Electronic Shelf Label

Environmental Impact on Increasing Sustainability in the Retail Sector

Prepared by: Sidharth Kwatra,
UBC Sustainability Scholar, 2023

Prepared for:
Daoping Bao,
Vice Chairman of International EPaper Association
CEO & President of Smart Label Solutions Inc.

Kenny Zhang,
Senior Advisor of E-Tag Technology Corp.

August 2023

CANADA

iEPA International E-Paper Association

SLS Smart Label Solutions Inc.

etag

Disclaimer

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organizations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of Smart Label Solution Inc. staff on behalf of the International EPaper Association (IEPA) and E-Tag Technology Corp. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of the International EPaper Association, Smart Label Solutions, E-Tag Technology Corp. or the University of British Columbia.

Acknowledgements

The author acknowledges that the work for this project took place on the unceded ancestral lands of the nsyilxcən (Syilix Okanagan), xwməθkwəyə̓ m (Musqueam), Skwxwú7mesh (Squamish), Stó:lō and Səlílw̓ ətaʔ/Selilwitulh (Tsleil- Waututh) Nations.

The author would like to thank the UBC Sustainability Scholars Program International EPaper Association and Smart Label Solutions for providing me with a wonderful opportunity to participate in this program. Moreover, the author would like to thank all those who helped for their contribution, feedback, and support throughout this project, including Daoping Bao (Vice Chairman of the International EPaper Association and CEO & President at Smart Label Solutions Inc.), Kenny Zhang (Advisor at Smart Label Solutions Inc.), Linda Peng (Director of Marketing and Sales at Smart Label Solutions Inc.), Karen Taylor, and UBC Library staff.

Table of Contents

1. EXECUTIVE SUMMARY ---------- 5

2. INTRODUCTION ---------- 6

2.1. Paper Shelf Label ---------- 7
2.1.1. Why are they important? ---------- 7
2.1.2. Challenges with Paper shelf Label ---------- 9
2.2. What is an Electronic Shelf Label? ---------- 9

3. GOAL AND SCOPE DEFINITION ---------- 11

3.1. Scope ---------- 11

4. METHODOLOGY ---------- 15

4.1. Functional Unit ---------- 15
4.2. System Boundaries ---------- 15
4.2.1. Paper shelf label ---------- 15
4.2.2. Electronic Shelf Label ---------- 17
4.2.3. Retail stores ---------- 17
4.3. Impact Category ---------- 17
4.4. Life Cycle Inventory Analysis ---------- 17
4.4.1. GHG emissions from Paper ---------- 17
4.4.2. GHG emissions from Electronic Label Solutions ---------- 20
4.4.3. Number of Retail Stores in Canada ---------- 20
4.4.4. Paper waste produced by the Retail stores. ---------- 21
4.5. Life Cycle Analysis Assumptions and Calculations ---------- 21

5. CALCULATIONS ---------- 22

6. RESULTS ---------- 24

6.1. Contribution towards Canadian Emissions ---------- 24
6.2. Sensitivity analysis ---------- 25
6.3. Case Study: SaaS solution by Pricer for Magros ---------- 25
(SaaS and the High Quality of the Solution Made Migros Choose Pricer, 2022) ---------- 25
6.3.1. Overview ---------- 25
6.3.2. Description ---------- 26
6.3.3. Calculations ---------- 26

7. LIMITATIONS ---------- 27

7.2. Recommendations for Further Research ---------- 28

8. CHALLENGES WITH ELECTRONIC LABELS AND RECOMMENDATIONS ---------- 29

8.1. Recommendations ---------- 29

9. CONCLUSION ---------- 31

REFERENCES ---------- 32

List of Figures

Figure 1: Photo of a paper shelf label used in Retail Shops (Image Source: Altexsoft, n.d.) __________________ 7
Figure 2: How electronic labels are used and what sizes are they available. Both images are from SLS. ________ 8
Figure 3: SLS workstation at RCC Store Trade Show____ 8
Figure 4: Picture of Electronic Shelf Label and how they are used in retail shops ________________________ 10
Figure 5:System boundary to produce paper ____ 16
Figure 6: Sources of the Data for Research Paper 1____ 19
Figure 7: Comparison of CO2eq saved for Canada when all Paper Labels are replaced by E-Labels with Total emissions produced in Canada from all sources ____ 24
Figure 8: Sensitivity Analysis for CO2 eq saved when Paper Labels are replaced by 1 E-Label _______________ 25
Figure 9: Potential CO2 emissions that will be saved by Migros Etrembières after 8 years of installing E-Label 26

List of Tables

Table 1:GHG emissions from the production of Paper as per different research papers ___________________ 20
Table 2: Property of the E-Label____ 20
Table 3: Number of Convenience Storesthe in the UK and Canada ____________________________________ 20
Table 4: CO2 emissions saved by 1 E-Label ____ 23

1. Executive Summary

The retail industry faces significant environmental challenges due to the excessive use of paper labels. Paper waste accounts for more than 1/3 of all waste in Canada, with only 25% of paper and paperboard recycled (Bale Force Recycling Equipment, 2021). Additionally, changing paper labels is time-consuming and can result in significant losses due to errors. Moreover, paper production contributes significantly to carbon emissions (Bale Force Recycling Equipment, 2021).

To address these challenges, this report evaluates the potential benefits of replacing paper shelf labels with electronic shelf labels (ESLs) in the Canadian retail sector with respect to GHG emissions. ESLs eliminate paper consumption and waste while enabling dynamic pricing and efficient label management. They have been successfully implemented in many regions, including North America, Europe, Asia, and Australia.

The research assesses the impact of adopting ESL in retail stores across Canada. Data collected from research estimate the total paper consumption within the industry. Available data shows that the market potential for ESLs in North America is valued at $126 billion, while the actual market size stands at $2.2 billion (Electronic Shelf Labels Market Revenue Trends and Growth Drivers, n.d..). The ESL market is projected to reach $4 billion within the next five years (Electronic Shelf Labels Market Revenue Trends and Growth Drivers, n.d.).

Nevertheless, the integration of ESLs introduces a new environmental challenge associated with battery waste, necessitating immediate attention from policymakers, industry standardization efforts, and the exploration of sustainable battery alternatives.

The adoption of ESL introduces an environmental concern: the disposal of used batteries. Approximately 2 million used batteries will be generated as waste in 2023, taking over 100 years to decompose in landfills. Immediate attention from policymakers is necessary to address this issue, along with industry standardization efforts and research into battery alternatives.

In conclusion, adopting ESLs presents a compelling opportunity to address the challenges associated with paper labels in the Canadian retail sector. ESLs offer potential benefits for retailers and customers by reducing paper waste and enabling dynamic pricing. However, addressing the environmental impact of battery waste must be a priority through government policy-making and industry standardization efforts. The market potential and successful implementation of ESLs further support their adoption in the retail industry.

2. Introduction

The importance of environmental sustainability is growing for both consumers and businesses worldwide. Consumers now consider a company's environmental impact when making purchasing decisions. As a result, many businesses are actively innovating and transforming their operations to reduce pollution levels and lower their carbon footprint. This trend is evident across various industries and sectors.

Excessive paper use and waste pose significant environmental challenges. Global paper consumption has surged by 400% in the past 40 years, with a substantial portion of harvested trees utilized for paper manufacturing (The Paper Consumption Problem: Statistics on the Paper Use, n.d.). This trend contributes to deforestation and resource depletion.

The paper industry ranks as the third-largest emitter of industrial air, water, and land pollutants in Canada. In 2015, it released approximately 174,000 tonnes of emissions (majorly from manufacturing), accounting for 5.3% of total emissions from all industries in the country. A majority of this waste (96%) was released into the air, exacerbating air pollution and its detrimental effects on ecosystems and human health (Environmental Effects of Paper, 2021).

Canada aims for net-zero greenhouse gas emissions by 2050. Reducing paper waste and carbon footprint are critical aspects of this commitment, aligning with broader social and economic concerns for a sustainable future (Government of Canada, 2020).

The retail industry is one of the sources of paper waste in Canada due to paper price label waste and associated carbon emissions. The report looks at potential reductions in carbon emissions when paper labels are replaced by electronic labels.

2.1. Paper Shelf Label

Shelf labels (also known as shelf tags) are product labels affixed to the edge of shelves in a physical store. They may be made of paper, metal, or plastic and can be attached to a shelf using screws or magnets. Other shelf labels may come in the form of replaceable inserts for permanent label holders.

Shelf tags have been a huge part of the retail industry for a long time, eventually evolving into different forms ranging from paper, metal, and plastic to e-paper screen displays. (Europe, n.d.)

Figure 1: Photo of paper shelf labels used in retail stores (Image Source: Altexsoft, n.d.)

2.1.1. Why are they important?

Shelf tags serve two primary purposes in the retail sector:

a. Customer Convenience:

Shelf tags act as place markers to facilitate customers in locating specific products while shopping. Similar to house numbers for residences, customers can rely on shelf tags to find the desired products within the store. This feature remains consistent unless the store undergoes rearrangement or remodelling.

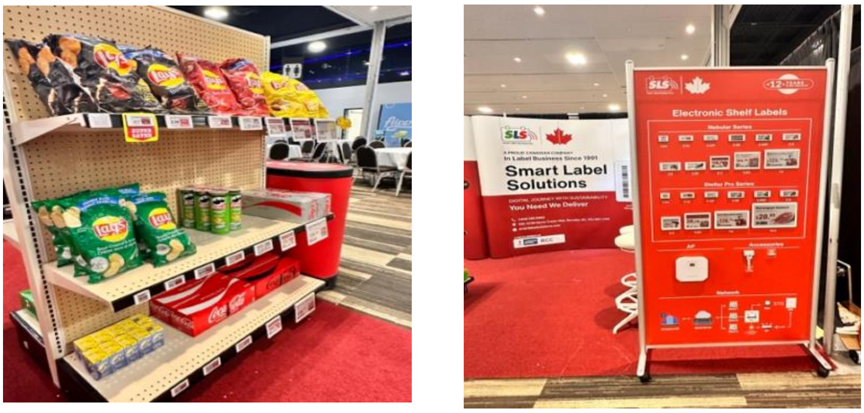

Figure 2: Example of placement, size and use of electronic labels. Photos courtesy of International EPaper Association and Smart Label Solutions Inc.

b. Operational Efficiency:

Shelf tags also play a vital role in simplifying tasks for staff members, particularly in terms of product reordering and restocking. In addition to displaying the product name and price, shelf tags may include a barcode or reorder number. This information serves as a quick reference for employees when scheduling new deliveries and managing low stock levels.

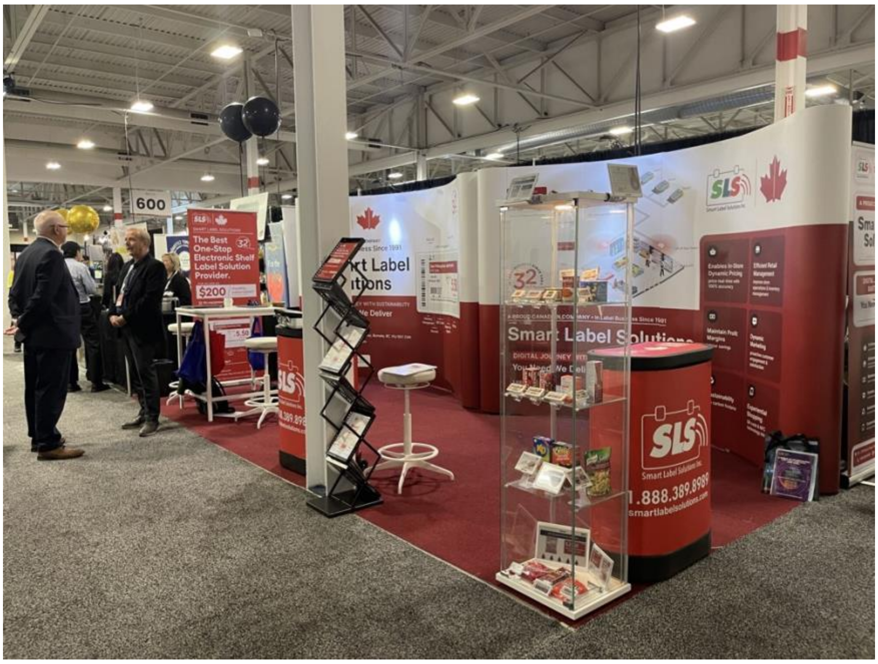

Figure 3: International EPaper Association and Smart Label Solutions Inc. booth at Retail Council of Canada (RCC) store trade show

2.1.2. Challenges with Paper shelf Label

Outlined below are critical points that underscore the challenges associated with current paper-based shelf labels:

a. High Potential for Waste: With most Canadian shelf labels made from paper, there is a high potential for waste. In the UK, an estimated 120,000 tonnes of label waste is generated annually (Benobon, 2021). Extrapolating this data to Canada, which has around 15% of the stores compared to the UK, it is estimated that Canada has the potential to produce approximately 18,000 tonnes of paper-label waste yearly.

b. Carbon Emissions and Environmental Concerns: Paper production contributes to carbon emissions, exacerbating environmental issues and climate change. The carbon footprint associated with paper production and disposal is a significant concern (Bale Force Recycling Equipment, 2021).

c. Time-Consuming Process: Changing paper labels is a time-consuming task, leading to productivity losses and potential errors. Minor error percentages can result in significant financial losses (Bale Force Recycling Equipment, 2021).

2.2. What is an Electronic Shelf Label?

Electronic shelf labels (ESLs) are digital wireless display systems in retail stores to show product prices. They are typically attached to the front edge of store shelving. ESLs connect directly to the store’s Enterprise Resource Planning and Point of Sale system systems, providing benefits such as reduced labour costs, improved pricing accuracy, and the ability to implement dynamic pricing.

Features of electronic shelf labels

a. **Reduced Waste and Carbon Footprint**

One ESL can replace thousands of paper shelf labels that can help reduce carbon footprint, which helps implement effective carbon management strategies to reduce environmental impact (As Global Heat Continues, Electronic Shelf Labels Help Reduce the Planet’s Carbon Footprint - BOWTZ International, n.d.)

b. **Efficient Price Management**

ESLs streamline price management by eliminating the need for manual updates. With a few clicks from a remote server, ESLs can automatically update prices on thousands of displays across multiple channels. This eliminates the need to reprint and replace paper labels and the time-consuming task of replacing price tags manually.

c. **Enhanced Pricing Accuracy**

By directly connecting to the store's ERP and POS systems, ESLs ensure pricing accuracy. They eliminate errors that can occur with manual price updates and provide real-time information to customers. This leads to a more seamless shopping experience and reduces potential pricing discrepancies.

d. **Dynamic Pricing Capabilities**

ESLs enable dynamic pricing, allowing stores to adjust prices in real time based on market demand. This flexibility maximizes profitability by capitalizing on pricing opportunities. Retailers can increase prices during high-demand periods and lower prices to stimulate sales, ultimately improving customer satisfaction and loyalty.

e. **Automated Price Updates**

With ESL, retailers can update prices across multiple displays simultaneously with just a few clicks from a remote server. This automation saves time and resources, as there is no longer a need to manually replace paper labels or deploy store staff to update price tags individually.

Figure 4: Picture of an electronic shelf label and a picture of an electronic shelf label applied in in retail shops

The ESL market is rapidly expanding, projected to grow to USD 4831.28 million by 2030 from USD 1395.18 million in 2022, at a CAGR of 23.0% (Global Electronic Shelf Label (ESL) Market Share 2030 Projection, n.d.). Leading industry players, like Hanshow, Pricer AB, Altierre Corporation, SES Imagotag, DisplayData Ltd., and Solum Co. Ltd., are driving this surge. Amidst this growth, the sustainability potential of e-labels takes center stage, notably in their ability to reduce emissions and cut paper waste in retail. This report will explore the emission savings achievable through the shift from paper to electronic shelf labels.

3. Goal and Scope Definition

The objective of this report is to evaluate the potential for reducing waste and greenhouse gas (GHG) emissions by replacing traditional paper shelf labels with electronic shelf labels (ESLs) in the retail sector. The findings from this research will assist Canadian retailers in identifying and substantiating the advantages associated with transitioning to ESLs.

The intended audience for this report is retailers, consumers, sustainability managers at companies, ESLs manufacturers, LCA practitioners, and other stakeholders interested in the environmental performance of paper shelf labels.

3.1. Scope

The scope of the study was a cradle-to-grave LCA for the uncoated paper used for the production of paper shelf labels. The values of the carbon emissions are the average values taken from the 3 different research papers given below:

1. Paper 1: Printing & Writing Papers Life-Cycle Assessment Summary Report
2. Paper 2: Life Cycle Impact Assessment Methodology for Environmental Paper Network
3. Paper 3: Uncovering energy use, carbon emissions and environmental burdens of pulp and paper industry: A systematic review and meta-analysis

Data collection basis and assumptions of the paper used in the study:

Research Paper 1: Printing & Writing Papers Life-Cycle Assessment Summary Report (Team, 2012)

Almost all office paper assessed in this study is produced by U.S. mills using a variety of pulp sources. About 4 percent of the fibre needed to produce office paper comes from recovered fibre, primarily market-deinked pulp (MDIP), with the balance being supplied by bleached kraft pulp. Most of the bleached kraft pulp used in uncoated freesheet is produced on-site, although bleached kraft market pulp (produced primarily in Canada and the U.S.) is also used.

Uncoated freesheet is paper free of mechanical wood pulp or paper made from pulps having a high freeness (the rate at which water drains from a stock suspension through a wire mesh screen or a perforated plate) (Uncoated Freesheet – Horizon Paper, US Paper Mill Representative, US Paper Broker, US Paper Merchant, US Paper Distributor, n.d.)

Assumptions made:

a. Operations required to convert paper rolls to finished products (i.e., cutting and packaging) typically take place at the paper mill. Further trimming to size takes place in discrete operations, and data for this is not readily available. As such, the analysis does not consider subsequent conversions throughout the office paper system.

b. Based on data from the U.S. Environmental Protection Agency (EPA) for "office-type papers," it has been assumed that, after use, 71.8 percent of used office paper is recovered for recycling, 5.2 percent is burned for energy, and 23.0 percent is sent to landfills.

c. System boundaries are set according to a cradle-to-grave approach (from raw material extraction to final disposal of paper products). Transport is also included. The data are from 2006 to 2007 or a date as close as possible to those years.

d. In this study, the inventory results document that 62 percent (mass basis) of the total life-cycle resource requirements (excluding water) for a ream of office paper is renewable (i.e., wood fibre).

Research Paper 2: Life Cycle Impact Assessment Methodology for Environmental Paper Network (Schultz & Suresh, 2018)

The geographical scope includes the production of 14 different paper grades in North America (USA and Canada). The life cycle impacts of 14 paper grades are assessed from the extraction and processing of all raw materials through the disposal of paper (end-of-life).

The pulp and paper mills included for each paper grade were identified based on data from Resource Information System, Inc. (RISI). These mills were selected based on location, capacity and grade of paper products produced, and factoring in the representativeness of the mills to present North American average results for all indicators in the Paper Calculator. The temporal scope includes the production of paper in 2016. The carbon emission value of the uncoated fresh sheet was considered for this study the paper.

Assumptions

a. The recycled content approach (also known as the 100-0 cut-off approach) is used to model impacts for recycled papers, whereby the impacts from the prior and subsequent life cycles are not included (see Section 3.3.2 for more detail).

Research Paper 3: Uncovering energy use, carbon emissions and environmental burdens of pulp and paper industry: A systematic review and meta-analysis (Sun et al., 2018)

The environmental impacts of pulp and paper making at the enterprise scale are typically quantified through an internationally standardized LCA method. Here, we reviewed LCA studies concerning pulp and paper based on a comprehensive search of the literature published in English.

Two rounds of review have been used to select the targeted studies based on the following principles. In the first step, only studies that quantified pulp and paper making in physical units for environmental impact categories and excluded those with non-physical functional units in the USA and Brazil.

Second, we only included studies that provide specific figures for environmental impacts and excluded those that provide only relative contributions between different processes.

A total of 45 cases of paper-making and 18 cases of pulp-making under different scenarios were screened and included in the review. Cases from the USA and Canada were combined into the North American group (NA). To ensure comparability between the cases, the system boundary of all case studies was set to the "cradle to gate" approach.

Assumptions made:

a. In the GHG emissions calculation in pulp and paper making, there is a key assumption of carbon neutrality inherent in the assumption that the wood comes from sustainably managed forest without land change in harvest as well as the assumption that carbon emissions in the papermaking, use, and disposal phases are neutralized by carbon sequestration in the biomass growth phase.
   However, not all wood is from sustainably managed forests, which means that far greater quantities of carbon emissions caused by land use change are neglected.

b. Furthermore, not all carbon sequestrated in wood would be emitted as CO2, such as in methane emissions from wastewater treatment and from landfills when paper ends its life as a landfill rather than incineration.

c. Because of the much stronger GWP of methane than CO_2, GHG emissions are largely underestimated. In order to show a clear picture of the carbon balance in the life cycle of pulp and paper, we recommend the reporting of fossil-fuel-related GHG emissions and biogenic GHG emissions separately, as is shown in some literature.

d. To find out the CO_2 emissions from the e-label, a Global report released by the E Ink has been used (E Ink. We Make Surfaces Smart and Green, n.d.)

4. Methodology

4.1. Functional Unit

The functional unit is the quantitative reference point of an LCA, which serves the purpose of providing a common basis for calculating all the environmental impacts (Schultz & Suresh, 2018)

This study requires that a functional unit be selected to provide equivalency between the paper shelf label and electronic shelf label for direct comparison. For paper shelf labels, the CO2 equivalent emissions generated by the number of paper labels in a retail store that can be replaced by 1 electronic label was calculated and compared with the GHG emissions produced by the electronic label.

Here, the diagonal length of the paper label and the electronic label was assumed to be 2.9 inches diagonally (Kozlowski, 2022). Also, it was assumed that an electronic label could last for 8 years. The difference between the emissions was later extrapolated to find the emissions that can be saved if electronic labels replace paper shelf labels.

4.2. System Boundaries

A system boundary identifies the life cycle stages, processes and flows considered in the LCA (Schultz & Suresh, 2018)

4.2.1. Paper shelf label

For this study, the average value of the Carbon emissions was considered from the 3 different papers. Each of them had a slight variation in the system boundary. The system boundary was set from the cradle to the grave (from raw material extraction to the final disposal of paper products). Transport is also included. In general, in all 3 papers, the system boundary has been separated into five life-cycle stages(Team, 2012):

a. Fibre procurement: includes forest operations, off-site chip production, off-site recovery and processing of recycled fibre and transport of all fibre (wood, market pulp and recycled fibre) to pulp and paper mills.

b. Pulp and paper production includes on-site production of chips, production of market pulps and on-site produced pulp, papermaking operations, converting of paper in rolls and reams, packaging and supporting activities (on-site steam and power production, on-site chemical production, effluent treatment, on-site waste management, etc.)

c. Production of the final product includes the activities involved in converting the paper into the specified paper product, such as printing, binding, etc. In the case of office paper, it is assumed that the ream produced at the pulp and paper mill is the final product (i.e., no "production of the final product" life cycle stage is included).

d. Use: includes transportation to the use phase.

e. End-of-life (EoL): includes EoL management of the paper product (landfilling, burning and energy recovery). Material that is recovered for recycling is assumed to leave the system boundaries.

A general description of the boundary is as follows:

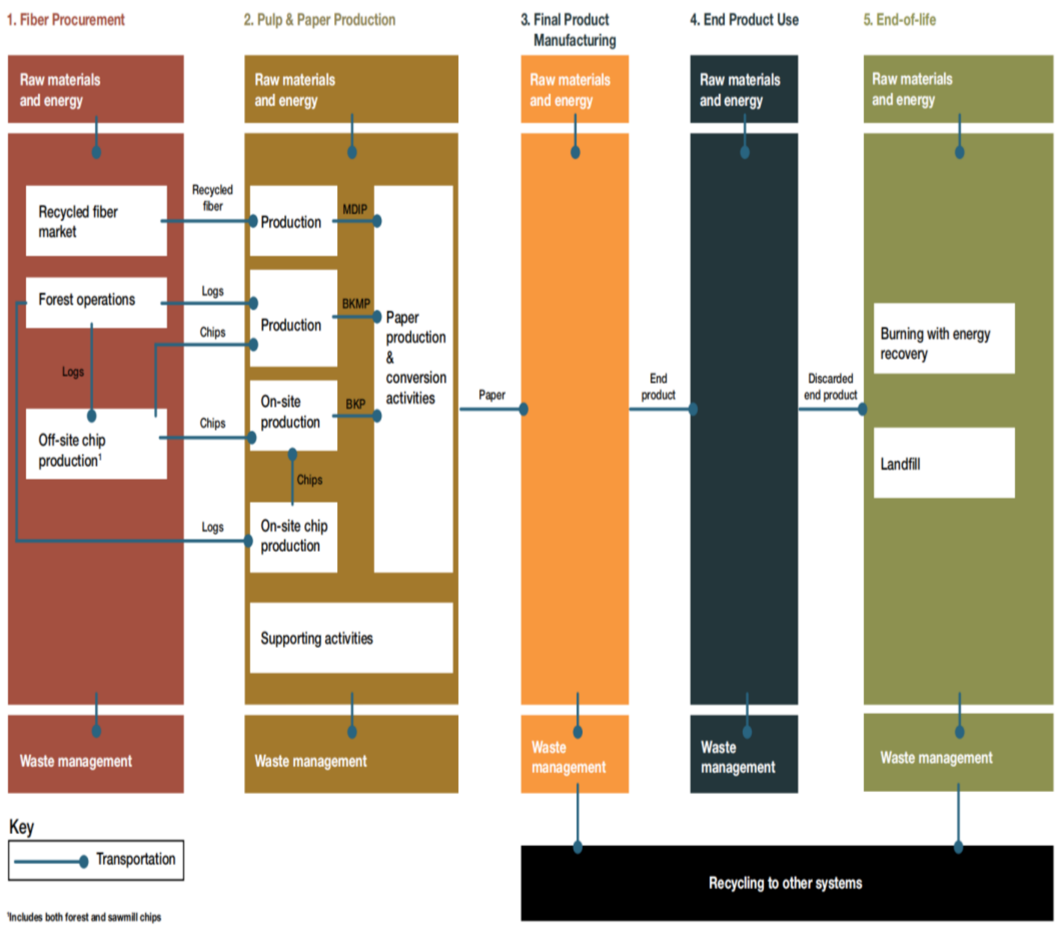

Figure 5: System boundary to produce paper

4.2.2. Electronic Shelf Label

For electronic shelf labels, the data is taken from the research conducted by the E Ink. (Kozlowski, 2022) The system boundary they have considered includes the raw material production, materials transportation and product manufacturing of the e-paper module assembly based on the functions of each site within the Company, including the Massachusetts site in North America and Hsinchu, Linkou and Yangzhou sites in Asia. (Kozlowski, 2022).

4.2.3. Retail stores

The scope of the study included the retail stores in Canada. The consumption of the paper was taken from the UK data (Benobon, 2021) and extrapolated for Canada based on the number of retail stores.

4.3. Impact Category

In this study, the impact of replacing the paper shelf labels with electronic shelf labels was analyzed for the following parameters:

Global warming (GW) Potential: Potential change in the earth's climate caused by the buildup of greenhouse gases (GHGs) in the upper atmosphere that traps heat from the reflected sunlight that would have otherwise passed out of the earth's atmosphere.

4.4. Life Cycle inventory analysis

4.4.1. GHG emissions from Paper

Data for each paper was collected from different sources. A brief overview of the data sources is as follows:

Paper 1: Life Cycle Impact Assessment Methodology for Environmental Paper Network (Schultz & Suresh, 2018)

Data points and sources are depicted in the figure below:

Parameters/ Flows	Data Points Collected	Data Source Used For the Assessed Paper Grades	
		100% Virgin Papers	100% Recycled Papers
General Information			
Paper mills in North America	• Number of pulp and paper mills, by grade in North America • Types of paper grade produced, by mill in North America	RISI database	
Production Outputs	• Annual production of all pulp and paper grades, by mill in North America	RISI database	
1. Wood Inputs Specific to the Pulp and Paper Mills			
(A) Wood Inputs	• Pulpwood harvest locations for pulp/paper mills	To calculate national average results for all paper grades, it is assumed that pulpwood is sourced from within 150 miles[19] of the location of pulp/paper mill	Not Applicable
	• Terrestrial ecosystem impacts and forest carbon storage loss, based on location of roundwood harvest	-US Forest Service[20] and Canadian National Forest Inventory[21] -IUCN Red List database[22] for assessing species impacted by wood harvest	Not Applicable
	• Amount of wood input consumed per metric ton paper	RISI database for all paper grades	Not Applicable
2. Waste Paper Input			
(B) Recovered fiber input (The user will enter a value from 0-100 to represent the desired recycled content)	• Amount of recovered fiber input consumed per metric ton paper	Not Applicable	RISI database
3. Energy Inputs			
(C) Energy Inputs	• Amount of fuel consumed, by type per metric ton paper	RISI database	
	• Amount of electricity consumed per metric ton paper	RISI database	
	• Amount of steam purchased per metric ton paper	RISI database	
	• Black liquor generated and consumed	RISI database	Not Applicable

Parameters/ Flows	Data Points Collected	Data Source Used For the Assessed Paper Grades	
		100% Virgin Papers	100% Recycled Papers
4. Chemical Inputs			
(D) Chemical Inputs	• Amount of chemical inputs by type per metric ton paper	-USLCI data is used for the following paper grades: coated freesheet, uncoated freesheet, coated groundwood, uncoated groundwood -Ecoinvent v3.3 is used for the remaining paper grades	Not applicable
5. Other Inputs			
(E) Other Inputs	• Amount of other material inputs by type per metric ton paper	-RISI database for coatings, fillers and starch for all paper grades	
	• Water consumption per metric ton paper	Ecoinvent v3.3 data used for all paper grades	
6. Waste Outputs			
(F) Waste Products	• Air emissions, by substance per metric ton paper	-US EPA Toxic Release Inventory (TRI) database for all paper grades -Canada's National Pollutant Release Inventory (NPRI) for all paper grades	
	• Amount of BOD, COD and TSS emissions per metric ton paper	-USLCI data was used for the following paper grades: coated freesheet, uncoated freesheet, coated groundwood, uncoated groundwood, corrugating medium and linerboard -Ecoinvent v3.3 was used for the remaining paper grades	Not applicable
	• Amount of hazardous waste per metric ton paper	-US EPA Toxic Release Inventory (TRI) database for all paper grades -Canada's National Pollutant Release Inventory (NPRI) for all paper grades	
	• Amount of solid waste per metric ton paper	-USLCI data was used for the following paper grades: coated freesheet, uncoated freesheet, coated groundwood, uncoated groundwood, corrugating medium and linerboard. -Ecoinvent v3.3 was used for the remaining paper grades	Ecoinvent v3.3
7. End-of-Life			
(G.a) Recycling	• Amount of paper recycled per metric ton paper	For the end-of-life phase, recycling rates are assumed based on the 2014 US EPA Municipal Solid Waste (MSW) reports[25]. Based on information from the MSW reports, 80% of the materials not recycled are assumed to go to a municipal landfill and the remaining 20% are assumed to be incinerated. The following recycling rates were used for different paper grades: Coated freesheet, Uncoated freesheet, Coated groundwood, Supercalendered=44.4% Uncoated Groundwood= 68.2% All paperboards, linerboard and corrugating medium= 89%	
(G.b) Landfilling	• Amount of paper landfilled per metric ton paper		
(G.c) Incineration	• Amount of paper incinerated per metric ton paper		

Figure 6: Sources of the Data for Research Paper 1

Paper 2: Printing & Writing Papers Life-Cycle Assessment Summary Report (Team, 2012)
The data was collected from 72 mills in the U.S. and Canada, which produced 22.4 million short tonnes of printing and writing papers in 2006-07. This represents approximately 77 percent of all North American production within that period.

The LCA was conducted by the National Council for Air and Stream Improvement, Inc. (NCASI) — an independent, non-profit research institute recognized as a leading resource of environmental topics of interest to the forest products industry.

Paper 3: Uncovering energy use, carbon emissions and environmental burdens of pulp and paper industry: A systematic review and meta-analysis
During the Life Cycle Inventory Analysis for the LCA report, a thorough review was conducted of various studies related to paper and pulp manufacturing. A total of 45 cases focusing

on paper manufacturing and 18 cases focusing on pulp manufacturing were carefully screened and included in the review. These cases were chosen from different scenarios to ensure a comprehensive analysis of the environmental impacts associated with the entire life cycle of these products.

GHG emissions values are as follows:

Research Paper	GHG emissions, kg of CO2 equiv.
Paper 1	1977
Paper 2	5216
Paper 3	1650
Average GHG kg of CO2 equiv.	2948

Table 1: GHG emissions kg of CO2 equiv. Per tonne of paper waste from the production of Paper as per different research papers

4.4.2. GHG emissions from Electronic Label Solutions

The GHG values were taken from the report published by the E Ink LCA report. The LCA report published by them was in accordance with ISO 14067:2018 standard. (Kozlowski, 2022)

E-Label Dimension and company	GHG emissions, kg of CO2 equiv. per module
2.9 inch e-paper module produced by E Ink	0.59

Table 2: Property of the E-Label

4.4.3. Number of Retail Stores in Canada

The source for a number of retail stores in the UK was taken from the website Statista (Retail Trade Enterprises in the UK 2008-2017, n.d.)

The number of retail stores in Canada was found in a report published by Statista (Retail Trade Establishments by Region Canada 2021, n.d.)

Place	Number of Retail stores
United Kingdom	214659
Canada	143000
Ratio of stores in Canada to UK	0.67

Table 3: Number of Retail Stores in the UK and Canada

4.4.4. Paper waste produced by the Retail stores.

The data for the waste produced from paper shelf labels are taken from the study published by the environmental firm Prismm Environmental for the UK in 2016 (Sanderson, 2017). This data was then extrapolated as per the number of stores in Canada to find the label waste.

4.5. Life Cycle Analysis Assumptions and Calculations

Assumptions:

a. The GHG from the three research paper were averaged to get one value. All three papers had separate assumptions, as mentioned in section 2.1.

b. It assumed that the electronic shelf label used in retail shops in Canada has a size of 2.9 inches (diagonally) everywhere.

c. It is assumed that the 1 electronic label can last for 8 years, and the price on that label gets changed 2 times a day. This assumption, as per the ESG report published by E Ink (E Ink. We Make Surfaces Smart and Green, n.d.)

d. It is assumed that the paper label size is 2.9 inches. (75 gsm) and the weight of that label is assumed to be 0.53 g, which is 1/4th the weight of the paper sheet (Team, 2012)

e. It is assumed that a number of retail stores in Canada are consuming the same amount of paper labels each year.

f. The size of the stores in the UK and Canada are the same.

g. It is assumed that all the waste in the UK is produced by the retail store type.

h. Electricity supplied to electronic labels is assumed to be supplied from 100% renewable sources.

5. Calculations

a. Paper consumption per year by retail stores in Canada

Amount of paper waste produced by the retail stores in the UK. = 120000 tonnes/year

The ratio of the stores in convenience retail in Canada to the UK = 0.67

Amount of waste paper label waste generated in Canada = Raito*Waste in the UK

= 80000 tonnes/year

b. GHG emissions produced by Paper shelf label

The average value of the GHG emissions produced by the paper as taken from section 4.4.1 = 2948 Kg of CO2eq

GHG emissions from the total paper-label waste produced in Canada. =

$$\left(80000\ \frac{tonnes\ of\ paper}{year}\right) * \left(2948\,\frac{Kg\ of\ CO2}{tonne\ of\ paper}\right)$$

= 235840000 Kg of CO2 / year

= 0.235 Mt CO2 eq/year

Weight of 1 paper label in tonnes = 0.53*10^-6 tonnes

GHG emissions from 1 paper-label = 0.53*10^-6 tones*2948 Kg of CO2 eq/tonne

= 0.00156 Kg of CO2eq / paper label

c. GHG Saved by replacing paper shelf labels with electronic labels

Number of times the price of the product is changed in 1 day. = 2 times

Number of times the price of the product is changed in 1 year = 365*2 times

= 730 times

Number of years an e-label can last = 8 years

Therefore, a number of paper labels an e-label can replace. = 8*730 paper labels

= 5840 paper labels

Amount of CO2 eq emitted by 5840 paper labels = 5840*0.00156

= 9.11 Kg of CO2eq

Amount of CO2 eq produced by 1 electronic label (Kozlowski, 2022) = 0.59 kg CO2e

Therefore amount of CO2 emissions saved = 9.11 - 0.59

= 8.52 Kg of CO2eq per e-label

d. Sensitivity Analysis by changing the value of CO_2 emissions from lowest to highest CO_2 emission per tonne as different papers.

Research Paper Source	Kg of CO_2 eq emitted from 5840 Paper labels	Kg of CO_2 eq saved from replacing Paper Labels by 1 E-Label
Paper 2	16.14	15.55
Paper 3	5.10	4.52

Table 4: CO_2 emissions saved by 1 E-Label

.

6. Results

In a retail store in Canada, it was found that 1 electronic label can replace around 5840 paper labels over a time period of 8 years. The carbon emissions saved by 1 electronic label is 8.52 kg of CO_2 eq.

Paper waste saved if paper shelf labels are replaced by electronic labels in Canada is 8000 tonnes/year.

6.1. Contribution towards Canadian emissions

Total Emissions from Paper Labels: The total amount of emissions generated by paper labels is approximately 0.03% (0.235 Mt CO_2 eq/year) of Canada's total greenhouse gas (GHG) emissions. The total amount of GHG emissions produced each year is taken from the 2020 report by Environment and Climate Change Canada.

Total Emissions from Waste and Other Industries: As per the same report, the waste and other industries contribute 51 Mt CO_2e of emissions annually, accounting for 7% of Canada's total emissions.

Potential Emission Reduction by Adopting E-labels: By adopting e-labels, waste and other industries could reduce their emissions by 0.46%.

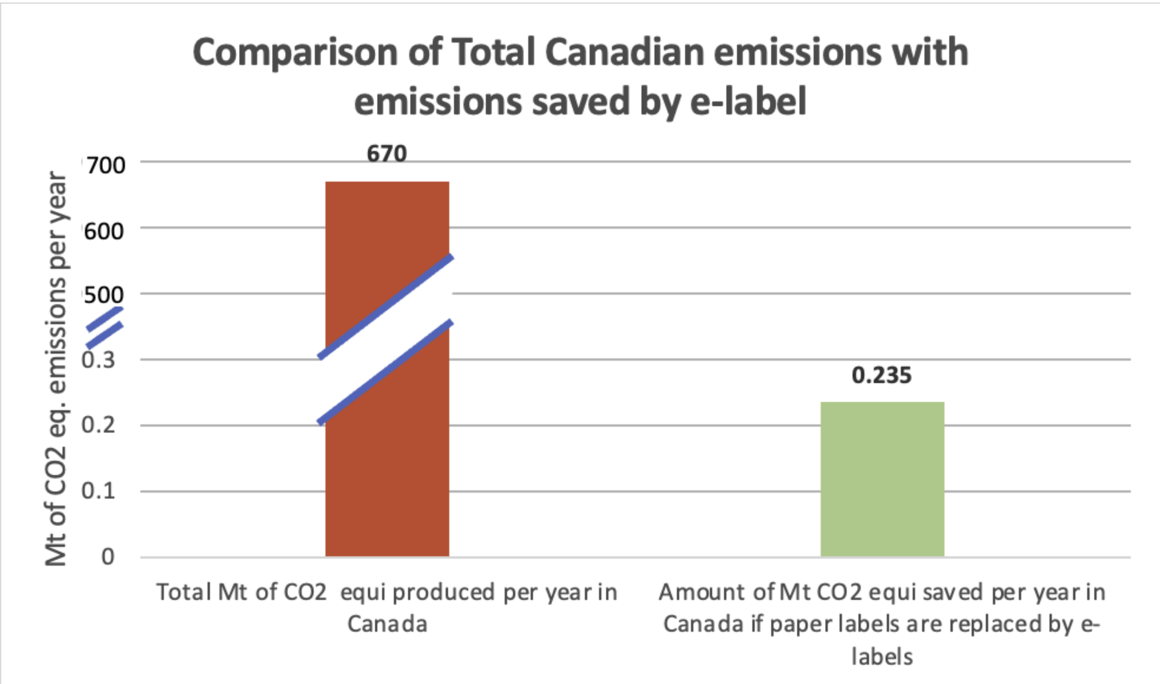

Figure 7: Comparison of CO2eq saved for Canada when all Paper Labels are replaced by E-Labels with Total emissions produced in Canada from all source

6.2. Sensitivity analysis

During the sensitivity analysis, we found that the maximum emissions saved by an electronic label are 9.42 Kg of CO2 eq as per Paper 1(Team, 2012). On the other hand, the minimum amount of CO2eq that could be saved is 2.6 Kg of CO2 eq. as per Paper 3 (Uncovering energy use, carbon emissions and environmental burdens of pulp and paper industry: A systematic review and meta-analysis).

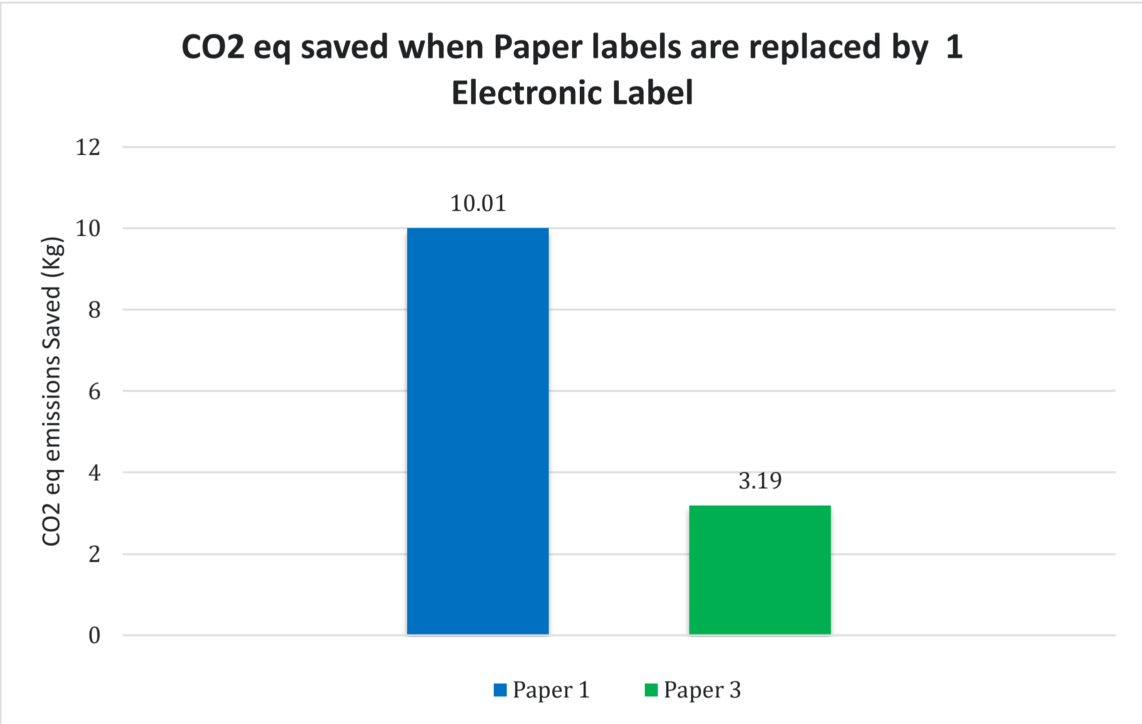

Figure 8: Sensitivity Analysis for CO2 eq saved when Paper Labels are replaced by 1 E-Label

6.3. Case Study: SaaS solution by Pricer for Magros

(SaaS and the High Quality of the Solution Made Migros Choose Pricer, 2022)

6.3.1. Overview

Client : Migros Etrembières
E-Tag provider: Pricer
Country: France
Sector: Grocery
Year: May 2022
Number and type of ESLs: 45,000 SmartTAG HD

6.3.2. Description

The Migros Etrembières store in Haute-Savoie, France, is a 5,000 m² hypermarket that had an old generation of electronic shelf labels on which a sticker had to be printed and then stuck. The store employees were spending a lot of time updating labels, and they were not customer-friendly.

45,000 labels were installed. The Fruits and Vegetables and Seafood departments also benefit from the advantages of an electronic shelf label, departments where origin and product updates are made daily. Store employees save a lot of time as they no longer have to print paper labels and put them on the shelves. The update is done directly on the shelf, and the update of information is almost immediate.

6.3.3. Calculations

Calculating the CO2 emissions that were saved by making this shift assumption is the same as taken in section 4.

Number of paper labels saved from May 2022 till May 2023 = 356*45000
= 16.42 million paper labels

Amount of CO2 eq emitted by 1 paper label = 0.00156 kg CO2 eq

The total amount of CO2 eq emitted by all the paper labels in 1 year = 25623 kg of CO2 eq.

Amount of CO2 eq emitted by 1 e-label (Kozlowski, 2022) = 0.59 kg of CO2 eq

Amount of CO2 eq emitted by 45k electronic labels = 26550 kg of CO2 eq

Let us assume the electronic labels are going to last 7 more years.

Therefore,

Amount of CO2 eq emissions by paper for a total of 8 years = 204984 kg of CO2 eq.

Amount of CO2 that could be prevented from emitting in 8 years by electronic labels
= 178434 kg of CO2 eq.

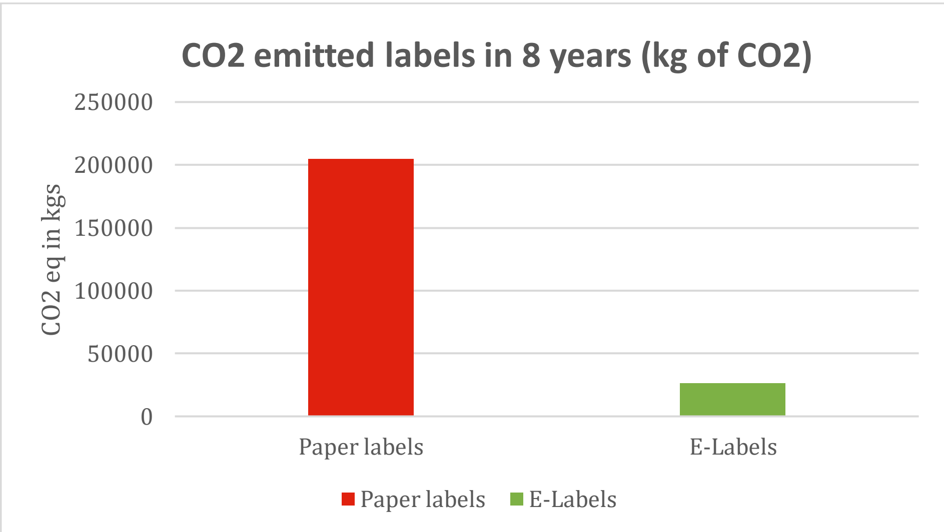

Figure 9: Potential CO2 emissions that will be saved by Migros Etrembières after 8 years of installing E-Label

7. Limitations

While conducting the life cycle analysis, several assumptions were made to streamline the assessment process. However, it is important to acknowledge that these assumptions introduce certain limitations that should be taken into consideration when interpreting the results.

a. Variation in GHG emissions: Averaging the greenhouse gas (GHG) emissions from three different research papers with separate assumptions might overlook the variations and nuances in the data. This can lead to a simplified or inaccurate representation of the actual GHG emissions associated with the electronic shelf labels.

b. Simplified paper label lifespan and usage: The calculations assumed a fixed lifespan of 8 years for electronic labels and a specific frequency of price changes (2 times a day) and, therefore, may not accurately reflect the variability in actual usage patterns. Different stores may have different usage intensities or may replace labels at different intervals, which can affect the overall environmental impact.

c. Paper label sizes may be oversimplified: As actual paper size and usage information were difficult to ascertain, calculations were based on a fixed size (2.9 inches) and weight (0.53 g) for paper labels, based on a specific gsm (75 gsm), may not represent the full range of paper labels used in retail. Different label sizes and weights can impact resource consumption and environmental performance.

d. Constant paper label consumption rate: Assuming a consistent consumption rate of paper labels across all convenience retail stores in Canada disregards potential variations in store size, store type, or regional differences. This assumption may not accurately reflect the paper label consumption and associated environmental impacts.

e. Uniformity of store size assumption: Assuming that the store sizes in the UK and Canada are the same overlooks the potential differences in store sizes and layouts, which can influence the scale of environmental impacts. Different store sizes can lead to variations in material consumption and waste generation.

f. Renewable electricity assumption: If electricity supplied to electronic labels is sourced from 100% renewable sources, it is an optimistic scenario. In reality, the electricity mix can vary, and labels may be powered by a combination of renewable and non-renewable energy sources. Neglecting this variability can lead to an overestimation of the environmental benefits associated with renewable electricity use.

7.2. Recommendations for Further Research

To further our understanding of sustainable labelling, the following areas offer promising directions for future research:

a. The first study involves conducting a comprehensive analysis of E-Labels, encompassing their complete lifecycle from creation to disposal. This study would encompass the evaluation of various factors, including energy consumption, material production, transportation, and end-of-life management, all contributing to the total lifecycle cost. By quantifying both the environmental and financial implications of E-Labels, this study can potentially uncover opportunities for optimizing their design and usage, paving the way for more sustainable labelling practices.

b. The second study centers around batteries utilized in the context of labelling, with a dual focus on waste management and sustainable materials. Research efforts will be directed toward understanding the existing waste stream associated with discarded batteries and identifying potential alternatives that are environmentally friendly. This study will also explore emerging technologies that have the potential to revolutionize the battery landscape in terms of sustainability, thereby contributing to the ongoing development of eco-friendly labelling solutions and reducing the environmental impact of battery disposal.

8. Challenges with Electronic Labels and Recommendations

The electronic shelf label (ESL) market in the North American retail sector has shown immense potential, with a projected revenue market of $126 billion in 2021. However, the actual market size of electronic labels currently stands at $2.2 billion, representing a mere 1.8% of its potential (Electronic Shelf Labels Market Revenue Trends and Growth Drivers, n.d.). This indicates significant room for growth in the ESL industry. In line with this growth potential, global shipments of ESLs exceeded 200 million in 2020 (Electronic Shelf Label Market Size & Share, Forecast Report 2027, n.d.). As the ESL market expands, it is crucial to address the environmental challenges associated with these electronic labels. This section will highlight the key challenges and provide recommendations to mitigate their impact on the environment.

Challenges:

a. Growing waste stream: The adoption of electronic shelf labels (ESLs) leads to the generation of a significant number of used batteries, as each label utilizes batteries with an average lifespan of two years.
b. Long decomposition time: These used batteries take over 100 years to decompose in landfills, contributing to environmental pollution and resource depletion.

8.1. Recommendations

To overcome those challenges, below are some of the recommendations.

a. Battery recycling programs: Implementing comprehensive and easily accessible battery recycling programs can ensure the proper disposal of used batteries from ESLs. This can minimize the environmental burden of battery waste and promote resource recovery.

b. Research and development of sustainable battery alternatives: Investing in research and development efforts to explore sustainable battery options, such as rechargeable or biodegradable batteries, can significantly reduce the environmental impact associated with ESLs. Innovations in battery technology can provide more environmentally friendly alternatives with longer lifespans.

c. Material substitution and design optimization: Encouraging ESL manufacturers to prioritize the use of sustainable and recyclable materials can minimize the environmental footprint of electronic labels. Emphasizing the principles of circular economy and product design optimization can help reduce the reliance on non-decomposable plastics and enhance the recyclability of ESL components.

d. Industry collaboration and standardization: Promoting industry-wide collaboration and standardization efforts can drive sustainability in the ESL market. Establishing guidelines and certifications for environmentally friendly ESLs can incentivize manufacturers to adopt more sustainable practices, including the use of eco-friendly materials and extended product lifecycles.

e. Consumer awareness and education: Increasing awareness among retailers and consumers about the environmental impact of ESLs can foster responsible consumption and disposal practices. Educating end-users about battery recycling options and choosing ESLs with sustainable attributes can contribute to a more sustainable retail industry.

9. Conclusion

This report demonstrates the potential of electronic labels in reducing paper waste and CO_2 emissions in the Canadian retail sector. By replacing 5840 paper labels with one electronic label over eight years, 8.52 Kg of CO_2eq can be saved. In the case of the retail sector of Canada, this savings shall be 0.235 Mt/year of CO_2 eq emissions if all the paper labels are replaced by e-labels. The sensitivity analysis confirms the effectiveness of electronic labels in curbing emissions. The Migros Etrembières case study further highlights the advantages of electronic labels in terms of GHG emissions saved.

However, the report acknowledges limitations in data assumptions and recommends further research, such as studying individual retailers, conducting life cycle cost analysis, and researching sustainable battery materials.

To address challenges associated with disposing of batteries used in e-labels, implementing battery recycling programs, exploring sustainable battery alternatives, and promoting material substitution and design optimization are recommended. Industry collaboration, consumer awareness, and education can enhance ESL sustainability.

In conclusion, the GHG analysis underscores the substantial emission reduction potential of electronic labels in fostering a more sustainable retail landscape. Moreover, the potential integration of e-paper technology, exemplified by the International EPaper Association and Smart Label Solutions in the billboard sector, holds the promise of reshaping advertising through dynamic displays while offering greener alternatives to energy-intensive e-paper billboards. This innovation could herald a sustainable era of outdoor advertising. Addressing challenges, such as battery waste, remains paramount to ensuring their comprehensive environmental soundness and effectiveness.

References

1. As Global Heat Continues, Electronic Shelf Labels Help Reduce the Planet's Carbon Footprint - BOWTZ international. (n.d.). Www.blozi.com. Retrieved August 22, 2023, from https://www.blozi.com/index.php/news/viewpoint/78-as-global-heat-continues-electronic-shelf-labels-help-reduce-the-planet-s-carbon-footprint.
2. Bale Force Recycling Equipment. (2021, July 15). Paper Waste: Why Does It Matter? BaleForce Recycling Equipment. https://baleforce.com/paper-waste-why-does-it-matter-and-how-to-manage-it/
3. Benobon, L. (2021, January 18). Electronic shelf labels, a green solution. Jrtechsolutions.ca.https://jrtechsolutions.ca/en/electronic-shelf-labels-a-green-solution/
4. Electronic Shelf Label Market Size & Share, Forecast Report 2027. (n.d.). Global Market Insights Inc. Retrieved May 29, 2023, from https://www.gminsights.com/industry-analysis/electronic-shelf-label-esl-market.
5. Electronic Shelf Labels Market Revenue Trends and Growth Drivers. (n.d.). MarketsandMarkets. https://www.marketsandmarkets.com/Market-Reports/electronic-shelf-label-market-40815676.html
6. Environment and Climate Change Canada. (2022, March 29). 2030 Emissions Reduction Plan – Canada's Next Steps for Clean Air and a Strong Economy. Www.canada.ca. https://www.canada.ca/en/environment-climate-change/news/2022/03/2030-emissions-reduction-plan--canadas-next-steps-for-clean-air-and-a-strong-economy.html
7. Environmental effects of paper. (2021, July 19). Wikipedia. https://en.wikipedia.org/wiki/Environmental_effects_of_paper
8. E Ink. We Make Surfaces Smart and Green. (n.d.). E Ink Report. Retrieved July 20, 2023, from https://esg.eink.com/en/report?year=all&page=1
9. Europe, S. (n.d.). What is a Shelf Tag? SoluM Europe. Retrieved July 10, 2023, from https://www.solumesl.com/en/insights/what-is-a-shelf-tag#:~:text=These%20are%20product%20labels%20that
10. Global Electronic Shelf Label (ESL) Market Share 2023-2030 with On-going Demand Status. (n.d.). MarketWatch. Retrieved July 10, 2023, from https://www.marketwatch.com/press-release/global-electronic-shelf-label-esl-market-share-2023-2030-with-on-going-demand-status-2023-05-05#:~:text=The%20latest%20research%20study%20on
11. Government of Canada. (2020, November 19). Net-Zero Emissions by 2050. Government of Canada
12. https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html

13. Kozlowski, M. (2022, August 26). E Ink Is Awarded the World's First ePaper Module Carbon Footprint Verification. Good E-Reader. https://goodereader.com/blog/e-paper/e-ink-is-awarded-the-worlds-first-epaper-module-carbon-footprint-verification
14. Kozlowski, M. (2022, August 26). E Ink Is Awarded the World's First ePaper Module Carbon Footprint Verification. Good E-Reader. https://goodereader.com/blog/e-paper/e-ink-is-awarded-the-worlds-first-epaper-module-carbon-footprint-verification
15. Retail trade enterprises in the UK 2008-2017. (n.d.). Statista. https://www.statista.com/statistics/293821/retail-trade-number-of-enterprises-in-the-united-kingdom-uk/
16. SaaS and the high quality of the solution made Migros choose Pricer. (2022, May 23). Www.pricer.com. https://www.pricer.com/case-studies/saas-and-solution-made-migros-choose-pricer
17. Schultz, T., & Suresh, A. (2018). SCS Global Services Report Life Cycle Impact Assessment Methodology for Environmental Paper Network Paper Calculator v4.0. https://c.environmentalpaper.org/pdf/SCS-EPN-PC-Methods.pdf
18. Sun, M., Wang, Y., Shi, L., & Klemeš, J. J. (2018). Uncovering energy use, carbon emissions and environmental burdens of pulp and paper industry: A systematic review and meta-analysis. Renewable and Sustainable Energy Reviews, 92, 823–833. https://doi.org/10.1016/j.rser.2018.04.036
19. Team, T. T. S. (2012, February 14). Printing and Writing Papers - Life-Cycle Assessment Summary Report. Two Sides North America. https://twosidesna.org/US/printing-and-writing-papers-life-cycle-assessment-summary-report/#:~:text=Printing%20and%20Writing%20Papers%20%E2%80%93%20Life%2DCycle%20Assessment%20Summary%20Report
20. The Paper Consumption Problem: Statistics on the paper use. (n.d.). www.inspakt.com. Retrieved July 10, 2023, from https://www.inspakt.com/blog/the-paper-consumption-problem-statistics-on-the-paper-use.
21. UK Convenience Store Statistics 2020 | Premierline. (n.d.). Premier BusinessCare. https://www.premierline.co.uk/knowledge-centre/uk-convenience-store-statistics-2020.html
22. Uncoated Freesheet – Horizon Paper, US Paper Mill Representative, US Paper Broker, US Paper Merchant, US Paper Distributor. (n.d.). Retrieved August 22, 2023, from https://www.horizonpaper.com/our-products/uncoated-freesheet/