DETAILED REPORT ANALYSIS

ENVIRONMENTAL AND SOCIAL LIFE CYCLE ASSESSMENT OF TWO END-OF-LIFE MANAGEMENT SCENARIOS FOR COMPUTER EQUIPMENT

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This document provides a comprehensive summary of a life cycle assessment (LCA) report prepared by the Interuniversity Research Centre for the Life Cycle of Products, Processes and Services (CIRAIG) and the **AG**ÉCO Group. The full report is available in French only (http://www.recyc-quebec.gouv.qc.ca/client/fr/rubriques/documentation.asp?idTypeLib=28).

Initially founded under the leadership of Polytechnique Montréal in collaboration with Université de Montréal and HEC Montréal, the CIRAIG was created to meet the demands of industry and governments to develop leading edge academic expertise in sustainable development tools. The CIRAIG is the only life cycle research center in Canada and is also one of the largest internationally.

The **AG**ÉCO Group has been active in the fields of agricultural, agrifood and environmental economics, sustainable development and corporate social responsibility for 10 years. The **AG**ÉCO Group has a team of versatile and experienced professionals who master both the research and analysis of primary data (surveying, focus groups, face to face interviews), the research of secondary data (review of relevant studies and publications, statistical data) and can thus provide unique, customized, and updated results. The **AG**ÉCO Group has a unique expertise in the field of socio-economic life cycle assessment. They have produced the very first implementation projects under this innovative methodology over the course of the last two years.

NOTE TO READERS:

Since this study was carried out in order to support a comparative assertion intended for public disclosure, a critical review was conducted by a committee of interested parties chaired by two LCA experts (an expert for the environmental component and an expert for the social component). Although this study meets the requirements of ISO 14044 (2006), and no significant non-compliance to the Guidelines for Social life cycle of products (UNEP, 2009) was found, the review committee wished to highlight some key points that warrant attention when conducting a public disclosure, but which exceed the scope of the LCA study. These comments are presented in the final report of the review committee, available in Appendix E of the final LCA report (in French only).

Finally, any use of the name CIRAIG, Polytechnique Montréal, or the **AG**ÉCO Group in communications for public disclosure, associated with this project and its results, aside from making this report available, are subject to prior written consent of a duly authorized representative from CIRAIG, Polytechnique Montréal or the **AG**ÉCO Group.

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Extended Abstract

Background

RECYC-QUÉBEC has mandated the Interuniversity Research Centre for the Life Cycle of Products, Processes and Services (CIRAIG) and the **AG**ÉCO Group to perform and document a comparison study, using the life cycle assessment (LCA) methodology, of two end-of-life management scenarios for used computer equipment, namely refurbishing and recycling.

The refurbishing scenario covers the operation of companies, such as Insertech-Angus, and some CFERs (*centres de formation en entreprise et récupération*), which consists of disassembling used computers from ICI (industries, commercial businesses and institutions) and reassembling them in order to produce units in good working order, for sale to individuals or institutions. Refurbishing computer equipment that still carry value in terms of usability allows for their reuse by users with less demanding requirements in terms of performance, or with an inadequate budget to purchase a new computer. This reuse leads to an extended product's life, resulting in reduced material and energy consumption for the production of new computers. It can also allow users, who would otherwise not be able to afford it, to possess their own computer equipment.

The recycling scenario involves companies that disassemble and separate the components in used computers in order to produce recycled raw materials. Recycling of computer equipment makes it possible to recover numerous materials found in computer products.

This study was conducted within the framework of a draft regulation issued by the Ministère du Développement durable, de l'Environnement et des Parcs (MDDEP) on the recovery and enhancement of products by companies. This regulation promotes the 4Rs approach in the development of end-of-life management programs for electronic products. This approach favours, in the following order: reduction, reuse, recycling and recovery. Such a regulation could potentially lead to the refurbishing of material that would otherwise have been treated directly by recyclers. In order to ensure that the regulation will reduce the end-of-life impact of computer equipment and generate social and economic benefits, it is necessary to compare the environmental and social performance of the two treatment options, namely refurbishing and recycling. As an important part of the refurbishing activities is performed by social integration and workplace training companies, adding a social component to this LCA study appeared particularly interesting. Moreover, an overview of the reuse sector was carried out simultaneously to the LCA study, and while the results of this overview could not be fully used to structure survey data collection, they were nevertheless useful for the result analysis stage.

Objectives

This study aims to assess the potential environmental and social impacts associated with two end-of-life management scenarios for used computer equipment, which are refurbishing and recycling, using the life cycle assessment (LCA) methodology. Its main goal is to identify and compare the key parameters and social and environmental hotspots of these two treatment options for computer equipment. It also seeks to validate the 4Rs ranking order for the two end-of-life management options of used computer equipment (computers, CRT monitors and LCD screens), namely refurbishing prior to reuse and recycling.

General Methodology

The environmental comparison study was conducted based on the life cycle assessment (LCA) methodology, as defined by the International Organization for Standardization (ISO) for comparative assertions disclosed to the public (ISO 14040 and 14044, 2006). LCA allows for a holistic understanding of all the environmental impacts throughout a product's life cycle, to ensure that an impact avoided in a certain life cycle stage does not generate impacts in other stages. A social comparison study was also carried out using the LCA methodology with respect to UNEP guidelines (2009).

As the draft regulation targets major information technology (IT) parks, the principal function of the study is to be able to "manage the end-of-life of computer equipment from ICI (industries, commercial businesses and institutions)". The functional unit is defined as "managing the end-of-life of 1,000 computers or 1,000 monitors (CRT or LCD) belonging to an IT park". These systems, however, are multifunctional, that is to say that in addition to managing the end of life of the hardware, certain products are produced, including:

- Reusable computer hardware in the case of reuse for office use;
- Recycled raw material in the case of recycling, which prevents the use of virgin raw material.

The LCA methodology, however, requires that the systems being compared be equivalent from a functional perspective. To restore balance, the activities or products that would normally offer these functions in the study system are credited. In order to achieve this, an assumption was made that the refurbished hardware replaced new hardware which would otherwise have been used had the refurbished product not been purchased. Impacts avoided, whether impacts associated with the production, use, or end-of-life management of this new product are credited with the refurbishment scenarios in the environmental assessment. In a similar manner, the impacts associated with the production of virgin material, which would be produced if recycled material was not available, are credited to the recycling process, included in each of the two systems compared. In the social assessment, however, the impacts associated with the production of new material were not measured due to practical reasons for data collection, and also because the objectives of the study primarily targeted the social and economic impacts occurring in the Quebec region (province of Canada). Figure 1 presents a schematic of the system boundaries in this study.

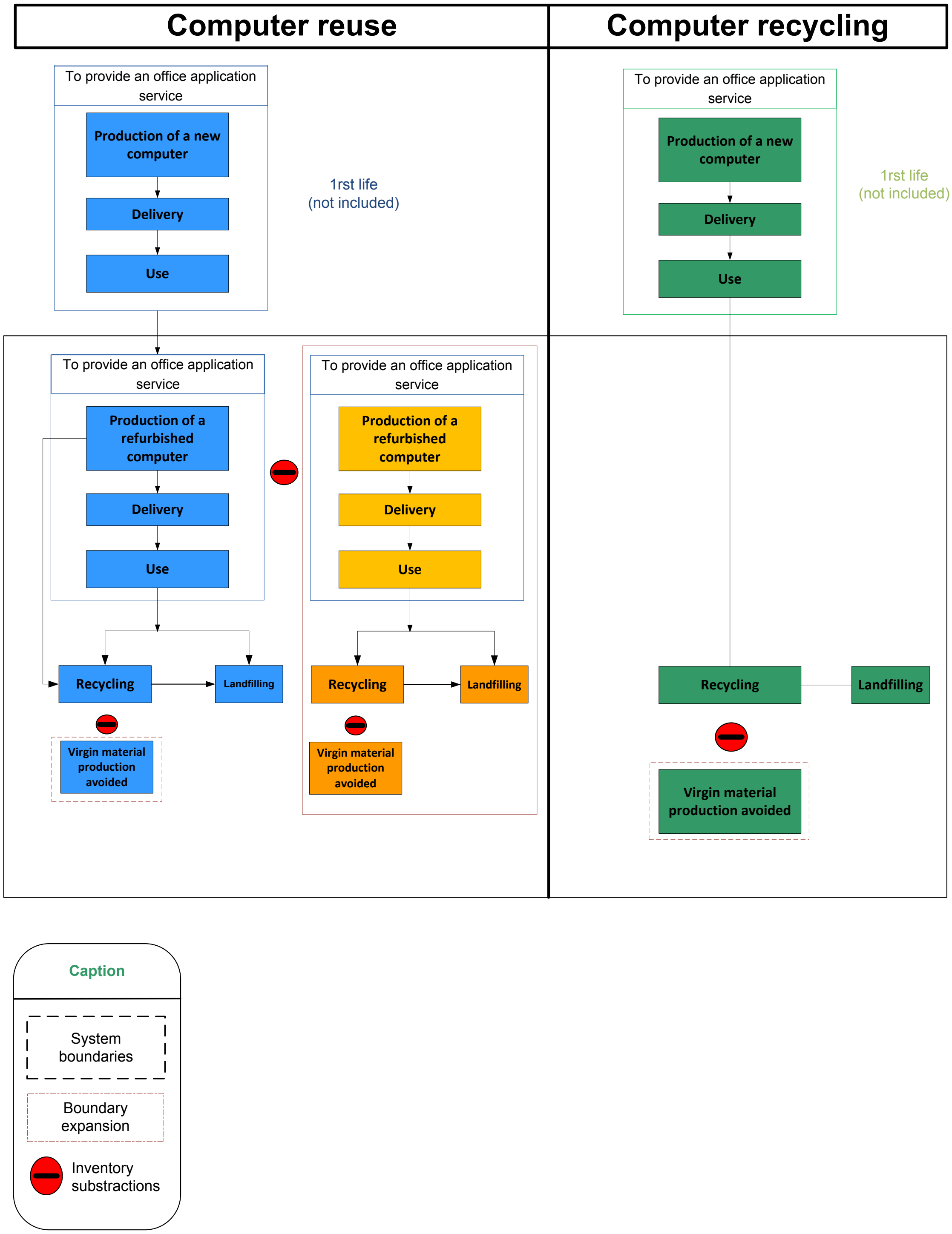

Figure 1: System boundary expansion to restore functional equivalence for systems comparison.

Although there is no reliable data to quantify it, there would be a certain proportion of refurbished equipment that would be sent to the landfill rather than recycling at the end of its second use. This would lead to a shift of potential impacts by diverting hardware from the recycling path to the landfill. To take into account this risk and to assess the resulting impact displacements, refurbishing scenarios consider different levels of recycling for the end-of-life of the refurbished equipment (0, 50 and 100% for the environmental assessment and 0 and 100% for the social assessment).

Specific methodology for the environmental component

The modeling of scenarios for the environmental assessment is based around eight key steps:

- Collection of used hardware;
- Refurbishment;
- Distribution;
- Use (energy consumption);
- End-of-life in a landfill;
- Recycling;
- Recycling of unrecoverable material from the refurbishing process;
- Credits for the life cycle of new computer hardware (by reusing refurbished computer hardware, it is assumed that the production, use and management in the end-of-life of new computer equipment is avoided).

The data used was retrieved from different contributors in the refurbishing and recycling sector for computer equipment and also from literature. Missing data for the environmental assessment was completed using the ecoinvent 2.01 European database. The life cycle impact assessment (LCIA) was conducted using the scientifically recognized IMPACT 2002+ method (Jolliet et al. 2003; Humbert et al., 2005).

Results of the environmental assessment

Figure 2 below shows the environmental component of the comparative results for scenario 1, which corresponds to the management of computers (scenarios 2 and 3 pertain to CRT and LCD screens, respectively). These results are presented for each of the four damage categories in the IMPACT 2002+ method (namely Human Health, Ecosystem Quality, Climate Change and Resources).

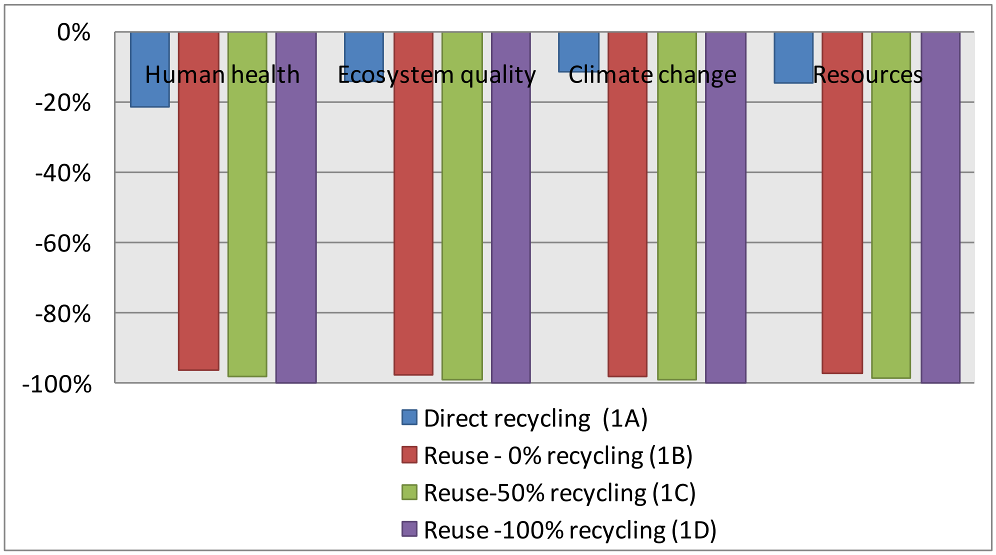

Figure 2: Score comparison for the four damage categories for the end-of-life management scenarios of computers (IMPACT 2002+).

The values presented in Figure 2 are net results: the scores combine the generated impacts as well as the credits gained. Negative scores mean that avoided impacts outweigh the generated impacts, and therefore the scenario can have potential environmental benefits. Thus, in both sectors, the environmental benefits generated through the prevention of virgin raw material use in the case of recycling, and avoiding the production of a new computer by using a refurbished computer, outweigh the impacts associated with the refurbishing or recycling operations. For each damage category, the scenario that has the -100% result is the scenario with the balance (or net result) that is the most beneficial from an environmental perspective, as it generates the greatest benefits compared to its impacts. It is thus clear that the refurbishing path is the most advantageous from an environmental standpoint - this holds true for all of the damage categories that were studied. Figure 2 also shows that the rate of recycling at the end of the second life has little influence on the overall results. This is explained by the strong contribution of the avoided impacts associated with the life cycle of new equipment, credited to the system for reusing (system hotspot). Thus, even when assuming that the refurbished hardware is sent entirely to the landfill, the impacts generated by landfilling are negligible compared to the avoided impacts of the production of new equipment. It should however be noted that there is currently no impact model that takes into account the long-term impacts of landfilling, and therefore the impacts of landfilling are perhaps underestimated.

Figure 3, presented below, shows the results for the computers in the climate change category, based on greenhouse gas (GHG) emissions. It is notable that the credit gained by avoiding the impacts associated with the life cycle of a new computer is dominant. This is highlighted in green in the figure.

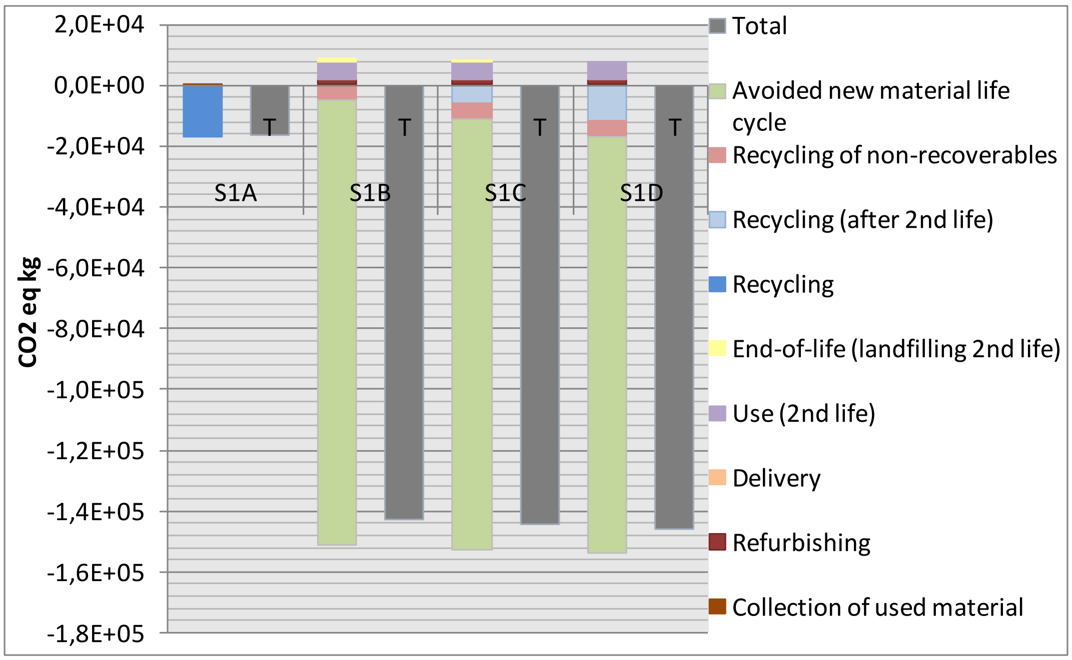

Figure 3: Contribution of the stages and total scores for the computer scenarios, climate change category (IMPACT 2002+).

The figure shows the contributions of the main steps for the systems under consideration. It illustrates the impacts generated by certain steps (energy consumption during the use phase in the second life, ...) and the environmental benefits from other steps, gained as credit (recycling, avoided life cycle impacts of new equipment, ...). The gray bar represents the balance (or net value) for the scenario. It shows that the benefits clearly outweigh the impacts generated, as the final score is negative (kg CO_2 eq. avoided).

Thus, in this damage category, for every 1,000 used computers sent to the refurbishing industry (which results in 704 refurbished computers), the reductions in GHG emissions are between 143 and 146 tons of CO_2 eq., depending on the recycling rate at the ultimate end-of-life of the computers. The same 1,000 computers sent to the recycling industry provide reductions of approximately 16.6 tons of CO_2 eq.

At first glance, one could think that the second life of the equipment could create a shift in the potential impacts, related to the energy consumption in this added use phase. A reversal in the results could be an anticipated concern, but the study results show that this isn't the case, even if the refurbished devices consume slightly more energy than new devices. The increase in impacts during the use phase of refurbished equipment is negligible compared to the avoided impacts associated to the production of new equipment.

Various sensitivity and uncertainty analyses confirm the robustness of the results. Methodological choices regarding how to model recycling affect the absolute results, but only slightly modify some comparative conclusions. The many assumptions made, on recovery rates among others, do not seem to generate a bias that could affect the conclusions of the study.

The LCIA method chosen, IMPACT 2002+, provides reliable results, which were validated using the sensitivity analysis of the ReCiPe (H) method. Both methods, although based on significantly different models, showed similar trends and thus confirmed the robustness of the conclusions.

As for the end-of-life management of the monitors, trends in the results are the same as those for the computers: refurbishing appears more favourable from an environmental perspective. Similar to above, avoiding new equipment and the gained associated environmental credits dominate the results.

Specific Methodology for the social component

The social LCA methodology is much younger than its environmental counterpart. It is still at a stage of theoretical development, and so the tools for its implementation are virtually non-existent. Despite the embryonic nature of social LCA, the desire and necessity to take into account the three pillars of sustainable development in the formulation of public policy, pushed in favor of the addition of a social component in this LCA. This study constitutes an early attempt to operationalize and integrate a social dimension into LCA, and shall be regarded taking into account all the limitations that such an exercise entails.

The social component of this study focuses on the same steps as the environmental component, with the exception of the steps concerning the production of a new computer and landfilling in the reuse scenarios. In the case of landfilling, it was noted that the difference in impact induced by the disposal of additional computers in the landfill for the stakeholders involved in this step was negligible, especially for the social aspect, and did not justify extra data collection focused on the landfill. For similar reasons related to the collection of data, and also because the objectives of the study favoured the documentation of impacts occurring in Quebec, the production of new computers was not documented.

Social LCA, rather than focusing on material and energy flows, is interested in social relationships established between the actors or stakeholders in any life cycle stage. Data collection for social measures therefore needs to initially allow the identification of the stakeholders, that is the groups of actors that are likely susceptible to impacts, whether positive or negative, resulting from one or multiple stages of the life cycle of the products studied, and then to identify those impacts. In the "*Guidelines for social life cycle assessment of products*"[1], five categories of stakeholders with whom the impacts can be observed, and six broad categories of social and socio-economic impacts, have been identified (Table 1). These categories each have numerous sub-categories that correspond to the documented impacts. For each impact sub-category selected for analysis, indicators have been developed. These indicators are qualitative, semi-quantitative or quantitative, as appropriate. In accordance with the guidelines, an additional stakeholder category was added: youth in integration and training programs

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[1] United Nations Environment Program, guidelines for social life cycle assessment of products, 2009.

Table 1: Categories of stakeholders and impact categories of social LCA

Stakeholder categories	Impact categories
Workers	Human rights
Consumers	Working conditions
Local Community	Health and safety
Society	Cultural heritage
Value Chain Actors	Governance
Youth in integration or training program	Socio-economic repercussions

Derived from UNEP (2009)

Most of the data used were collected from a limited number of companies in the computer equipment refurbishing and recycling sectors, using interview guides and questionnaires. The companies surveyed in the reuse sector are social integration and workplace training companies. The companies surveyed in the recycling sector are for-profit, private businesses. These companies are representative of the predominant model in each of the scenarios, but each scenario has both types of companies (social organizations and for-profit organizations).

To document the presence of potential social risks, a rating scale is used with three levels (low, moderate, high):

Semi-quantitative rating scale for the risk assessment of negative impacts		
■ High risk	◆ Moderate risk	● Low risk

Translating the indicator results into risk levels is based on expert judgment. Rating scales were developed for each indicator.

When possible, the social benefits were assessed on a scale with four levels (no benefits, low benefits, moderate benefits and high benefits). As with social risks, the qualitative or quantitative indicators used for measuring the benefits determine the method of evaluation.

Semi-quantitative rating scale for the assessment of benefits			
0 No benefit	+ Low benefits	++ Moderate benefits	+++ High benefits

Some indicators could not be translated into a semi-quantitative scale. In this case, a Yes/No statement indicates the presence or absence of benefits.

Key findings of the social LCA

Overall, the results demonstrate greater social and economic benefits for reuse, for all stakeholders. Table 2 presents the results for each stakeholder category, comparing reuse followed by recycling (second life), and direct recycling of computer equipment.

Table 2: Social risks and socio-economic benefits by stakeholder category, comparing reuse followed by recycling (second life), and direct recycling

Impact Sub-Category	Indicator	Reuse followed by recycling	Direct recycling
Society			
Public commitment on sustainability issues	Public commitment related to sustainable development	++	++
Compliance with the 4Rs approach	Nature of the activities in relation to the 4Rs approach	●	◆
Contribution to economic development	Job creation	+++	+
	R&D investments	Yes	Yes
	Added-value creation	+++	+
Local communities			
Community engagement	Volunteer work, sponsorship, financial support and other participation in community organizations and initiatives	+++	+
	Commitment with and involvement of community stakeholders	●	●
	Neighbourhood-related problems and annoyances (noise, odours, heavy trucking, visual annoyances, etc.)	●	●
Local employment	Local employment preferences (production jobs, executive jobs)	+++	+++
	Buy-locally practices and policies	Yes	No
Access to material resources	Access to computer equipment	Yes	N/A
Access to immaterial resources	Access to community-based services	+++	0
	Access to citizenship (reduction of digital gap)	Yes	No
Youth in integration and training program			
Access to non-material resources	Access to training	Yes	N/A
	Access to labour market	Yes	N/A
Access to material resources	Access to a salary	Yes	N/A

Impact Sub-Category	Indicator	Reuse followed by recycling	Direct recycling
Workers			
Salaries	Average salary of production workers	●	●
	Transparency of collective bargaining or wage conditions	●	●
Hours of work	Number of hours per week of work	●	●
	Paid overtime	●	●
Equal opportunities	Equal employment goals	●	●
	Policies for controlling discrimination	●	●
Health and safety	Health and safety training	●	●
	Number of accidents reported to the CSST	●	●
Benefits and social security	Working conditions offered	++	+
Consumers			
Feedback mechanisms	Monitoring customer satisfaction	●	●
	Product warranties	●	●
End-of-life liability	Information and services available regarding the end-of-life of the product	●	N/A
Responsible purchasing	Possibility of a purchase that conforms to sustainable development ethics	Yes	N/A
Actors in the value chain			
Relations with suppliers	Respect for confidential data	◆	●
Promotion of social responsibility	Responsible procurement policy	++	0
	Responsibility for the end-of-life of products	++	+++

Reuse activities generate additional economic benefits to direct recycling by creating jobs and giving back a value to an asset that had little or none. The reuse system facilitates access to computer resources for people experiencing poverty or social exclusion, and offers computer training to communities (training on the use of a computer, accessing on-line government services, etc.). Access to computers for these groups of individuals promotes equal opportunities for the democratization of knowledge and access to citizenship. The social integration activities and workplace training associated with the reuse sector generate benefits for youth struggling with exclusion or academic underachievement. These youth, facing difficulties in integrating the workforce, the education system, and/or society, can benefit from professional training and an initial paid work experience. These skills enable youth to integrate or reintegrate the labour market or the school system and, for some, to free themselves from economic dependence. Finally, the industry can reuse the implementation of the 4Rs approach, thus contributing to the Quebec society values and allowing consumers to engage in a purchase that is in line with the personal ethics of sustainable development, a purchase that minimizes environmental footprint and promotes social development. The lack of a certification to ensure the protection of confidential data and ecological disposal of products at the end-of-life, however, is a challenge for the reuse sector.

A second comparison was made to reflect the assumption where the reused material is not recycled at the end of its second use, but is rather sent to a landfill. Table 3 presents the indicators for which results are different from the first comparison.

Table 3: Social risks and socio-economic benefits by stakeholder category - comparison of reuse without recycling and direct recycling

Impact sub-category	Indicator	Reuse without recycling	Direct recycling
Society			
Compliance with the 4Rs approach	Nature of the activities in relation to the 4Rs approach	◆	◆
Contribution to economic development	Job creation	++	+
	R&D investments	0	++
	Added-value creation	++	+
Actors in the value chain			
Promotion of social responsibility	Responsibility for the end-of-life of products	+	+++

The low recycling rate of computers by individuals and small organizations leads to non-compliance with the 4Rs approach, since after the second use, the reused material is sent to a landfill rather than recycled. As we know, landfilling is the last level of the approach, namely disposal. As such, landfilling should be given an elevated risk score. However, since landfilling follows a step of reuse, we cannot assign a score corresponding to the last level of the rating scale. Indeed, this scenario requires us to put the reuse/disposal case with the recycling case into perspective and to establish a hierarchy between these two cases. The answer to this dilemma must therefore come from comparing the environmental impacts of the two scenarios as the 4Rs approach is based on an environmental analysis. The environmental LCA has demonstrated the superiority of reuse over recycling, even when the material is landfilled at the end of its second life. It should be noted that this result is only valid under the assumption that refurbished computers are a substitute for new ones. This assumption is debatable and we have no data to assess the proportion of customers who would have purchased a new computer if refurbished computers had not been available.

Given the uncertainty about environmental impacts, it is interesting to look at the balance in terms of the social impacts. This is nothing more than putting the social benefits of reuse with the environmental impacts of landfilling into perspective. The fact that the material is directed to a landfill after the second use does not reduce the social and economic benefits of reemployment activities (job creation and added value), but deprives the society of social and economic impacts of recycling (investment in research and development, job creation and added value), hence the score in these three sub-categories for system reuse changes. This reduction, however, is not sufficient to reverse outcome for the higher economic and social benefits of the reuse system. Indeed, the impacts on the local community and youth inclusion, or on training associated with the reuse system remain unchanged, and are clearly superior to the recycling system because of the social economy perspective of these business strategies.

Finally, although the reuse system has commitments to accountability at the end-of-life towards its PC suppliers, it cannot guarantee these suppliers that the reused equipment will be recycled and reuse cannot provide a report for this equipment. For this reason, the score in this category was changed from moderate benefits to low benefits.

Main limitations of the study

This study used data from recycling and refurbishing businesses that use the standards of professional practice in their industry and correspond to the dominant business model in their respective sectors. Thus, the results may not be representative of some companies that do not fit the dominant business model or do not operate under professional practice (for example, a company that exports its waste abroad).

This study, which fits within the context of implementing extended producer responsibility regulations, does not cover possible end-of-life options for computer equipment, such as landfilling and incineration. As a matter of fact, the objective of the mandate was to determine which of the two alternatives considered in the regulation, namely direct recycling or refurbishing for reuse, have the greatest impacts, or potential benefits, in both environmental and social contexts. Similarly, exporting computer hardware at its end-of-life and the resulting impacts were not considered, since the study was conducted within the framework of draft regulations that already contain specific requirements for the companies involved.

It is also important to note that the model used for the environmental component of this study is based on the main hypothesis that using refurbished computer hardware prevents the purchase of new computer hardware by consumers. Environmental LCA, from a methodological point of view, requires functional equivalence. It is therefore appropriate to "credit" the avoided impacts associated with the life cycle of new computers to the scenarios in which the refurbished equipment provides service. This is justified by the assumption that in the absence of refurbished computer hardware, users would buy new computer hardware. Without this assumption, it would have been very difficult to make the systems functionally equivalent. Indeed, it is possible that users would not buy a new computer and decide to have other activities at home instead (watch television, go to an internet cafe, etc.). However, the wide variety of possible alternative activities generated such a significant uncertainty that their inclusion would have undermined the quality of the results. This essential hypothesis therefore poses an important limitation to the extrapolation of results to all contexts of users of refurbished computer equipment. This limit is also highlighted by the social aspect, which takes into account the impacts associated with giving computer access to individuals who otherwise would not have access.

From a methodological standpoint, it is also important to note that the IMPACT 2002+ impact assessment method does not include long-term emissions of the computer hardware at the landfill. In particular, the potential leakage of contaminants such as lead, cadmium, beryllium, and mercury into groundwater are not evaluated. This absence can be compensated by the development of characterization factors that would take long-term impacts of emissions from landfills into account. Despite the current lack of knowledge, it is possible to state that the characterization of these emissions will lead to increased impacts for the landfill, however it is difficult to quantify to what extent.

For the social aspect of LCA, it should be noted that several variables are more subjective in nature. The reliance on expert judgment for scoring -rather than the outcome of a measurement- adds to the subjective nature of this tool. A fundamental limitation of the social LCA tool is that it is still under development, and there aren't many references available for use in the evaluation process. For this reason, we felt it was important to provide as much transparency as possible on the implementation conditions, in order to contribute to the advancement of this field.

Despite the limitations mentioned above, the results of this study lead to the conclusion that favouring reuse of functional computer hardware is justified on an environmental basis, and that it generates potentially higher social and economic benefits in a global perspective.

Conclusions

This environmental and social life cycle assessment was conducted in accordance with the international standards ISO 14040 and 14044 and UNEP, to ensure that the results are consistent with best practice, and are based on up-to-date scientific knowledge.

This study clearly shows the net environmental benefits of refurbishing used computer hardware compared to direct recycling for an IT park. Recycling recovers materials that will prevent the production of virgin materials. For its part, the refurbishment can extend the useful life of computer hardware that will delay the requirement for the production of new computer hardware. Since the total impact resulting from the production of new computer hardware is much higher than the sum of the impacts associated with the production of virgin resources used in manufacturing, the environmental benefits of refurbishment is much higher than that of recycling, and that holds true for all the damage categories. The hot spot that emerges from this study is related to the credits associated with the prevention of manufacturing new computer hardware.

According to the results obtained from the environmental aspect of the study, it can be confirmed that the 4Rs approach -which is at the heart of the draft regulation issued by the Ministère du Développement durable, de l'Environnement et des Parcs (MDDEP) on the recovery and enhancement of company products- is respected for the end-of-life management of computer hardware in IT parks.

It is important, however, to keep in mind that the model under consideration assumes that refurbished computer hardware must replace devices that provide an equivalent service. In this study, the equivalent service would have been fulfilled using new computer hardware. This assumption may not be representative of the whole refurbished products sales market as it only concerns consumers who would have purchased a new computer if refurbished products had not been available. It therefore limits the extrapolation of these results to all the products refurbished in Quebec. This comparison raises concerns, however, since a user who cannot fulfill his computer needs might compensate by several other hypothetical actions (for example, watching television, go to an Internet café, etc.) that would also cause environmental impacts. It is therefore essential that the systems compared with the LCA tool are equivalent in terms of function.

The environmental assessment results are supported by the social assessment results, which confirm higher social benefits in the reuse system in comparison with direct recycling. In addition to complying with the 4Rs approach, the reuse system yields higher benefits in comparison to direct recycling for the society, local communities, youth inclusion and training, and the promotion of social responsibility to other actors in the value chain. The main benefits associated with reuse are related to higher economic benefits, access to material and immaterial resources for local communities, youth integration or training, community involvement demonstrated by companies, and providing the opportunity of reuse to consumers wanting to practice the personal ethics of sustainable development. On the other hand, the reuse sector does not provide the same guarantees as the recycling industry with respect to the protection of confidential data and end-of-life liability (ecological recycling), because it does not have demanding certifications in this area. However, this can be more considered as a risk rather than a confirmation that confidential data are not well protected or that products are disposed of in a non-responsible manner. As for the environmental assessment, the results in terms of benefits are not inversed if the reused hardware is diverted for recycling at the end of its second use.

Some of the social impacts assessed in the LCA are related to the product being studied, while others are more related to the nature or behaviour of the businesses that deal with the products themselves. In Quebec, the reuse sector is made up of a large number of social businesses and many of the impacts documented in this study arise from the activities of social integration or training in the workplace of these companies. Only a few impact sub-categories are directly associated with the nature of the product itself, the refurbished computer. It can be argued that the social impacts from insertion activities and training attributed to the refurbished computers are incidental and should rather be attributed to the social businesses themselves. And yet, on the contrary, life cycle assessment is precisely intended to take into account all the impacts generated by the product, including those associated with the behaviour of businesses involved through its entire life cycle. In this regard, considerations pertaining to social impacts of social insertion and training in the workplace as well as specific social corporate behaviour is coherent with the essence of social life cycle assessment.

The social life cycle assessment conducted in this study was based on UNEP's Guidelines published in 2009. However, social life cycle assessment is an assessment method for social impacts that is still under development, and which currently has few concrete documented applications. This current project, instigated by Recyc-Québec, represents an important step to advancing this field by providing a real case study, that of computer reuse and recycling.

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