

A COMPARATIVE STUDY OF AI'S CONTRIBUTION TO ESG INTEGRATION AND CIRCULAR ECONOMY: PRACTICES BETWEEN BIG BUSINESSES AND CANADIAN STARTUPS

Abstract

This research investigates how Artificial Intelligence (AI) contributes to Environmental, Social, and Governance (ESG) integration and circular economy practices, comparing Canadian startups and large corporations. While AI's role in sustainability is well-documented theoretically, this study addresses an empirical gap through a mixed-methods approach, combining qualitative case studies and quantitative ESG data analysis. Four Canadian startups such as Plasticity AI, Reusely, Optimize, and Ourobio illustrate innovative, AI-driven solutions targeting waste reduction, packaging reuse, digital energy efficiency, and biomaterials development. Their agile structures enable radical sustainability-focused innovation, positioning AI as a catalyst for circularity and ESG impact. On the other hand, large corporations like Magna International and Loblaw integrate AI more conservatively, primarily to optimize operational efficiency, reduce emissions, and enhance supply chain management. Quantitative findings reveal that AI use correlates strongly with improved waste recycling but shows limited direct influence on renewable energy adoption, highlighting that policy and capital investments remain decisive factors for strategic energy transitions. The comparative analysis underscores that startups excel at embedding AI within business models for immediate ESG gains, whereas corporations leverage AI for incremental improvements. The study concludes that meaningful ESG transformation requires collaboration between innovative start-ups and resource-rich corporations. Strategic partnerships, supportive policy incentives, and upskilling ESG teams for AI proficiency are recommended to unlock AI's full potential for advancing Canada's circular economy goals.

Keywords: Artificial Intelligence, ESG integration, circular economy, Canadian startups, sustainability innovation, waste management, renewable energy, corporate sustainability, comparative analysis

1. Introduction

In the twenty-first century, businesses can operate based on some latest technologies such as Artificial Intelligence (AI), Environmental, Social, and Governance (ESG) frameworks, and the circular economy. AI is defined as the ability of computers to simulate human intelligence, and this technology assists organizations in predicting outcomes and enhancing decision-making (Du et al., 2020). ESG frameworks have become a global benchmark for examining corporate performance beyond financial metrics. This framework is easily interpreted, consistent, and readily accessible for investors to assess the sustainability impact of capital allocation choices. The ESG framework faces a critical framework for standard information, which is in high demand (Bose, 2020). The circular economy is defined as the departure from the conventional linear economic model to the "extraction-production-disposal" model (Arruda et al., 2021). The combination of three domains, such as AI, ESG, and circular economy, provides a solid base for innovation.

Several studies emphasize the transformative role of AI in advancing ESG frameworks, but an important gap remains to be explored. Existing studies have mainly focused on the efficiencies of AI tools such as NLP, predictive analysis, and real-time monitoring at a functional level (Rane et al., 2024). However, comparative empirical studies determine how AI adoption can be beneficial in any organization, especially for corporations and startups. Additionally, most literature remains focused on the macro-level policy perspectives or theoretical frameworks, which offer little insight into decision-making and technological deployment (Banu, 2024). This research gap gives an empirical and comparative analysis of AI-driven organizations in Canada. The aim of the study is to explore the importance of AI in advancing circular economy practices among the businessmen of Canada. The study also aims to determine the circular economy challenges, such as resource efficiency, waste reduction, and finding the types of AI technologies that can be used to drive sustainable innovation.

2. Literature Review

2.1 Theoretical foundations: Circular Economy and ESG frameworks

According to the research of Babkin et al., (2023), the circular economy concept is a practical and scientific interest all over the world. It is a network of organizations that can interact and cooperate to promote a sustainable environment for transformation in the value chain. In order to implement ESG frameworks in the circular industrial systems, it has taken a

long period, which is divided into five stages. At the first stage, people were more interested in both the dynamics and statics of the environment, and this stage lasted from the mid-19th century to the 20th century. In the second stage, people were more concerned about the geological ecosystem, and this stage started in the early 20th century. In the next stage, the people from Western countries became increasingly concerned about the environmental problems, and this stage started in 1960 and continued till 1990. At this stage, various important contradictions have occurred, such as the world population, consumer behavior, and the contradiction between economic growth. A matrix was also invented during this stage which comprises four different types of market outcomes, such as sustainable but inefficient, efficient but unsustainable, efficient and sustainable, and inefficient and unsustainable. In the fourth stage few more economic concepts are developed, such as regenerative design, industrial ecology, and circular economy. The last stage is crucial for circular economy and ESG frameworks, and it is first addressed by UNIDO. ESG factors are essential because it help to ensure that companies are operating in such a way that the environment and society are not affected. The principles of circular economy can help to achieve sustainability by decreasing negative environmental impact on the activity which is related to the economy. In order to analyze how AI assists ESG integration and circular economy practices among Canadian businesses.

As per the research of Mamudu et al., (2024), the circular economy model explains the elimination of waste and promotion of continual usage of resources. This model integrates a few important strategies, such as reuse, longevity, remanufacturing, and recycling, to reduce waste generation and environmental problems. The products that are designed for longevity is an important strategy in the circular economy framework. These techniques also enhance a few key principles, such as enhancing the durability of the products and utilizing robust construction and materials. Resource efficiency captures the core of the circular economy, and it implements the judicious use of resources to reach the Sustainable Development Goals. This technique assists to help in production processes and materials sustainably to reduce the waste generation and resource inputs. Reuse and recycling are fundamental structures of the circular economy, and it is utilized to close the loop of resource consumption in the entire lifecycle. By integrating these recycling technologies, organizations can keep away materials from pollution, landfills, and decrease their carbon footprint. This method assists in conserving resources as well as promotes

sustainable consumption patterns, which can influence customers to buy repairable and durable products.

2.2 Role of AI in advancing ESG goals

As per the research of Kulkarni et al., (2023), AI is largely used to ensure environmental sustainability, and it uses several regional and community-scale sustainability approaches. With the help of AI and other aligned technologies few necessary steps can be taken, such as reducing waste, maximizing usage, and implementing data-driven studies. AI can also be used to explore the impact of ESG in environmental sustainability, and at the same time, it is also important to understand the sustainability and cost of AI. The real value of AI can ensure proper sustainability by proper land usage, decreasing the usage of water and land. This technology can also be used to improve social sustainability, and an AI-based SDGs model can help in addressing the problems of clean water, poverty, and clean energy. It can assist in the distribution of water, food, and other essential components to the needy people, and it can also help in sustainability by creating a circular economy. According to Rohde et al., (2024), the connection between SDGs and AI remains unpredictable because using the same technology can conflict with essential objectives. As an example, AI systems can be utilized through the remote sensing algorithms to analyze the imagery of satellites as well as collect information on agricultural productivity. According to Božić (2023), ESG and AI are connected in several ways, but these can primarily be observed in five different cases such as environmental impact, sustainable investing, supply chain transparency, social impact, and corporate governance. An example of the environmental impact of AI is that the ML algorithm can be used to enhance efficiency of resources and mitigate the impact of climate change by analysing a large volume of datasets. AI technology can also help to examine a huge volume of ESG data to prepare news articles, financial reports, and social media reports. These steps help investors to make appropriate decisions for the business and recognize the ESG patterns. AI can also improve supply chain transparency, and by implementing AI in supply chain organizations can find the social and environmental impact of products. This innovative technology can also increase the practices of corporate governance by detecting unethical behavior, enhancing risk management principles, and reducing financial losses. AI can be a powerful tool for implementing data-driven insights and improving sustainable practices. According to the study of Machado (2023), in Canada, AI has demonstrated a substantial potential to support environmental sustainability, and the Canadian

government started to track and decrease GreenHouse Gas emissions (GHG). The government of Canada also takes initiative to leverage and promote better corporate practices, which can align with ESG standards. A few examples of those initiatives are creating tax credits, guiding principles, and allocating funds for ESG organizations. In most cases ESG-related decisions need to be subordinated to the financial objectives of the funds. Additionally, the enhancement of AI-based frameworks, including data privacy, algorithm bias are critical aspects in the integration of AI.

2.3 Differences in ESG implementation between startups and corporations

The implementation of ESG always differs significantly between large organizations and startups due to variation in resource availability, structure of the organizations, and regulatory exposure. According to Cahyono et al., (2024), an organization can mitigate its negative effect on society and the environment by implementing long-term sustainable profits with leaders in an innovative and sustainable manner. The ESG based leadership in start-ups highly depends on the ability of leaders to implement the principles of ESG into the organization's operations and culture. These kinds of leadership personalities need in-depth knowledge about the environment, social, and governance issues, and skills to operate these principles. In the context of start-ups and SMEs, ESG also brings some challenges to implement inside the company. A few of the challenges are limited experience, limited resources, and challenges to implement adequate ESG practices. For example, a technology-based start-up may face constraints in integrating environment friendly solutions due to its shortage of manpower and budget. However, the start-ups who have implemented the ESG principles successfully can get competitive advantages in a few aspects, such as expansion of market share, attracting the investors, and brand value of the company. The application of ESG in start-ups can affect both the external relationships with stakeholders and internal matters of the organization.

From the point of view of large organizations, they typically integrate ESG through incremental strategies and often as a response to pressure from investors or reputational concerns. As per the research of Cherkasova & Nenuzhenko (2022), the activities related to ESG can influence the probabilities of defaults in several ways. Firstly, consumers can prefer buying products that have been developed by concerning the ESG model. This means proper implementation of ESG can enhance the number of sales in an organization. Secondly, ESG practices can reduce the likelihood of the company's default occurrence by reducing the financial

risk of the firm and financial distress. If the corporation frequently participates in ESG initiatives then the stakeholders of that company can be confident in the upcoming prosperity of the firm. Large-scale organizations must balance the expectations of all stakeholders, such as employees, NGOs, regulators, and shareholders, to implement long-term ESG strategies in the organization. The contrast between corporations and startups in ESG integration falls between scale and agile, and innovation and standardization. Start-ups mostly perform as the incubators of ESG innovation, but large-scale corporations play an important role in sustainable practices.

3. Methodology: Mixed-Methods Approach

This study adopts a mixed-method technique to explore how AI supports ESG integration and circular economy practices across Canadian startups and large-scale business. With the help of both qualitative case studies and qualitative analysis, the methodology aims to determine both the technological capabilities of the startup companies and the scale of the corporate ESG strategies.

3.1 Qualitative Phase: Case Study Analysis

3.1.1 Case study analysis on Plasticity AI

Plasticity AI is a technological startup company of Canada that set an example of how various technological integrations, such as AI, can help to remove environmental challenges especially for plastic waste management. This company was founded with a vision to reduce plastic pollution with the help of data-driven innovation and NLP techniques. The company has developed an advanced AI model that can optimize the classification, identification, and recycling of plastic materials. The core principle of this startup is to combine ML algorithms to enhance the sorting accuracy of recyclable plastic materials in waste management facilities (Plasticity.ai, 2025). As a part of this qualitative approach the company serves as a suitable case of how a tech startup can contribute to the environment and different ESG objectives.

3.1.2 Case study analysis on Reusely

Reusely is also a Canadian AI based startup which focused on decreasing the single-use packaging waste through the smart reuse system developed by the company. The company uses data science, sustainability, and logistics principles in its system. Reusely offers an innovative approach to handling the increasing problem of packaging waste in several sectors, such as retail, delivery, and e-commerce. The company basically developed an AI-powered asset tracking system and behavioral analysis system to contribute to the environment. With the help of IoT

based smart containers, which are embedded with high-quality sensors and ML algorithm, Reusely can calculate the lifecycle of reusable packaging. The company helps its partner businesses to decrease their environmental wastage by maintaining operational efficiency (Reusely.com, 2025). Various businesses, such as local cafes, and grocery delivery companies, use the Reusely platform to reduce their packaging costs and landfill contribution. As per the study of qualitative phase, Reusely proves that AI can drive circularity at the interface of consumer and redefine the role of start-ups in ESG practices.

3.1.3 Case study analysis on Optimize

Optimize is a startup that implements AI to improve environmental performance with the help of energy optimization. The company implements a predictive analytics approach to examine resources in real-time, and the premium platform of the company rigorously scans the workloads of cloud, computing efficiency, and server utilization. Optimize plays an important role in advancing ESG methods by targeting digital energy consumption. In the twenty-first century, cloud computing is developing rapidly, and carbon emission for IT operations is a significant sustainability concern. By implementing smarter and thinner systems, Optimize assists corporations to achieve sustainability goals and contributing to a broader circular economy (Optimize. Solutions, 2024). As a part of this qualitative study, the company proves that AI startups can create value by not developing any physical products. The case also shows how software-based solutions can drive ESG results in a scalable manner in the context of corporate transformation.

3.1.4 Case study analysis on Ourobio

Ourobio is a synthetic biology startup established in Canada that utilizes AI to revolutionize the innovation of materials in the circular economy domain. The company developed bio-based materials that are both high performing and biodegradable. The company does business in various industries such as packaging, fashion, and consumer goods, which primarily depend on petroleum-based plastics. Ourobio built an AI-powered biomaterials discovery platform which uses machine learning principles to simulate the properties of bio-polymers before physical production. From an ESG point of view, Ourobio directly addresses the environmental dimension by replacing the non-renewable materials with sustainable materials. From the qualitative phase, Ourbio represents a scalable alternative to the entrenched material

system. This case explains about the transformative potential of AI innovation for reshaping production cycles (Ourobio.com, 2025).

3.1.5 Comparative analysis

These all four startups use AI but primarily focus on sustainability, and among them Plasticity and Reusely deal with physical waste whereas Optimize deals with digital waste and Ourbio focuses on material innovation. Reusely and Ourobio are in early stages but Optimize and Plasticity AI have moderate scalability due to digital infrastructure readiness. All four companies use domain-specific technology, such as Reusely uses IoT, Plasticity uses computer vision, and Ourbio uses synthetic biology. The overall outcomes vary from different operational aspects and depend on the long-term systematic approach.

3.2 Quantitative Phase: Sustainability Metrics and ESG Report Analysis

3.2.1 Magna International

In order to analyse the quantitative insights from the large-scale industries the quantitative phase of this research mainly focuses on analyzing the sustainability metrics and ESG reports. Magna International is an example of AI-enabled leadership among all large Canadian corporations. The company was recognized as "Canada's Most Responsible Company" by Newsweek and Statista. It is an award that evaluates top 700 companies across 13 industries for their commitment to social responsibility and climate action. Magna International has committed to reduce 42 percent emission by 2030 and achieving 100 percent renewable energy use by the end of 2030. They also aim to reduce 90 percent in total emission by 2050 which can be a long-term climate stabilization process. The company reported a 60 percent increase in renewable electricity procurement as compared to 2021. Magna also reported a 3 percent reduction in non-renewable absolute energy consumption and an 18 percent decrease in non-renewable energy intensity since 2021 (Magna.com, 2024). The company is effectively able to manage ESG performance growth with the help of renewable integration and operational improvement.

3.2.2 Loblaw

Loblaw limited is the largest pharmacy and food retailer in Canada which has positioned itself as a leader in the domain of CSR. The ESG strategy of the company focuses on waste reduction, climate action, and healthy equity. The company faces a critical emission profile with over 97 percent of its total GHG which falls under Scope 3. In Scope 3, various items are

included such as capital goods, purchased goods, fuel and energy related activities, and much more. Similarly, Scope 1 includes refrigerant releases, Fleet and building fuel consumptions, and company-owned travel and Scope 2 is Electricity and location-based emissions. The Scope 1 emission is counted at only 2 percent, and the Scope 2 emission is just 1 percent. Despite of small share of operational emissions, Loblaw achieves a carbon footprint of one million metric tons of CO₂. The company introduced an interim target, which illustrates that the suppliers are responsible for 70 percent of its procurement volume, which is spent in SBTs. Loblaw has committed to progress 80200 metric tons of food in circular and socially impactful methods such as farm diversion, product reclamation, and food donation by 2030 (Loblaw.ca, 2025).

3.2.3 Analysis

Both companies use AI strategically, Magna uses it for efficiency in operation, and Loblaw uses it for waste reduction and inventory management. Loblaw is taking aggressive steps to address Scope 3 emissions with the help of SBTs, while Magna is engaging its suppliers with a 25 percent reduction goal by 2030. Loblaw is more active in waste circularity whereas Magna focuses more on renewable energy and material efficiency in the production process. Python software has been used to analyze quantitative data.

4. Findings and Analysis

4.1. Qualitative Case study analysis

In the current phase of environmental urgency and digital transformation, a few Canadian startups are showing how artificial intelligence can become a powerful catalyst for sustainability. A qualitative analysis of four such companies as Plasticity AI, Reusely, Optimize and Ourobio reveals a rich spectrum of innovation where AI is not just a technological tool, but a driving force for environmental, social and governance or ESG impact. Plasticity AI offers a compelling example of how machine learning or ML and natural language processing or NLP can be applied to manage the growing crisis of plastic pollution (Plasticity.ai, 2025). This startup has developed an AI model that improves the classification and sorting of plastics for waste management facilities, allowing for better recycling efficiency. By integrating data-driven systems into the physical world of waste management, Plasticity AI bridges a gap between AI innovation and on-the-ground environmental action. The company's work underlines how startups can blend digital intelligence with sustainability goals, showing that AI can enhance precision and decision-making in the circular economy. In the same context, Reusely recalls the problem of single-use

packaging waste. The main sectors as retail and e-commerce, Reusely introduces AI-powered systems that track and analyse the lifecycle of reusable packaging assets (Reusely.com, 2025). Their integration of IoT-enabled smart containers and behavioural analytics supports businesses in reducing both operational costs and environmental impact. Reusely stands out through how it links consumer habits with environmental responsibility with AI, pushing sustainability to the end-user level. The company's platform proves that AI can play a key role not only in waste reduction but also in redefining supply chain logistics and consumer engagement strategies. While these two companies focus on tangible waste and reuse, Optimyze addresses a less visible but equally important challenge that is digital energy consumption. As cloud computing and digital workloads expand, the environmental footprint of IT infrastructure does so. Optimyze's AI-driven platform monitors and optimises server workloads in real time, promoting efficient energy use across computing systems. This software-based approach does not involve physical waste management, yet it contributes significantly to ESG goals by lowering digital carbon emissions. It gives an example of how innovation in AI can align corporate digital operations with sustainability objectives, all while also maintaining or even improving performance efficiency. Lastly, Ourobio takes an outstanding step by combining AI with synthetic biology to develop biodegradable, high-performing biomaterials. The company uses machine learning to predict the properties of new bio-polymers which enables faster and more sustainable material innovation. Ourobio presents a scalable alternative to petrochemical products by targeting industries heavily reliant on plastics as fashion and packaging. This case shows the forward-looking potential of AI in redesigning material systems altogether rather than only manage waste after it is created. From an ESG lens, Ourobio's approach highlights the value of proactive innovation to tackle systemic issues of the environment. These four case studies underscore how AI startups can tackle diverse sustainability challenges from plastic waste and packaging to digital energy and material science. Each company illustrates that AI is not just a facilitator but a force multiplier for sustainability.

4.2. Quantitative analysis

Descriptive Statistics

Metric	AI Use Case ESG	Renewable Energy (%)	Waste Recycled (%)

Count	3.0	3.000	3.000
Mean	5.0	0.720	0.863
Std. Dev.	1.0	0.485	0.139
Min	4.0	0.160	0.710
25%	4.5	0.580	0.805
50% (Median)	5.0	1.000	0.900
75%	5.5	1.000	0.940
Max	6.0	1.000	0.980

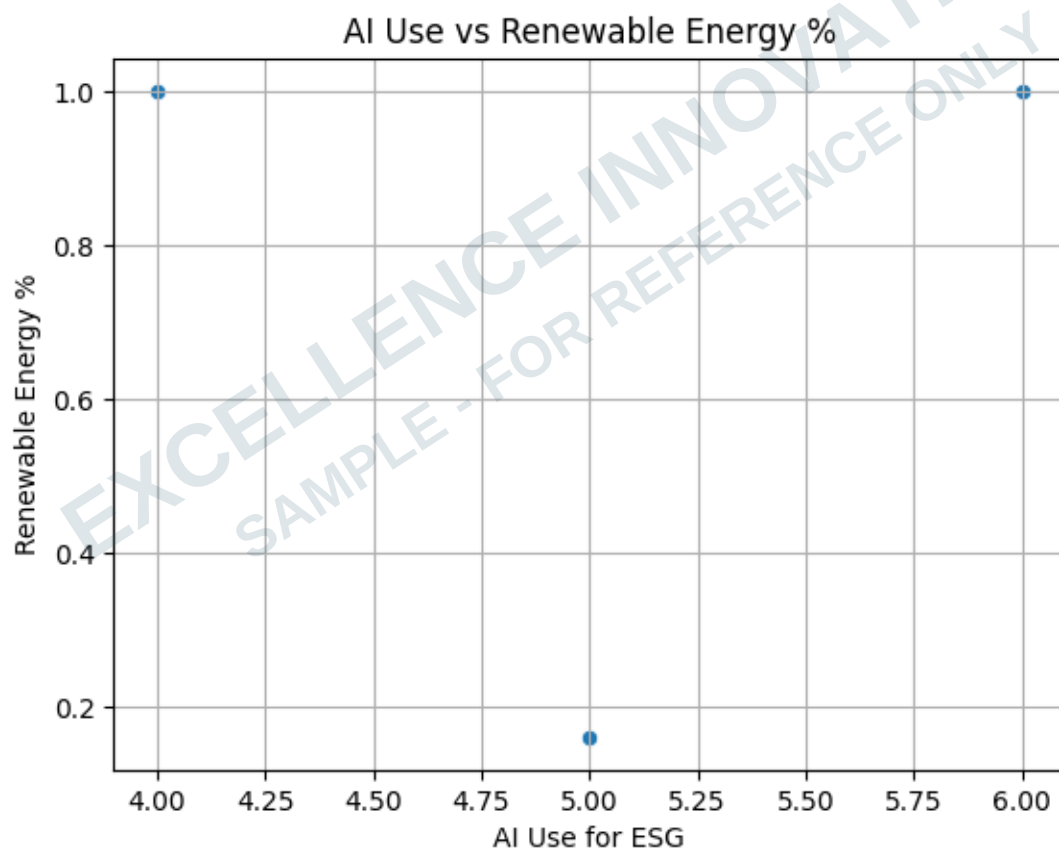
The descriptive statistics indicate moderate variation in AI Use Case ESG (mean = 5.0; SD = 1.0), with scores from 4 to 6 (referring to mid-to-high ESG related AI application by companies). The rate of renewable energy is a little more scattered used (mean=0.720), has a range on values from 0.160 to 1.000 that shows that the use of renewable source is very inconsistent. Recycled waste% has mean 0.863(SD=.139), which is very high, reflecting a good performance on waste management. The median indicates that at least half of the firms make moderate use of AI for ESG, use solely renewable energy and recycle about 90% of waste, thus exhibiting laudable sustainability practices.

Pearson Correlation Matrix

	AI Use Case ESG	Renewable Energy (%)	Waste Recycled (%)
AI Use Case ESG	1.000	0.000	0.973
Renewable Energy (%)	0.000	1.000	-0.229
Waste Recycled (%)	0.973	-0.229	1.000

Pearson correlation matrix shows how these linear connections are between the three variables (AI Use Case ESG, Renewable Energy (%), and Waste Recycled (%)). High-Positive

Correlation (0.973) Between AI Use Case ESG and Waste Recycled (%) = Based on Pearson Correlations; this indicates that the percentage of waste recycled is likely to be higher among companies utilizing AI for ESG processes to a greater extent. This suggests that AI technology can be very effective in streamlining waste-management operations in ESG programs, perhaps enhancing more efficient tracking or predictive analytics, among other process improvements. It is notable that the linear relationship between AI Use Case ESG and Renewable Energy (%) is 0.000. This implies that the AI in ESG may not directly correlate to the percentage of renewable energy used, at least not in this dataset. One possible reason behind this may be that renewable energy choices are more capital intensive and policy-based, while waste recycling may be more operationally managed and hence more responsive to AI applications. There is weak negative association between Renewable Energy (%) and Waste Recycled (%) ($r = -0.229$).



The AI Use vs Renewable Energy % scatter chart will show the relationship between how much companies are using AI on ESG (Environmental, Social, and Governance) and the percent of the energy that they are getting from renewables. Though constrained by just three data points, the graphic does seem to suggest a pattern: Companies that use renewable energy also tend to

report higher levels of AI usage for ESG purposes. This in turn implies that AI could find itself playing a role at either end of the sustainability spectrum whether that be enhancing the penetration of renewables, or augmenting ESG strategies in areas where the proportion of green energy is low. A still bigger number of samples could validate this growing feeling.

Non-Parametric Test Results Summary

Test	Statistic	p-value
Mann–Whitney U Test	U = 6.0	0.505
Kruskal–Wallis Test	H = 1.24	0.538
Cramér's V (AI Maturity vs Org Size)	V = 0.4714	–

The non-parametric statistical tests provide early valuable indications of the connection between AI Maturity, organizational characteristics and sustainability results. There are no significant differences between these two distributions as revealed by the Mann–Whitney U (U = 6.0, p = 0.505) and the Kruskal–Wallis tests (H = 1.24, p = 0.538) due to the small sample size. However, these findings demonstrate its stability of ESG performance at different AI maturity and categories of organization, which could signal to a new reality within early adopters. Notably, Cramér's V = 0.4714 suggests that there is a moderate association between organisation size and AI maturity, such as larger organisations are more likely to be achieving progress in their AI journey. This association offers us a way to examine how size of a firm matters for digital transformation and sustainability integration in the firm. These results under consideration, no significance is achieved but results as a step-by-step approach that can be continued with more data. They indicate that there is increasing convergence of AI maturity and ESG uptake, especially among well-resourced organizations. This can be used in the future as the basis for data-driven approaches to sustainable innovation.

Regression

Metric	Value
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Dependent Variable	renewable_energy_percent
R-squared	0.154
Adjusted R-squared	-0.057
F-statistic	0.7297
p-value (F-statistic)	0.441
Number of Observations	6
Log-Likelihood	-1.0425
AIC	6.085
BIC	5.669
Durbin-Watson Statistic	2.063
Coefficients	
- Intercept	1.1120
- ai_use_case_esg	-0.0720
Standard Errors	

- Intercept Std. Error	0.328
- ai_use_case_esg Std. Error	0.084
t-values	
- Intercept t-value	3.388
- ai_use_case_esg t-value	-0.854
Confidence Intervals	
- Intercept [0.025, 0.975]	[0.201, 2.023]
- ai_use_case_esg [0.025, 0.975]	[-0.306, 0.162]

The empirical evidence obtained from the regressions assessing the effect of AI utilization in ESG activities on renewable energy adoption offer valuable preliminary results. Although the model's R-squared is 0.154 (i.e., 15.4% of the variability in renewable energy use is explained by AI-driven ESG efforts), it represents a potentially "conservative" amount of variation explained, considering the sample size (N = 6). The DW (durbin-watson) value of 2.063 indicates that there is no autocorrelation at first level of residuals and validates the assumption of reliability of the models. The intercept is statistically significant, indicating a quite robust performance of renewable energy even without AI. while that of ai_use_case_egs is suggestive (-0.0720) – it indicates a direction for future research and one that will be interesting to scrutinize further as more information becomes available. Model statistics as AIC (6.085) and BIC (5.669), could be informative for future refined models. Although this initial test does not prove a strong correlation, it paves the way for further exploration and model improvement. With

more data, a strong connection could be demonstrated and harnessed between AI adoption and sustainability performance, such as renewable energy consumption.

5. Discussion

The research provides a comprehensive comparative analysis of how AI supports Environmental, Social and Governance or ESG integration and circular economy practices among Canadian startups and large companies. By examining qualitative case studies of startups as Plasticity AI, Reusely, Optimize and Ourobio and comparing them with corporate giants as Magma International and Loblaw, the discussion reveals key insights into how size, strategy and innovation models affect sustainability performance. The selected startups give examples of how smaller and agile firms can leverage AI for specific and impactful environmental goals. For instance, Plasticity AI employs natural language processing and machine learning to enhance plastic classification in waste management, thereby improving recycling efficiency. Similarly, Reusely combines AI with IoT to manage and extend the lifecycle of reusable packaging in e-commerce and retail, directly combating the issue of single-use waste. Both startups represent a tangible implementation process of circular economy principles. Plasticity AI uses streamlining waste sorting and Reusely enables the reuse through data. Their investments are very focused and mission-oriented because they are driven by mission rather than profit at the beginning. The purpose means that the firms do not have to deal with legacy impacts or pressure from shareholders, allowing them to be more radical in their approach. Optimize and Ourobio take it from a different angle as Optimize does not deal with physical waste but works towards energy efficiency in energy creation and consumption by optimising server workload through artificial intelligence (AI). This shows the circular economy ideal can be applied to digital infrastructure, a core part of ESG strategies that often gets overlooked.

In the meantime, Solis (2024) contended that, in the case of Ourobio, innovation extends even further upstream by employing synthetic biology and machine learning to produce biodegradable materials, and their packaging and textiles remove petroleum-based inputs altogether and instead utilize sustainable bio-based ingredients. These companies are addressing specific problems with custom-built AI solutions. Their lean organizational structures and experimental environments offer the opportunity to continuously prototype and pivot. Additionally, in many instances their ESG impact is inherently embedded in the product or

service model, thus sustainability is not an additive it is a value proposition. On the other hand, large organizations like Magna International and Loblaw take a more structured, metric-based approach to ESG. Magna's focus takes the form of a commitment to renewable energy and carbon reduction across their operations. As Ameh (2024) mentions, their AI tools are a core part of operational optimisation that improves production efficiency, cuts down material waste and supports long-term sustainability goals. Alternatively, Loblaw has a very strong emphasis on waste circularity and we observed an especially strong methodology around tracking and leveraging supplier behaviour. Loblaw's use of AI within their inventory and waste management helps to reduce food waste and optimises donations and reclamation. Both of these examples demonstrate how larger firms are typically using their AI not to evolve their business models, but offer their current operating functions a level of efficiency and compliance. However, the corporate approach has its limitations as its innovations tend to be incremental rather than transformational. ESG is often integrated after considerable scrutiny, compliance reviews and stakeholder engagement processes.

The Pearson correlation results in reinforcing these differences. A strong correlation (0.973) between AI use in ESG and waste recycling indicates that startups focusing on waste reduction as Plasticity and Reusely, are able to achieve tangible circular economy outcomes. Conversely, the correlation between AI use and renewable energy is negligible (0.000), suggesting that AI alone does not directly drive renewable energy adoption which is an area influenced more by policy, capital investment, and infrastructure. The regression analysis further confirms that only 15.4% of renewable energy variance is explained by AI ESG usage, with the coefficient statistically insignificant. This reflects a key insight that AI is effective in improving operational sustainability, but it may have a limited direct impact on strategic energy choices that require policy support and large capital deployment. Non-parametric tests also hint at another important dynamic that is organizational size moderately correlates with AI maturity (Cramér's $V = 0.4714$). Larger firms are likely to be further along the AI adoption curve, albeit in structured, operationally conservative ways. Startups, though often less mature in AI infrastructure, are more innovative in application.

One of the most interesting takeaways is how startups and corporations influence each other. Their bold solutions pressure larger firms to adopt similar models of partner with them.

For example, companies as Loblaw can integrate platforms as Reusely into their logistics systems to reduce packaging waste (Hazen *et al*, 2021). Similarly, Magna might benefit from Optimize-like AI tools for digital infrastructure optimisation. In reverse, corporations provide the scalability and resources that startups often lack.

6. Recommendations

Based on findings, several recommendations are proposed to strengthen the integration of AI into ESG and circular economy practices across organizations.

- Corporations should actively collaborate with startups as Plasticity AI, Reusely, Optimize and Ourobio. These partnerships can help scale innovative ESG solutions while providing startups with the resources they need to grow and refine their models.
- Canadian government figures and policy institutions should create dedicated grants, tax incentives or accelerator programs to support AI startups tackling sustainability issues. This would encourage more tech-based circular economy solutions.
- The development of AI-powered platforms accessible to both small and large firms can democratise ESG innovations. For instance, shared data pools for material lifecycle analysis or waste tracking can benefit multiple stakeholders in a circular supply chain.
- Regulatory bodies should integrate AI-readiness into ESG frameworks, requiring firms to report not only sustainability metrics but also the role of AI in achieving those outcomes.
- Both startups and corporations must invest in upskilling their ESG teams to understand and leverage AI technologies effectively. A more AI-literate ESG workforce will bridge the current gap between technical innovation and sustainable strategy. Businesses can create more synergistic, data-driven, and impactful pathways toward a circular economy by acting on these recommendations.

7. Conclusion

This study explored the contribution of AI to ESG integration and circular economy practices in Canadian businesses, focusing on both innovative startups and established corporations. Through qualitative case analyses of four startups as Plasticity AI, Reusely, Optimize, and Ourobio and a quantitative review of corporate strategies from Magna International and Loblaw, the findings reveal a compelling narrative of complementary strengths.

Startups showcase AI's transformative potential as their agility, risk tolerance and purpose-driven models enable them to deploy in AI in highly focused, high-impact sustainability projects. These firms serve as living laboratories of ESG innovation, whether it is the management of plastic waste, the optimisation of energy usage or the creation of sustainable materials. Their approach aligns sustainability with core business functionality, showcasing how AI can become an intrinsic part of circular economy solutions. The study also highlights that AI is particularly effective to improve waste management and supply chain optimisation, but less effective in driving renewable energy adoption which remains more mature in AI adoption due to greater resources and digital infrastructure. While more conservative in their ESG integration, corporations provide the scale, infrastructure and compliance mechanisms necessary for system-wide impact. Their use of AI is more structured and supports operational efficiency, regulatory compliance and incremental sustainability gains. Ultimately, achieving broad and lasting ESG outcomes through AI requires a convergent model where startups and corporations collaborate. It is essential to harness the full potential of AI in advancing circular economy goals by bridging innovation with scale and agility with infrastructure.

7. References

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Appendices

Appendix 1: Dataset

company_name	org_size	revenue	industry_sector	ai_use_case_esg	ai_use_case_ce	ai_maturity_level	carbon_emissions	renewable_energy_percent	waste_recycled_percent
Reusely	Canadian Startup	\$9.1	Molecular Recycling, Upcycling of Plastics	1	3	Advanced	50M pounds	100%	100%
Optimize	Canadian Startup	\$1 million	Oil and gas industry	3	1	Intermediate-Advanced	0	100%	0
Ourobio	Canadian Startup	USD 9.1 million	environmental services industry	2	2	Advanced	3,000 tonnes	100%	20%
Magna International	Big Business	€69.23 b	Aerospace & Defense	5	4	Intermediate-Advanced	645 kilotonnes	16%	90%
Loblaws	Big Business	\$60.92 b	Semiconductors / AI Hardware	4	6	Early-Intermediate	3.65 million metric tons	100%	71%

Appendix 2: Python code

```
# Step 1: Import necessary libraries
import pandas as pd
import numpy as np
from scipy import stats
import matplotlib.pyplot as plt
import seaborn as sns
import nltk
from nltk.corpus import stopwords
from collections import Counter
import re

# Step 2: Load Excel
file_path = '/content/drive/MyDrive/Selected_Variables_Row_Format.xlsx'
df = pd.read_excel(file_path)

# Step 3: Clean ai_maturity_level (remove tab characters)
df['ai_maturity_level'] = df['ai_maturity_level'].str.replace(r'\t+', '', regex=True).str.strip()

# Step 4: Convert numeric-like fields to numeric
df['renewable_energy_percent'] = pd.to_numeric(df['renewable_energy_percent'], errors='coerce')
df['waste_recycled_percent'] = pd.to_numeric(df['waste_recycled_percent'], errors='coerce')
df['ai_use_case_esg'] = pd.to_numeric(df['ai_use_case_esg'], errors='coerce')

# Step 5: Subset f

# Step 5: Subset for analysis
startups = df[df['org_size'].str.contains("Startup", na=False)].iloc[0:3]
large_firms = df[df['org_size'].str.contains("Big Business", na=False)].iloc[0:3]

# For demo, simulate blog data from company description
nltk.download('stopwords')
stop_words = set(stopwords.words('english'))
```

```

# ✅ QUANTITATIVE ANALYSIS (Large Firms)
# =====

print("\nDescriptive Statistics (Large Firms):")
print(large_firms[['ai_use_case_esg', 'renewable_energy_percent', 'waste_recycled_percent']].describe())

# Pearson Correlation
print("\nPearson Correlation Matrix:")
correlation_matrix = large_firms[['ai_use_case_esg', 'renewable_energy_percent', 'waste_recycled_percent']].corr()
print(correlation_matrix)

# Linear Regression
import statsmodels.api as sm
X = large_firms[['ai_use_case_esg']]
X = sm.add_constant(X) # add intercept
y = large_firms['renewable_energy_percent']
model = sm.OLS(y, X).fit()
print("\nLinear Regression Summary (AI use -> Renewable %):")
print(model.summary())

# =====
# Optional: Plot
# =====
sns.scatterplot(data=large_firms, x='ai_use_case_esg', y='renewable_energy_percent')
plt.title("AI Use vs Renewable Energy %")
plt.xlabel("AI Use for ESG")
plt.ylabel("Renewable Energy %")
plt.grid(True)
plt.show()

import pandas as pd
import numpy as np
from scipy.stats import chi2_contingency

# Step 1: Create a contingency table
contingency_table = pd.crosstab(df['ai_maturity_level'], df['org_size'])

# Step 2: Define function to compute Cramér's V
def cramers_v(confusion_matrix):
    chi2, p, dof, expected = chi2_contingency(confusion_matrix)
    n = confusion_matrix.sum().sum()
    phi2 = chi2 / n
    r, k = confusion_matrix.shape
    return np.sqrt(phi2 / min(k - 1, r - 1))

# Step 3: Run Cramér's V
v = cramers_v(contingency_table)
print(f"\nCramér's V (AI Maturity vs Org Size): {v:.4f}")

```