing and the insights gained from the participants about the concept, design, and functionality of the prototype.

The survey results show that the prototype increased participants' awareness of the state of global warming and Canadian wildfires. However, a notable point from this survey is that most of the participants, who all live in Canada, did not feel threatened by Canadian wildfires, but are aware of the changes and increase in wildfires in recent years.

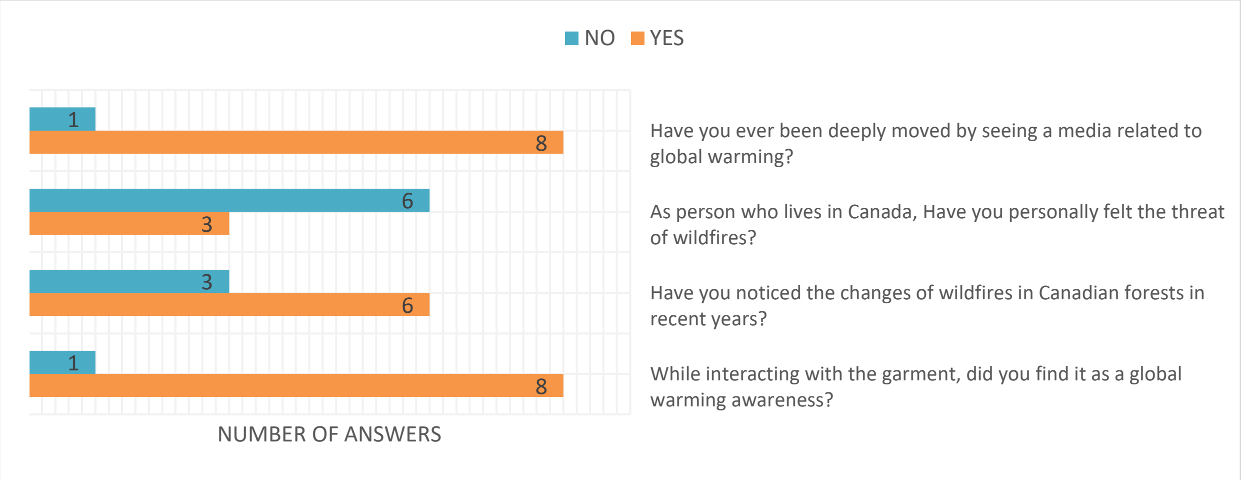

Figure 34. Participant responses to Yes/No questions in the survey

Participants' experiences with “The Canada Wildfire Vest” were for the most part positive, with a high average score. The concept and design received the highest votes in the survey and were evaluated positively. Most participants reported gaining a greater awareness of the current conditions in Canada after the initial experience. In response to the question: "Are you willing to discuss this project and the concept of global warming with your friends?", their answer indicated a positive inclination.

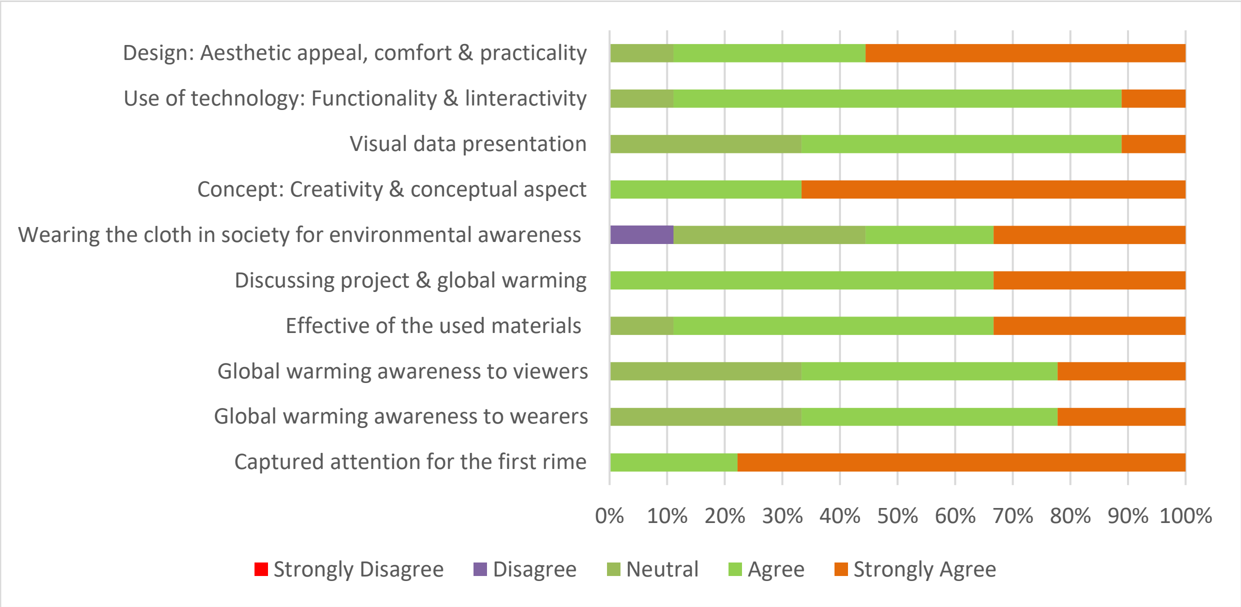

Figure 35. Participant responses to the question

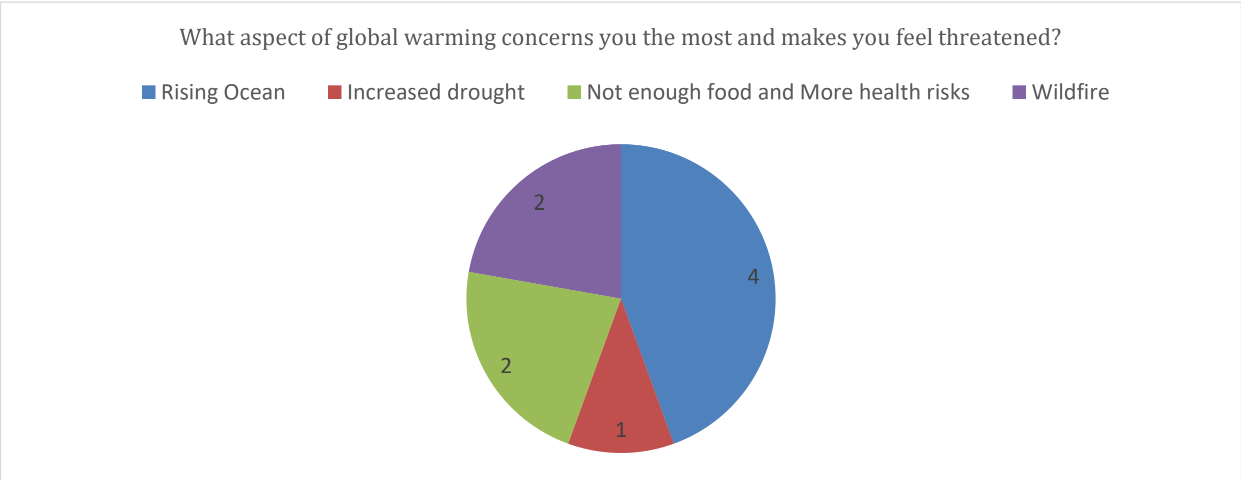

Figure 36. Participant responses to the question: “What aspect of global warming concerns you the most and makes you feel threatened?”

6.3 Findings and Discussion

In addition, the conversations during the user testing process also provided valuable insights into the relationship between the initial design prototype and its future development. Participants generally embraced wearing such garments in public to raise awareness about global warming and had a positive attitude towards its impact. Especially, the use of heating pads to raise the temperature on the garment attracted a lot of attention from participants, leading them to further contemplate the issue of rising global temperatures (Chart 2). The use of zippers and their control and interaction were appreciated by most participants, and one participant pointed out that raising the zipper, which illuminated LEDs in warm colors resembling forest fires on the map of Canada, symbolized feeling guilty and assuming more responsibility for the conditions on Earth. Additionally, suggestions were made regarding adding more features, such as adding the sound of burning wood or controlling the heating pad temperature.

From the participants' perspective, the changes in lighting and the design of the provincial maps were the most visually appealing and suitable parts of the experiment. Furthermore, the design of the back of the garment with recycled fabrics garnered significant attention, and the creative arrangement of denim fabric pieces resembling melting was praised. While the garment was comfortable to wear, criticisms were voiced regarding its weight, suggesting the use of lighter materials in subsequent samples. Overall, this experiment emphasized the importance of hands-on awareness of global warming, information visualization and design, and user performance and satisfaction to create a positive user experience. However, it should be noted that the initial prototype only portrays a small part of the impact of global warming and certainly, a collection of works will have a greater impact. Therefore, it can be envisaged that in the future, alongside different garments with various themes of global warming, it can be more effective in raising awareness.

ID	Responses
1	The warmth of the provinces against my chest mostly
2	I think the LED color and tree iconography suggest wildfire
3	The change in the LED lights when pulling up the zipper along with the warmth that I could feel when I touched the garment.
4	Lights and the water flaps
5	LEDs and colors are a good way to show the severity of global warming and wildfires. Can this be more intuitive so that it is easier to understand that the theme is wildfires? The maps with province initials are helpful!
6	Heating pads worked into the garment and the symbol of the melting of natural ice.
7	The LEDs which showcased the high number of wildfires and the zip which allowed me to move through years
8	The heating pads embedded in the garment almost replicated the rising temperature, as well as changing colours of the LEDs.

Chart 2. Participant responses to the question: "What elements of the garment suggested global warming?"

7. Conclusion

The thesis journey began with a personal challenge: How could a fashion designer address environmental concerns while embracing the power of wearable technology? Recognizing the fashion industry's impact on global warming, I set out to bridge this gap by creating garments that foster environmental awareness. The initial aim focused on designing wearable garments. However, the *Eco-Wearable* research evolved into a more specific objective: developing a garment capable of visualizing climate data. This objective drove the iterative process, which involved continuous refinement of construction methods, environmental data analysis, visualization techniques, and ultimately, the presentation of the results. Throughout each stage, research questions were revisited to ensure the project's value and effectiveness in raising awareness.

This iterative approach led to the creation of "The Canada Wildfire Vest," a testament to the potential of wearable technology in fostering environmental understanding. While the initial scope aimed for a broader exploration of global warming, this focused effort resulted in a powerful tool for communicating the urgency of wildfires in specific regions. 'The Canada Wildfire Vest" may not offer a one-size-fits-all solution to climate change, but it serves as a spark of awareness. It demonstrates how wearable technology, designed with sustainability in mind, can empower individuals to engage with environmental issues and inspire positive change.

The project can be expanded to incorporate data on other environmental challenges, creating a collection that addresses diverse issues across the globe. The project currently uses temperature sensory and visual representations to translate data. Future iterations could explore other sensory experiences, like auditory or texture, to create a more immersive data connection. Additionally, future iterations can explore real-time data integration for a more dynamic user experience. While the current prototype prioritizes recycled materials, further research into bio-textiles and other eco-friendly materials could significantly reduce the environmental footprint. Investigating energy harvesting techniques to power the wearable features, such as developing a solar electric system for wearable technology, could minimize reliance on external batteries and enhance sustainability efforts.

This collection can be displayed in exhibitions related to climate change and wearable technologies or sustainable fashion shows. Such venues provide an opportunity to showcase the project to a wider audience and create awareness on a larger scale. In the future, this collection can be exhibited in exhibitions related to climate change or wearable and sustainable technologies, to create an opportunity to show this project to the audience and create awareness in a wider way.

7.1 Reflections

7.1.1 Reflections on Methodology

This project embraced the Research through Design (RtD) methodology, a powerful approach that utilizes design practice to gain deeper insights into complex issues (Zimmerman & Forlizzi, 2014). RtD proved to be an ideal fit, allowing me to explore the potential of wearable technology in raising awareness about environmental issues. The core of RtD lies in the creation of experimental solutions, in this case, "The Canada Wildfire Vest" prototype.

This tangible prototype served as a proof of concept, integrating wearable technology, light displays, and a heating pad to visually represent global warming and wildfire risk in Canada. The wearable display not only showcased temperature fluctuations over time but also physically simulated them through heating, creating a powerful multi-sensory experience for users and observers. This approach reinforced the value of integrating both design and research throughout the project.

The design process itself presented valuable learning opportunities. As Stappers & Giaccardi (2017) suggest, design necessitates confronting various challenges –conflicting knowledge, bridging the gap between theory and technology, and reconciling dreams with reality. The act of designing itself can be a catalyst for knowledge generation, prompting us to question assumptions and identify underlying values. Data collection and analysis played a crucial role in informing the design. By focusing on historical temperature data and wildfire occurrences in Canada, the research aimed to establish a link between rising temperatures and increased wildfire frequency and intensity. This analysis involved processing data from various sources, including graphs, Excel files, and GIS software.

Finally, data visualization played a vital role in transforming raw data into impactful representations that could effectively communicate research findings. By employing data graphs and tables, the project aimed to create visually intuitive displays of wildfire trends over time and across Canadian provinces. Overall, the RtD methodology proved to be an effective framework for this project. The iterative process, the creation of a tangible prototype, and the integration of design and research activities all contributed to a deeper understanding of the chosen topic and a powerful communication tool in the form of "The Canada Wildfire Vest."

7.1.2 Reflections on Exhibition

The exhibition provided an opportunity to showcase completed works to a wider audience, resulting in insightful feedback and engaging conversations. One key aspect of the final exhibition installation was the projection of a video onto a screen depicting 3D garment designs in a forest wildfire scenario in the foreground and melting ice in the background, capturing visitors' attention, and drawing them closer to the project's theme.

Figure 37. Front and behind view of “The wildfire Vest” 3D model presented on screen in the exhibition.

Overall, the installation included the following components:

- Display of wearable garments on mannequins, with additional panels showcasing the design details on the back of the garments.
- Posters illustrating the stages of construction, design, and data collection.
- Video presentation on a screen.

Figure 38. A picture of the exhibition

Figure 39. A picture of the exhibition

The most intriguing aspect of the exhibition was the project's ability to explain its concepts to visitors with no prior knowledge. After familiarizing themselves with the project's concept, some visitors continued discussions on the impact of fast fashion on global warming, while others raised topics such as wildfires or other factors contributing to global warming in their own countries. These discussions led to visitors expressing interest in trying on the garments to not only interact with the zipper but also to feel the warmth of the garment on their bodies. “The Canadian Wildfire Vest” was successful as a display and equally as a performance, where visitors could don the wearable, see themselves in a mirror and experience embodied data.

The feedback received was positive, with many visitors eager to zip up the garment themselves to witness its effect. Hence it melded informational biosensing together with affect, prompting an emotional and response to wearing wildfire data. Subsequent discussions often delved into specific provinces or regions, with visitors sharing personal anecdotes or experiences related to wildfires. A visitor highlighted the natural occurrence of some wildfires in the cycle of nature but expressed concern over their current uncontrollable increase. They inquired whether there was data distinguishing between naturally occurring wildfires and crisis-induced ones, prompting a realization that such categorization was absent in the data collection process, which mainly focused on the number of wildfires, or the hectares burned. One of the most common questions asked was which provinces were most affected by wildfires. Most participants grasped the underlying message of the project and immediately engaged in critical thinking about their role and responsibility in addressing global warming. I can confidently say that one of the main goals of this project was to initiate discussions about the crises resulting from global warming and to encourage individuals to be curious, informed, and aware of past and potential future events.

7.2 Challenges & Limitations

As the research progressed, it became clear that a single project, within the defined scope, could not capture the entirety of the crises related to global warming. Examining data from every location over time and visualizing its impact in a truly impactful way requires a much broader investigation that cannot be contained in one project. However, by focusing on a specific location and aspect, Canada Wildfire, this project was able to contribute to a deeper understanding of this facet of global warming.

Data collection presented its own set of challenges. The lack of available temperature data for Nunavut required the exclusion of this territory from the circuit, and no LEDs were lit there. This therefore highlights the unique environmental challenges of Nunavut, such as melting polar ice, the multifaceted nature of global warming, and the need for diverse research perspectives moving forward. Another limitation pertained to the environmental impact of the wearable technology itself. While prioritizing recycled materials and minimal energy consumption were key design principles, the use of electronic components necessitates further exploration of eco-friendly alternatives. This thesis research serves as a reminder that even environmentally conscious endeavors require continuous efforts towards sustainability.

Beyond the data and materials, the prototype itself had its limitations. Ideally, the heating pad and LEDs could be integrated for a more seamless user experience. Additionally, while the use of recycled denim for the backside of garment was a sustainable choice, it contributed to the significant weight. Future iterations could explore lightweight recycled materials and lighter power banks for energy supply. These challenges present valuable opportunities for future development, which will be sure to receive greater attention in future work. "The Canada Wildfire Vest" may not offer a solution to global warming, but it stands as a testament to the potential of wearable technology to inspire positive change towards visibility and awareness of environmental threats.

7.3 Future Work

This project inspired me, as someone who has always been concerned about the environment, to act by exploring the potential of wearable technology to raise awareness about the multifaceted challenges of global warming. “The Canada Wildfire Vest” served as a motivating start that led me to the idea of a larger project: designing a collection with the aim of environmental awareness. Moving forward, this project envisions a broader scope and will transform into a collection titled "Earth Crisis."

“Earth Crisis” is a collection of wearable garments, each designed to highlight an aspect of global warming in a specific location. Future iterations can depict other aspects of global warming's impact. For example, my home country of Iran is facing droughts, and other regions and potential challenges include rising coastal flood threats in countries across Europe, food insecurity and increased health risks due to rising temperatures in southern Africa. By creating a collection that spans the globe, “Earth Crisis” will weave a powerful narrative about the interconnectedness of environmental issues. Each wearable piece can serve as a conversation starter and prompt viewers to consider the diverse impacts of global warming on different regions and ecosystems. Furthermore, the “Earth Crisis” collection can be designed digitally. Instead of producing physical garments for each iteration, the project can pivot to a digital platform. This would allow for broader accessibility and significantly reduce the environmental footprint. 3D modeling and augmented reality experiences can create immersive presentations of each garment and the environmental issues it represents. This thesis was the beginning of a journey to promote greater environmental awareness through wearable technology. The “Earth Crisis” collection will serve as a vision for the future, and it is hoped that it can have a positive impact on the visibility of climate crises and draw greater attention to this critical issue.

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Appendices

Appendix A: Poster

Appendix B: Consent Form

Consent Form

Date: February 2024
Project Title: Eco-Wearables: Merging Art and Technology for Environment Crisis Awareness

Principal Investigator: Maryam Dehghani
dehghanimaryam@ocadu.ca Faculty of Arts and Science
OCAD University

Faculty Supervisor
Dr. Sara Diamond
Faculty of Arts and Science
OCAD University
sdiamond@ocadu.ca

OVERVIEW & PURPOSE

You are invited to participate in a research study about wearable technology and environmental crisis awareness. I will explore the ways that global warming data can be translated into visual and physical feedback on the garment, creating a connection between the wearer and the Earth by simulating the effects of climate change. I aim to develop wearable technology that enhances environmental awareness, with a specific focus on Canadian wildfires. As a participant you will have the opportunity to participate in prototyping activities to evaluate my research. The purpose of participation in this experiment is to collect feedback through a questionnaire about the experience of using this wearable technology to better understand climate change.

WHAT'S INVOLVED

As a participant, you'll be requested to don a garment and observe yourself in a mirror while interacting with the garment.

You will be requested to share your experience after wearing the garment by filling out an anonymous questionnaire that takes approximately 15 minutes to complete. This questionnaire includes both text-based and multiple-choice questions. Additionally, I will make some sketches or notes from the reactions of participants while wearing the clothing that do not reveal their identity.

POTENTIAL BENEFITS

The aim of this study is to raise awareness about the detrimental effects of climate change, exemplified by wildfires. The potential benefits for society lie in fostering a greater understanding of environmental issues, encouraging more individuals to become environmental advocates, and ultimately contributing to positive changes in behavior towards environmental conservation.

While this survey is designed to gather feedback from participants after wearing the garment, both positive and negative responses can propel me toward improving my project. Utilizing this feedback aligns with my objective of fostering an understanding of an environmental challenge and raising awareness among individuals.

POTENTIAL RISKS

During your participation there is a very low risk that the thermal elements used in the clothing will become excessively warm. You will be able to remove the garment. A series of pre-test assessments will be conducted to minimize any potential risks during the experimentation process.

Please contact the lead researcher if you have questions and do not participate if you have concerns related to the heating pads. You can discontinue participation at anytime should the garment become uncomfortable. You may also stop participation at any time for any other reason. There is no expected cost to you associated with ending your participation.

CONFIDENTIALITY

Data collection will occur through a questionnaire. You will not be asked to identify yourself on the questionnaire. I will immediately separate your questionnaire from your email address. Your name will not be included in any other way associated in data collected in my research. The Thesis will be stored in the library of OCAD and the anonymized research data including questionnaire responses, such sketches, and notes will be stored in OneDrive for two years. Access to this data will be restricted to the researcher and supervisors only.

INCENTIVES FOR PARTICIPATION

An incentive is not offered for participating in this research experiment and the participant will not be paid to participate in this study.

VOLUNTARY PARTICIPATION

Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study.

Further, you may decide to withdraw from this study at any time during the experience. Questionnaire responses will be immediately separated from email addresses hence withdrawal of participation will not be possible after your participation in the experiment.

Your choice of whether or not to participate will not influence your future relations with OCAD University or the investigators involved in the research.

To withdraw from this study, you may contact Dr. Sara Diamond by email: sdiamond@ocadu.ca

PUBLICATION OF RESULTS

Results of this study may be published in scholarly journals, students' theses, and/or presentations to conferences and colloquia. In any publication, data will be presented in aggregate forms. Quotations from interviews or surveys will not be attributed to you without your permission. Results of this study will be published in Maryam Dehghani's Thesis in May 2024. Personal information will not be attributed to any participants in this study.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please contact the principal investigator Maryam Dehghani at dehghanimaryam@ocadu.ca. If you have questions later about the research, you may contact the Faculty Supervisor Dr. Sara Diamond sdiamond@ocadu.ca

This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University [insert REB approval #].

If you have questions regarding your rights as a participant in this study please contact:
Research Ethics Board c/o Office of the Vice President, Research and Innovation
OCAD University
100 McCaul Street
Toronto, M5T1W1
416 977 6000 x4368
research@ocadu.ca

AGREEMENT

I agree to participate in this study described above. I have made this decision based on the information I have read in the Information-Consent Letter. I have had the opportunity to receive any additional details I wanted about the study and understand that I may ask questions in the future. I understand that I may withdraw this consent at any time.

Name: ______________________________

Signature: ______________________________ Date: ______________________________

Thank you for your assistance in this project. Please keep a copy of this form for your records.

Appendix C: Survey and Questionaries

Link: **https://shorturl.at/kDGK6**

Appendix D: Invitation

Invitation

Date: **February**

Dear Participant,

You are invited to participate in a research study about wearable technology and environmental crisis awareness. I will explore the ways that global warming data can be translated into visual and physical feedback on the garment, creating a connection between the wearer and the Earth by simulating the effects of climate change. I aim to develop wearable technology that enhances environmental awareness, with a specific focus on Canadian wildfires. As a participant you will have the opportunity to participate in prototyping activities to evaluate my research. The purpose of participation in this experiment is to collect feedback through a questionnaire about the experience of using this wearable technology to better understand climate change.

Participation will take approximately Less than 30 minutes of your time.

Possible benefits of participation include gaining insight into climate change and a sense of social responsibility for sustainable practices. Questionnaire participation empowers individuals to be part of broader efforts to develop strategies to mitigate and adapt to climate change impacts.

There is very low risk known with participation in this study. Specific sections of the garment incorporate heat pads to convey a sense of temperature rise to the participants. These heating pads are the only parts that may have potential minor risks.

If you have any questions about this study or require further information, please contact the Principal Investigator Maryam Dehghani or the Faculty Supervisor Dr. Sara Diamond using the contact information provided below. This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University [insert approval #]. If you have any comments or concerns, please contact the Research Ethics Office through research@ocadu.ca.

Principal Investigator: Maryam Dehghani
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Faculty Supervisor:
Dr. Sara Diamond
Faculty of Faculty of Arts and Sciences
OCAD University
sdiamond@ocadu.ca

Appendix E: Arduino Source Code

```
/*
Project Name: Eco-Wearables: Canada Wildfire Vest
By: Maryam Dehghani
*/

#include <Adafruit_NeoPixel.h>
// The digital pin used to control the pixel strip
int ledpinNumber = 3;
// The number of pixels in the strip
int numberOfPixels = 118;
int brightnessval=50;
  Adafruit_NeoPixel strip = Adafruit_NeoPixel(numberOfPixels, ledpinNumber, NEO_GRB + NEO_KHZ800);

void setup() {
 pinMode(5,INPUT);

  // initialize pixel strip
  strip.begin();
  // set pixels to off to begin
  strip.show();
  strip.setBrightness(brightnessval);

 for (int i=0; i<119; i++)
  {
  strip.setPixelColor(i, 0, 0, 0);
  strip.show();
  }
}
void loop() {

if(digitalRead(11)==HIGH) zone0();
if(digitalRead(15)==HIGH) zone1990();
 if(digitalRead(16)==HIGH) zone2000();
 if(digitalRead(17)==HIGH) zone2010();
 if(digitalRead(10)==HIGH) zone2020();
}
void zone0()
{
  for (int i=0; i<119; i++)
  strip.setPixelColor(i, 0, 0, 0);
  strip.show();
  delay(500);
}
void zone1990()
{
for (int i=0; i<119; i++)
 strip.setPixelColor(i, 0, 0, 0);
  strip.show();
  delay(500);
```

```
//qc
  strip.setPixelColor(0, 255, 255, 0);
  strip.setPixelColor(27, 255, 0, 255);
  strip.setPixelColor(12, 255, 255, 0);
  strip.setPixelColor(20, 255, 255, 0);
  strip.setPixelColor(10, 255, 255, 0);
  strip.setPixelColor(15, 255, 255, 0);
  strip.setPixelColor(6, 255, 255, 0);
  strip.setPixelColor(30, 255, 0, 255);
  strip.setPixelColor(16, 255, 255, 0);
  strip.setPixelColor(9, 255, 255, 0);

//nl
strip.setPixelColor(25, 255, 0, 255);
strip.setPixelColor(24, 255, 0, 255);

//nb-ns
strip.setPixelColor(23, 255, 0, 255);
strip.setPixelColor(22, 255, 0, 255);

//mb
strip.setPixelColor(36, 255, 0, 255);
strip.setPixelColor(34, 255, 0, 255);
strip.setPixelColor(38, 255, 0, 255);
strip.setPixelColor(32, 255, 0, 255);
strip.setPixelColor(39, 255, 0, 255);
strip.setPixelColor(31, 255, 0, 255);
strip.setPixelColor(35, 255, 0, 255);

//sk
strip.setPixelColor(40, 255, 0, 255);
strip.setPixelColor(41, 255, 0, 255);
strip.setPixelColor(42, 255, 0, 255);
strip.setPixelColor(43, 255, 0, 255);
strip.setPixelColor(44, 255, 0, 255);

//nt
strip.setPixelColor(59, 255, 0, 255);
strip.setPixelColor(60, 255, 0, 255);
strip.setPixelColor(61, 255, 0, 255);
strip.setPixelColor(62, 255, 0, 255);
strip.setPixelColor(63, 255, 0, 255);
strip.setPixelColor(64, 255, 0, 255);
strip.setPixelColor(65, 255, 0, 255);
strip.setPixelColor(66, 255, 0, 255);
strip.setPixelColor(68, 255, 0, 255);
strip.setPixelColor(69, 255, 0, 255);


//yt
strip.setPixelColor(73, 255, 0, 255);
strip.setPixelColor(71, 255, 0, 255);
```

```
strip.setPixelColor(77, 255, 0, 255);
strip.setPixelColor(79, 255, 0, 255);

//ab
strip.setPixelColor(81, 255, 0, 255);
strip.setPixelColor(85, 255, 0, 255);
strip.setPixelColor(85, 255, 0, 255);
strip.setPixelColor(88, 255, 0, 255);
strip.setPixelColor(90, 255, 0, 255);

//bc
strip.setPixelColor(98, 255, 0, 255);
strip.setPixelColor(100, 255, 0, 255);

//on
strip.setPixelColor(106, 255, 0, 255);
strip.setPixelColor(103, 255, 0, 255);
strip.setPixelColor(113, 255, 0, 255);
strip.setPixelColor(116, 255, 0, 255);
strip.setPixelColor(110, 255, 0, 255);

  strip.show();
  delay(500);

}
void zone2000()
{
  for (int i=0; i<119; i++)
  strip.setPixelColor(i, 0, 0, 0);
  strip.show();
  delay(500);
for (int i=0; i<119; i++)

//qc
  strip.setPixelColor(0, 210, 105, 20);
  strip.setPixelColor(28, 105, 20, 210);
  strip.setPixelColor(11, 210, 105, 20);
  strip.setPixelColor(30, 105, 20, 210);
  strip.setPixelColor(14, 210, 105, 20);
  strip.setPixelColor(21, 105, 20, 210);
  strip.setPixelColor(26, 105, 20, 210);

  //mb
  strip.setPixelColor(31, 105, 20, 210);
  strip.setPixelColor(39, 105, 20, 210);
  strip.setPixelColor(33, 105, 20, 210);
  strip.setPixelColor(37, 105, 20, 210);
  strip.setPixelColor(36, 105, 20, 210);
  strip.setPixelColor(34, 105, 20, 210);

  //sk
  strip.setPixelColor(43, 105, 20, 210);
```

```
  strip.setPixelColor(40, 105, 20, 210);
  strip.setPixelColor(42, 105, 20, 210);
  strip.setPixelColor(44, 105, 20, 210);

  //nl-nb-ns
strip.setPixelColor(22, 105, 20, 210);
strip.setPixelColor(23, 105, 20, 210);
strip.setPixelColor(24, 105, 20, 210);

//nt
strip.setPixelColor(59, 105, 20, 210);
strip.setPixelColor(61, 105, 20, 210);
strip.setPixelColor(63, 105, 20, 210);
strip.setPixelColor(69, 105, 20, 210);
strip.setPixelColor(64, 105, 20, 210);
strip.setPixelColor(66, 105, 20, 210);

//yt
strip.setPixelColor(72, 105, 20, 210);
strip.setPixelColor(74, 105, 20, 210);
strip.setPixelColor(75, 105, 20, 210);
strip.setPixelColor(77, 105, 20, 210);
strip.setPixelColor(79, 105, 20, 210);
strip.setPixelColor(78, 105, 20, 210);

//ab
strip.setPixelColor(80, 105, 20, 210);
strip.setPixelColor(82, 105, 20, 210);
strip.setPixelColor(85, 105, 20, 210);
strip.setPixelColor(87, 105, 20, 210);
strip.setPixelColor(91, 105, 20, 210);
strip.setPixelColor(90, 105, 20, 210);

//bc
strip.setPixelColor(97, 105, 20, 210);
strip.setPixelColor(94, 105, 20, 210);
strip.setPixelColor(99, 105, 20, 210);
strip.setPixelColor(92, 105, 20, 210);
strip.setPixelColor(102, 105, 20, 210);

//on
strip.setPixelColor(106, 105, 20, 210);
strip.setPixelColor(103, 105, 20, 210);
strip.setPixelColor(110, 105, 20, 210);
strip.setPixelColor(113, 105, 20, 210);
strip.setPixelColor(116, 105, 20, 210);

  strip.show();
  delay(500);
}
void zone2010()
{
```

```
  for (int i=0; i<119; i++)
  strip.setPixelColor(i, 0, 0, 0);
  strip.show();
  delay(500);
for (int i=0; i<119; i++)

//qc
  strip.setPixelColor(1, 255, 0, 0);
  strip.setPixelColor(9, 255, 0, 0);
  strip.setPixelColor(30, 0, 0, 255);
  strip.setPixelColor(28, 0, 0, 255);
  strip.setPixelColor(20, 0, 0, 255);
  strip.setPixelColor(15, 0, 0, 255);
  strip.setPixelColor(10, 0, 0, 255);
  strip.setPixelColor(26, 0, 0, 255);
  strip.setPixelColor(21, 0, 0, 255);
  strip.setPixelColor(15, 255, 0, 0);

  //nl-nb-ns
  strip.setPixelColor(22, 0, 0, 255);
  strip.setPixelColor(23, 0, 0, 255);
  strip.setPixelColor(25, 0, 0, 255);

  //mb
  strip.setPixelColor(39, 0, 0, 255);
  strip.setPixelColor(34, 0, 0, 255);
  strip.setPixelColor(31, 0, 0, 255);
  strip.setPixelColor(37, 0, 0, 255);
  strip.setPixelColor(33, 0, 0, 255);
  strip.setPixelColor(36, 0, 0, 255);

//sk
  strip.setPixelColor(40, 0, 0, 255);
  strip.setPixelColor(41, 0, 0, 255);
  strip.setPixelColor(42, 0, 0, 255);
  strip.setPixelColor(44, 0, 0, 255);
  strip.setPixelColor(43, 0, 0, 255);

//nt
  strip.setPixelColor(61, 0, 0, 255);
  strip.setPixelColor(68, 0, 0, 255);
  strip.setPixelColor(70, 0, 0, 255);
  strip.setPixelColor(64, 0, 0, 255);
  strip.setPixelColor(65, 0, 0, 255);
  strip.setPixelColor(62, 0, 0, 255);
  strip.setPixelColor(60, 0, 0, 255);
  strip.setPixelColor(69, 0, 0, 255);


//yt
strip.setPixelColor(73, 0, 0, 255);
strip.setPixelColor(72, 0, 0, 255);
```

```
strip.setPixelColor(71, 0, 0, 255);
strip.setPixelColor(79, 0, 0, 255);
strip.setPixelColor(76, 0, 0, 255);
strip.setPixelColor(77, 0, 0, 255);

//ab
strip.setPixelColor(80, 0, 0, 255);
strip.setPixelColor(82, 0, 0, 255);
strip.setPixelColor(86, 0, 0, 255);
strip.setPixelColor(88, 0, 0, 255);
strip.setPixelColor(91, 0, 0, 255);
strip.setPixelColor(83, 0, 0, 255);
strip.setPixelColor(85, 0, 0, 255);
strip.setPixelColor(90, 0, 0, 255);
strip.setPixelColor(87, 0, 0, 255);
strip.setPixelColor(89, 0, 0, 255);

//bc
strip.setPixelColor(96, 0, 0, 255);
strip.setPixelColor(94, 0, 0, 255);
strip.setPixelColor(98, 0, 0, 255);
strip.setPixelColor(95, 0, 0, 255);
strip.setPixelColor(97, 0, 0, 255);
strip.setPixelColor(93, 0, 0, 255);
strip.setPixelColor(100, 0, 0, 255);
strip.setPixelColor(101, 0, 0, 255);

//on
strip.setPixelColor(104, 0, 0, 255);
strip.setPixelColor(112, 0, 0, 255);
strip.setPixelColor(109, 0, 0, 255);
strip.setPixelColor(108, 0, 0, 255);
strip.setPixelColor(106, 0, 0, 255);
strip.setPixelColor(110, 0, 0, 255);
strip.setPixelColor(111, 0, 0, 255);
strip.setPixelColor(114, 0, 0, 255);


  strip.show();
  delay(500);
}
void zone2020()
{
  for (int i=0; i<119; i++)
  strip.setPixelColor(i, 0, 0, 0);
  strip.show();
  delay(500);
for (int i=60; i<80; i++)
  strip.setPixelColor(i, 0, 0, 255);
  strip.show();
  delay(500);
}
```