UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Zero Emissions Through Zero Waste:

Reducing Greenhouse Gas Emissions at UBC Through Waste Reduction

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Executive Summary

The purpose of this study was to quantify the lifecycle greenhouse gas emissions associated with office furniture at UBC, in order to estimate the emissions savings achieved by diverting surplus products from the landfill. This paper is accompanied by an excel-based modelling tool in which GHG emissions calculations were carried out. This study was done to inform updates to the UBC Climate Action Plan and Zero Waste Action Plan.

The long-term goal of UBC's Climate Action Plan is to achieve net zero campus emissions by 2050, with a 67% emissions reduction by 2020 [1]. The current target of the Zero Waste Action Plan is to achieve 80% diversion of campus solid waste away from landfill by 2020 [2]. UBC is not on track to meet its current emissions target or waste diversion target. Additionally, UBC does not currently track or report on scope 3 emissions. The latest version of the UBC GHG inventory only reports on scope 1 emissions (direct emissions from owned/controlled resources), scope 2 emissions (indirect emissions from the production of purchased energy), and paper usage. Consequently, the current CAP only accounts for and aims to reduce scope 1, 2 and paper emissions. Emissions from furniture production and disposal fall into the category of scope 3 emissions – indirect emissions that occur in the value chain of a reporting company.

If UBC wants to reach long term emissions and waste related goals, it must begin to account for scope 3 emissions. This study serves as a preliminary investigation into the impact of emissions from furniture production and waste management.

The current annual furniture spending at UBC is estimated at $6 million, and a previous SEEDS study estimated that 400 tonnes of furniture was disposed of by the university in 2018 [3]. This is a substantial amount of furniture being manufactured, shipped to campus, and disposed of every year, and all of those processes in the lifecycle of a furniture item produce GHG emissions.

Based on the modelling tool produced in this study, the lifecycle GHG emissions produced by the 400 tonnes of furniture disposed of in 2018 were equal to 1,718 tonnes of CO_2e. If 100% of the $6 million worth of furniture purchased every year is eventually sent to landfill, it has an associated lifecycle GHG emission of 3,897 tonnes of CO_2e. The 3,897 tonnes of CO_2e produced over the lifecycle of campus furniture annually is greater than 10% of the current total campus emissions from scope 1 and 2 sources and paper [16]. This is quite a substantial amount of emissions coming from material production and waste management for campus furniture alone. The magnitude of this figure suggests that UBC scope 3 emissions are likely very high, and the university should take steps to track, report, and reduce these emissions.

In the case of furniture, over half of the total lifecycle emissions associated with products being disposed of can be saved if furniture is reused on campus. This is because reusing furniture eliminates the need for manufacturing replacement products and does not produce any waste material that must be managed.

Based on the findings of this study, it is recommended that UBC implement a furniture reuse program on campus, such as the one suggested by Carissa Kirk in a previous SEEDS study [3]. It is also recommended that UBC implement more sustainable furniture purchasing practices, and conduct a follow up study to this project to improve the accuracy of emissions data.

1.0 Purpose

This study aimed to develop estimates of lifecycle greenhouse gas (GHG) emissions associated with waste products at the University of British Columbia (UBC) in order to quantify the potential for emissions savings by reusing surplus products, with a focus on office furniture. A spreadsheet-based modeling tool was created for this project, in which users can compare the emissions impact of various waste-management and circular-economy practices. It will serve to influence UBC's next update to the Climate Action Plan, CAP2030, which will define the universities emissions reduction activities and targets over the next 10 years.

The primary target of UBC's Climate Action Plan (CAP) is to achieve net zero emissions by 2050, with a 67% emissions reduction by 2020. Unfortunately, 2020 emissions targets have not been met. Additionally, GHG emissions associated with waste and materials are not currently included in those targets [1]. Waste and material emissions fall under scope 3 emissions, or indirect emissions that occur in the value chain of a reporting company [6]. UBCs CAP currently only accounts for scope 1 (direct emissions from owned/controlled resources) and scope 2 (indirect emissions from the production of purchased energy) [6].

In December 2019, UBC endorsed a declaration on the current state of climate emergency. In accordance with the Paris Agreement goal of limiting global warming to 1.5°C, the declaration includes commitments to accelerating action on emissions reductions, and to broadening the scope of CAP to extend beyond the university's direct operation. The latest version of the action plan, CAP2030, aims to account for scope 3 emissions in areas such as commuting, air travel, food, materials, and waste.

In 2010, UBC also began the development of a Zero Waste Action Plan, which outlined goals and actions for the university to move towards a zero-waste community, ie. one in which unwanted products and materials are utilized as resources that can be reused, and virtually zero garbage is produced. The primary target of this action plan was to reduce campus waste in accordance with the Metro Vancouver regional diversion targets of 70% waste diversion away from landfill by 2016, and 80% diversion by 2020 [2]. The university has stated that the 2016 targets were not met, and subsequently the 2020 targets will not be met either.

While progress is being made on emissions and waste reduction on campus, the university must take significant action to ensure its long-term goals are met. It has been estimated that roughly 400 tonnes of furniture were sent to landfill by UBC in 2018 [3], and due to lack of centralization and reporting practices, current numbers of furniture waste are not accurately known. Preliminary investigations have indicated promising financial benefits of reusing furniture on campus, but the contributions to scope 3 emissions are yet unknown. This study aims to quantify the emissions impact of office furniture waste, and thus demonstrate the potential for GHG and waste savings through reuse rather than disposal.

A study conducted at the University of Cambridge to analyze scope 3 emissions determined that over 70% of the university's total emissions were from scope 3 sources. Of those, around 3% were associated with material waste, and 52% were from goods and services procurement [4]. These results suggest that UBC's scope 3 emissions are likely also a significant portion of total GHGs, and that there is huge potential for emissions savings by reusing existing products and purchasing fewer new ones.

2.0 Background

As noted in the previous section, the estimated amount of furniture disposed of by UBC in 2018 was around 400 tonnes [3]. Furniture is disposed of for a variety of different reasons, including damage, lack of a formalized repair process, lack of storage space, lack of a formalized reuse/redistribution process, poor ergonomics, undesirable aesthetics, and building renovations. Other than a small number of single-material objects (ie. metal filing cabinets) which can be recycled more easily than composite products, it is estimated that essentially all this furniture is sent to the landfill. UBC's furniture disposal rates are important to consider not only due to the amount of solid waste produced, but due to the associated lifecycle greenhouse gas emissions.

Throughout a products lifecycle, various processes contribute GHG emissions that pollute the atmosphere and contribute to global warming. According to the US Environmental Protection Agency, the most important greenhouse gases to account for in a lifecycle GHG inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and perfluorocarbons (PFCs) [5]. Carbon dioxide is by far the most abundantly emitted GHG; however, the other gases mentioned are more potent, and thus have a higher warming potential. To simplify units, GHG emissions are reported in terms of CO_2e, or carbon dioxide equivalent units, which account for the total amount of all greenhouse gases produced in terms of their global warming potential relative to that of CO_2.

According to a study done by the Ellen Macarthur Foundation, 45% of all global GHG emissions are associated with making materials, products, and food [9]. The remaining 55% of emissions are from energy production and use. Of the emissions from product lifecycles, an estimated 10.2 billion tonnes CO_2e is produced annually by material processing and manufacturing [9]. That means just over 20% of annual global emissions are coming just from materials.

The lifecycle emissions of these materials and products come from a series of "upstream" processes (raw material extraction, processing, manufacturing, and transportation) that happen before it reaches its user, and a series of "downstream" processes (transportation and disposal) that occur after the product has reached the end of its useful life [6]. While it is easy to consider how production plants and transportation contribute to the carbon footprint of an item, factors such as landfill gas – the emissions produced when organic material in landfills does not decompose properly [5] – are less widely examined. To fully understand the emissions impact of office furniture waste, it is necessary to consider every stage along the products lifecycle. Some examples of GHG sources and savings at different stages of a material lifecycle are identified in figure 2-1 below.

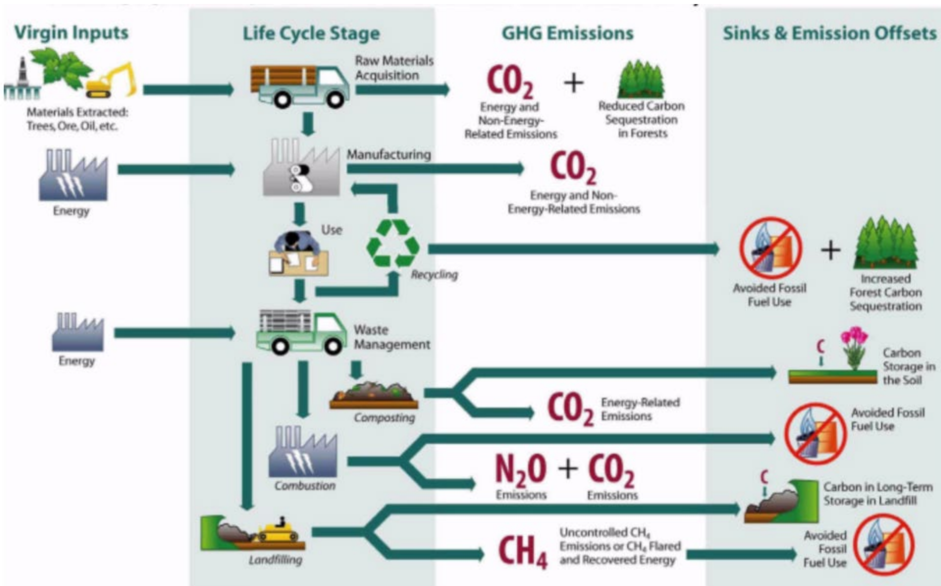

Figure 2-1. Examples of GHG sources and sinks associated with a materials lifecycle [5].

Different materials and products have different net GHG impacts depending on how they are manufactured, used, and disposed of. For unpowered items such as furniture, it is assumed that there are no emissions associated with the use stage of the lifecycle. Analysis has shown that the majority of the emissions associated with furniture products come from the material processing and manufacturing stages [13]. One study found that the manufacturing of metal and plastic alone accounted for around 70% of the GHG emissions for a task chair [7]. Therefore, one of the most effective ways to reduce GHG emissions from furniture products is to manufacture less furniture and reuse existing items for as long as possible. The breakdown of materials and processes contributing to the total emissions of a task chair can be seen in figure 2-2 below. Note that this table only considers the upstream (cradle to gate) emissions of the chair, and emissions are represented as their percentage of total emissions, not as kg CO_2e produced.

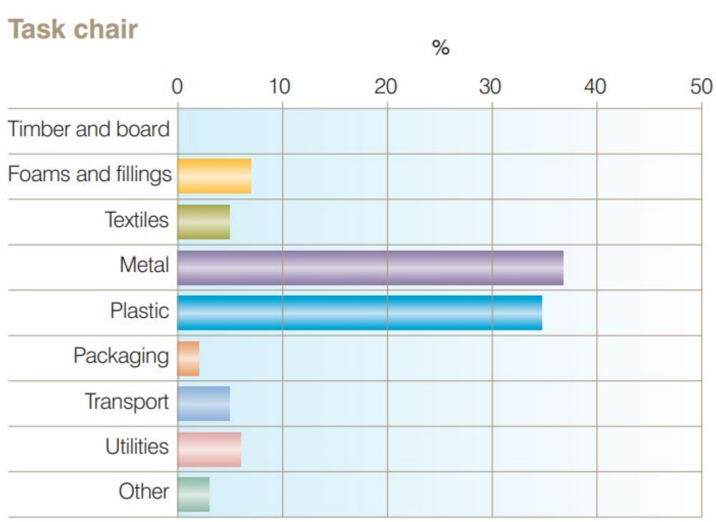

Figure 2-2. Contribution of different processes and materials to the total upstream emissions of a task chair [7].

As can be seen from figure 2-2, transportation makes up <10% of the total upstream emissions of an office chair. The same is also true for other office furniture products. Most of the emissions come from material extraction and processing. The amount and type of material used in a product will change its associated emissions, as metal and plastic processing create more emissions per kilogram than wood does. The specific impacts of different materials are discussed further in section 3.2.

In the United States alone its estimated that 13.5 million tonnes of furniture is sent to end-of-life processes annually. Less than 1% of this furniture is recycled, with nearly all of it being disposed of in landfills [18]. In British Columbia, current landfill emissions are generally considered to be around 4 million tonnes of CO_2e per year, though some analysis suggests they may actually be much higher (in the range of 13-19 Mt per year). Assuming landfill emissions are actually 4 million tonnes of CO_2e per year, this accounts for 6.4% of total annual GHG emissions in the province, which is more than the emissions produced by all BC homes [8]. However, this figure does not account for the lifecycle emissions associated with producing and transporting new material, only those from disposing of existing items. While it is not a furniture-specific figure, it is important to note the substantial carbon footprint that disposing of solid waste in BC has, and that furniture disposal is a contributing factor to those emissions. Methane produced by material decomposition in landfills makes up an estimated 63% of the emissions from solid waste disposal. When it comes to furniture, decomposition of wooden items in landfill have the greatest contribution to methane production. As such, the impact of keeping wooden furniture items from being sent to landfill could be quite substantial.

Waste reduction of furniture can be achieved by applying circular economy practices such as reusing and repairing existing furniture items before disposing of them and purchasing new ones. Circular economy practices aim to decouple economic growth from the consumption of finite resources, by designing out waste, keeping existing materials in use, and regenerating natural systems [9]. In cases where obtaining new furniture is necessary, it is best to choose items that are second hand, or those with longer warranties that are built to last [13]. As mentioned earlier in this section, in the current extractive, “take-make-waste” economy, 45% of global GHG emissions can be attributed to the production of materials, products, and food. Designing products to be reused, repaired, or recycled at the end of their initial lifetime could significantly reduce this contribution, as the production emissions from new items can be avoided.

3.0 Methods

3.1 Introduction

There are different waste disposal and waste mitigation processes that can be used to deal with surplus office furniture at UBC. The end of life processes identified for analysis in this study were reuse, refurbishment, recycling, and disposal (landfill). Although recycling is not currently common practice for surplus furniture on campus, many furniture items have the capability to be disassembled and recycled as their constituent materials [15]. Similarly, furniture refurbishing is not commonly done, but several of UBC’s office furniture suppliers offer refurbishing and repair services that the university could choose to utilize. While Vancouver does have a waste-to-energy facility, no solid waste from UBC is currently sent there, so incineration was left out of this analysis.

In line with UBC's CAP and Zero Waste Action Plan goals to minimize emissions and material waste, this analysis takes a source reduction approach to quantifying GHG savings. When a material is "source reduced" it means that less of it is produced in comparison to a baseline [5]. In this case the baseline practice is landfilling, in which the impact of replacing the disposed-of material is taken into account. When comparing this to a reuse scenario, emissions savings come from the avoided production of replacement products, as well as the avoided production of any waste material which must be managed. For refurbishment, both the waste diversion from landfill and the additional material used for repairs is accounted for. In recycling the reclaimed material is used in place of some virgin material when producing new products. This also reduces the amount of material waste produced by the initial product. However, when any material is recycled, some portion of it will be unsuitable for reuse. This amount varies depending on material type. Calculations for all waste-management strategies are explained further in section 3.4.

Because this type of GHG emissions analysis is relatively new, there was no one data source or study which gave all the necessary emissions factors for a lifetime GHG inventory of UBC office furniture. Data had to be taken and compiled from a variety of sources from the US, UK, EU, and Canada. Unfortunately, emissions data specific to Canada was limited in comparison with sources from other countries. The majority of factors used in the modelling tool were obtained from the UK Department for Environment, Food, and Rural Affairs (DEFRA) database, because it contained most of the required weight and spend based factors.

For the purpose of this study, it is assumed that all material used for furniture manufacturing is virgin material, except when directly considering the impact of furniture recycling. Furniture from some of UBC's suppliers may use a mix of virgin and recycled materials, but there is no clear data on composition of recycled material in office furniture at the university.

To account for users with varying input data, the modelling tool has been set up to calculate emissions savings in two different ways: on a material weight basis, and on a spending basis. These two models are explained further below.

3.2 Weight-Based Model

Material emissions factors are generally calculated in units of mass of emissions per mass of material, so there is more existing data with fewer assumptions and approximations for use in this model versus the spend-based model. For that reason, it is recommended that the weight-based model be used whenever that information is available to the user. This method considers four categories of furniture materials:

- wooden furniture (desks, shelves)
- metal furniture (filling cabinets)
- composite furniture (task chairs)
- various materials (miscellaneous furniture)

Emissions calculations for wooden furniture are done using emissions factors for medium-density fiberboard (MDF), an engineered wood product commonly used in desks and shelving. Calculations for metal furniture are done using emissions factors for steel cans. This was done based on the assumption that metal used in furniture products is typically steel, and due to the availability of data on the production, recycling, and landfilling of steel cans. Emissions factors for composite furniture are a calculated average of those for plastic (HDPE/LDPE/PET) and metal (steel cans), assuming a 50/50 split in the product by weight. The various materials category uses emissions factors that are a calculated average of wood (MDF), plastic (HDPE/LDPE/PET), and metal (steel cans), assuming products are an equal composition of wood, metal, and plastic by weight.

If the mass input data is known for specific material streams then these should be used, as they yield more accurate values for lifecycle GHG emissions than the average furniture category. This is because different materials produce different levels of emissions during different processes along their lifecycles [5].

Of the materials considered, steel processing and manufacturing from virgin sources produces the greatest amount of emissions per kilogram of material produced. Manufacturing 1 tonne of filing cabinets will produce more GHG emissions than manufacturing 1 tonne of wooden desks. However, when considering recycled material impacts, emissions are higher from recycled plastic than from steel or wood. Emissions from downstream processes also vary by material. The landfill emissions from MDF are higher per kilogram of material disposed of than for other materials considered [5, 10]. More landfill emissions are saved by diverting wooden desks than by diverting metal filing cabinets.

If the mass of specific materials to be considered is unknown, but the total furniture mass is known, then the various materials category can be used for calculating approximate emissions. The various materials category is an average of data for common furniture materials and should be suitable for calculating approximate lifecycle emissions but will not be accurate as if specific material weights are known.

3.3 Spend-Based Model

The emissions modelling tool is also set up to calculate the approximate emissions associated with an amount of furniture, given the dollar amount spent on the item(s). This method is less accurate than the weight-based tool, as many of the emissions factors had to be adapted from weight-based data into units of mass of emissions per dollar spent on furniture.

Mass-based emissions factors were converted to spend units by multiplying by a mass to spend conversion factor. The conversion factor is the ratio of the spend-based furniture production emissions factor to the weight-based furniture production emissions factor, both of which were obtained from DEFRA data. This conversion factor is approximate, as the weight-based production factor is a calculated average of the production emissions factors for several materials that are commonly used in furniture. It is not known what materials or assumptions were used to calculate the spend-based furniture production emissions factor from the DEFRA guide, as their methods are not thoroughly explained. Additionally, DEFRA spend-based data is given in units of British pounds spent and had to be converted to Canadian dollars. The exchange rate used for this conversion is the average exchange rate from the year the data set was published (2009). Despite these approximations, the mass to spend conversion factor should be suitable as a rough starting point for spend-based emissions calculations.

This method only considers one material category, “furniture,” which is an average of data for various materials commonly used in furniture. This is because spend-based emissions data is limited, and factors for specific materials could not be found or calculated with enough accuracy for them to be included in the modelling tool.

3.4 Waste Management Strategies

As previously mentioned, this study considers four different waste-management and mitigation strategies: reuse, refurbishment, recycling, and disposal. Each strategy has different associated upstream and downstream emissions, based on the processes that material undergoes. These are outlined in the following sections.

3.4.1 Reuse

The first step in calculating lifecycle emissions for material reuse is to determine the material processing and manufacturing emissions [6]. This is done by multiplying the inputted spend or weight-based data by the respective production emissions factor. Production factors account for raw material processing, product manufacturing, and transportation from production facilities to distribution facilities. In addition to this, transportation from the furniture supplier to UBC must be taken into account to find the total upstream emissions.

For transportation, emissions factors were obtained in terms of kg CO_2e produced per km driven for heavy-duty trucks used to ship furniture. To find transportation emissions this factor must be multiplied by the kilometer distance driven by a shipping truck [12]. The capacity of a shipping truck is approximately 3000 kg of furniture products (or approximately $19,800 worth of furniture when converted to spend data). Thus, an additional shipping factor is required to determine the number of shipments needed to transport a given amount of furniture. This is calculated by dividing the inputted quantity of furniture by the shipping truck capacity. This factor assumes that shipping trucks are always transporting full loads of furniture. It can be multiplied by the distance driven and the per kilometer emissions factor of the shipping trucks to determine the total GHG emissions produced.

The modelling tool is currently set up to use the average distance from all UBC office furniture suppliers to the campus, but could be updated with specific distances if the user knows which supplier furniture is or was obtained from. For furniture purchased in Vancouver this shipping distance will be an overestimate of the contribution of shipping to total emissions, as some of UBC’s suppliers are located as far away as Ontario. However, the average distance was used for this analysis as it is likely that the user will not know where furniture is being shipped to from.

For the reuse scenario, it is assumed that there are no downstream emissions, as the furniture is reused on campus. This requires negligible transportation and does not produce any material waste that would need to be dealt with. The modelling tool only calculates emissions savings from products being reused at UBC one time, but it can be assumed that reusing multiple times would achieve greater savings as you are repeatedly eliminating the need for manufacturing of replacement products. A diagram of material flows through a reuse-scenario lifecycle, and the type of emissions associated with each stage, is shown below.

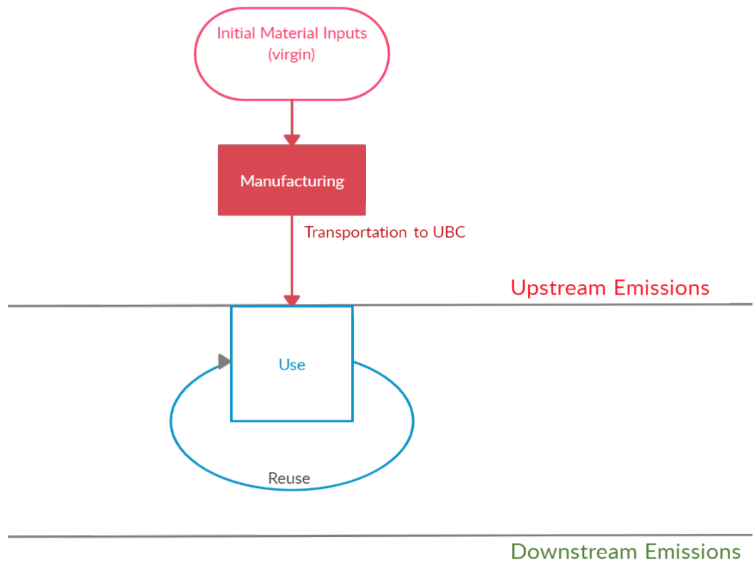

Figure 3-1. Lifecycle processes of material in a reuse scenario.

3.4.2 Refurbishment

For refurbishment, upstream emissions will be the same as those calculated for the production and transportation in the reuse scenario. It is still assumed that furniture is produced from virgin material sources, and that the transportation distance to UBC campus is the average distance from all of its office furniture suppliers.

Downstream emissions in refurbishment must account for the roundtrip transportation from UBC to the location where repairs will occur, as well as the production of materials used in refurbishment. Downstream transportation emissions are calculated with the method described in section 3.4.1, and the calculated average distance between UBC and its Vancouver-based suppliers which offer furniture repair. UBC has some suppliers in other provinces that offer refurbishing services, but those were left out of this analysis on the assumption that the shipping distance would negate much of the benefit of actually refurbishing the items.

While it is commonly agreed upon that refurbishing/repairing furniture is more environmentally beneficial than disposing of it and producing new items, quantitative data for the emissions produced by refurbishing is extremely limited. One study conducted for The Refinishing Touch (a furniture repair company) by carbonfootprints.com suggested that the carbon footprint of materials used to refurbishing is roughly equal to 1/100th of that from the initial furniture manufacturing [14]. Similar results for average material usage and emissions were found in another remanufacturing study [13].

While actual material emissions from refurbishing would vary depending on the furniture item, the material type, and the repair work it needs, this benchmark is used to calculate an approximate value in this study. Further study of furniture refurbishment would be necessary to determine a more accurate value of its impact on emissions.

As in the reuse scenario, refurbishment only considers the emissions impact of furniture being repaired and returned to campus one time, however it would be possible for this process to be carried out multiple times to further prevent the manufacture of replacement furniture products and prevent the production of waste material.

Figure 3-2 below shows material flows through a refurbishment-scenario lifecycle, and the type of emissions associated with each stage.

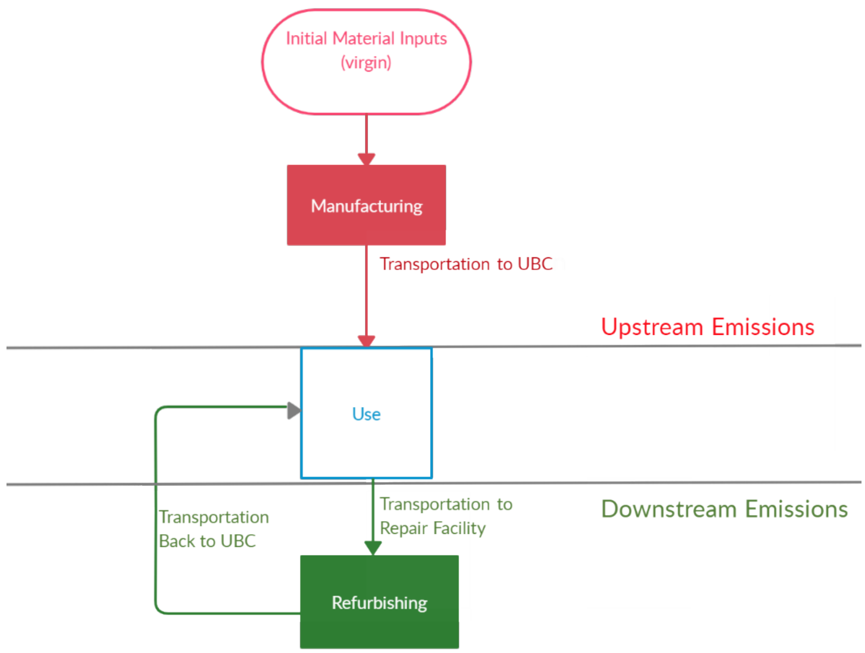

Figure 3-2. Lifecycle processes of material in a refurbishing scenario.

3.4.3 Recycling

In recycling, the upstream emissions account for both the initial production of furniture items from virgin materials, as well as the production of replacement furniture from a mixture of virgin and recycled inputs. This is done based on the assumption that when furniture is sent away from UBC to be recycled, it is replaced with an equal amount of new furniture. The emissions savings of recycling over landfilling of products is accounted for by the reduced emissions from using recycled inputs in the production of replacement furniture.

Manufacturing items from recycled inputs produces fewer greenhouse gas emissions than from virgin inputs, as the material has already been extracted and undergone initial processing. However, for a given amount of material sent to recycling, only a portion of it is actually suitable for reuse [5]. Therefore, production emissions for replacement furniture consider a mix of virgin and recycled inputs.

Upstream emissions for the recycling scenario also accounts for the transportation of furniture from suppliers to UBC, as outlined in previous sections.

Downstream emissions come from shipping furniture items to the Vancouver recycling depot, and from the emissions associated with disassembly and sorting material at the recycling facility. Downstream emissions of replacement products are not considered in this analysis, as the end-of-life strategy used to manage these products could differ from that used with the initial furniture items. A diagram of material flows through a recycling-scenario lifecycle, and the emissions associated with each stage, is shown below.

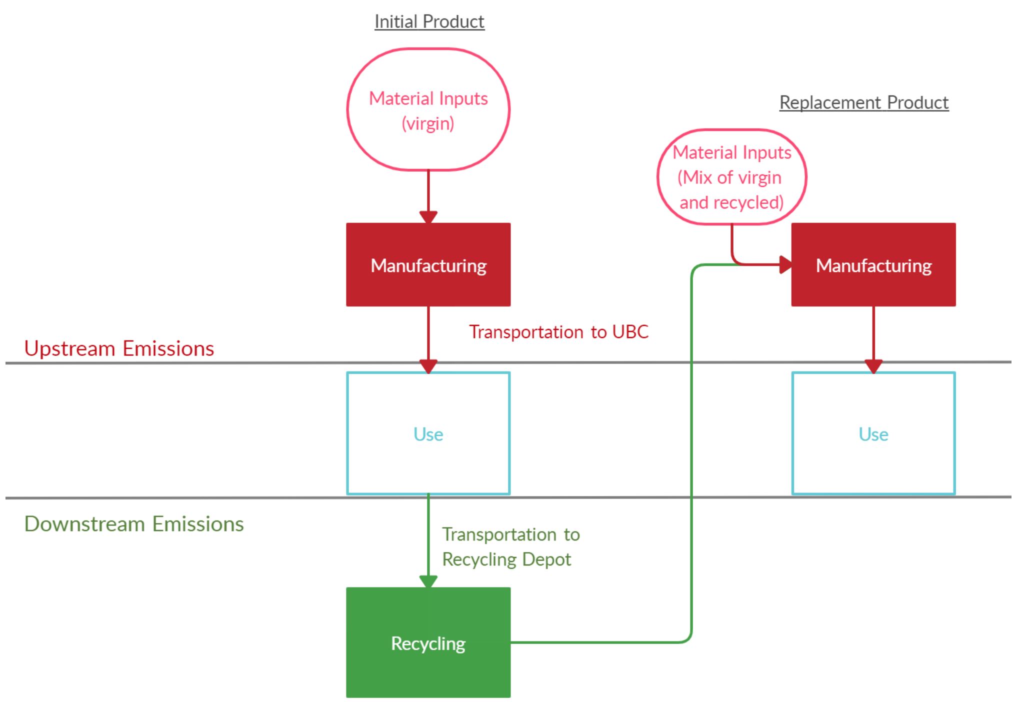

Figure 3-3. Lifecycle processes of material in a recycling scenario.

3.4.4 Landfill

For the disposal scenario, upstream emissions account for the initial production of furniture from virgin materials, as well as the production of replacement furniture, again from virgin materials. This is done based on the assumption that furniture sent to the landfill is replaced with an equal amount of new furniture, and all inputs are virgin as no material is recovered from items sent to the landfill. Upstream emissions also account for the transportation from suppliers to UBC campus.

Downstream emissions account for the transportation from UBC to the Vancouver landfill, as well as emissions produced as materials decompose in the landfill over time. Again, this scenario does not consider the end-of-life emissions impacts of replacement products. A diagram of material flows through a landfilling-scenario lifecycle, and the emissions associated with each stage, is shown below.

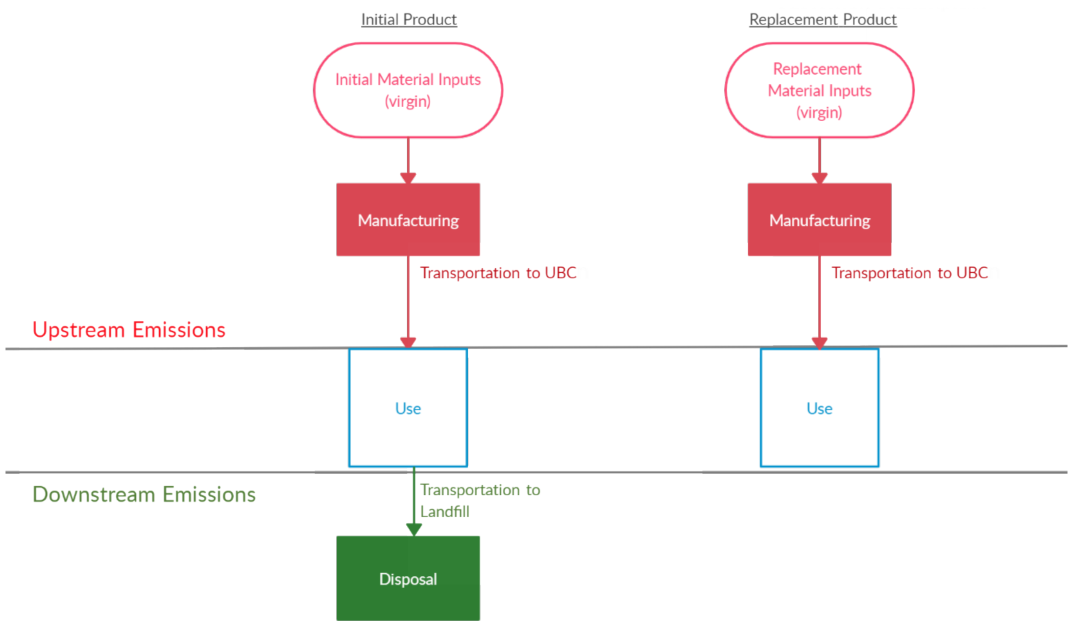

Figure 3-4. Lifecycle processes of material in a disposal/landfilling scenario.

3.5 Emissions Savings Calculations

Based on the total lifecycle GHG emissions for a given quantity of furniture, the modelling tool can be used to determine emissions savings for different end of life processes.

The user can compare two different waste-management strategies by inputting the percentage of furniture to be reused, refurbished, recycled, and landfilled, in comparison to a baseline strategy set by the user. For example, if the current practice for dealing with surplus furniture is to send 5% to be recycled and the remaining 95% to the landfill, the user can compare this with the theoretical emissions which would be produced by reusing 50% of the furniture, recycling 10%, and only sending 40% to the landfill.

3.6 Data Range

As previously mentioned, this type of emissions analysis is quite novel and research yielded a variety of different emissions factor data. To account for some of the error in emissions calculations, emissions factors from several different sources were compiled and compared with those used in this analysis. This was done to determine a reasonable range in which emissions savings is likely to fall within. While many of these data sources were left out of the primary analysis because they were assumed to be less relevant than the chosen factors (due to lacking certain emissions factors, being from a different part of the world, calculated in different units than those used in this model) it is important to account for them when considering error. Many assumptions and approximations were made in this analysis due to the lack of data specific to UBC's furniture suppliers and waste-management practices, so considering emissions factors from a variety of sources helps give a more clear picture of the likely range of actual emissions.

The largest range in emissions factor data was found for material processing and manufacturing, so most of the data compared in the tool is for these processes. For transportation and end-of-life scenarios, the factors found were either very similar, or there were not enough different sources reporting these factors to do a comparison. The range of emissions factors for the processes and materials for which sufficient data was available are tabulated in the data section of the modelling tool. The tool could be updated to calculate the emissions range for different materials and inputs, but at this point it is only included as reference information.

It should be noted from the data compilation in the modelling tool that weight-based emissions factors from DEFRA are generally similar to or larger than those obtained from other sources. The emissions from furniture production in the weight-based portion of the tool may be a slight overestimate of the actual value. The DEFRA spend-based emissions factor for furniture production is lower than those obtained from other sources, and thus emissions calculated in this portion of the tool may be an underestimate of the actual total carbon footprint. Despite these discrepancies with other sources, DEFRA data was still chosen for the modelling tool whenever possible, as it is the most thorough dataset, and the only dataset found which allows for the direct comparison of weight-based and spend-based furniture production emissions factors.

4.0 Results

4.1 Spend-Based Results

The approximate annual spending on office furniture at UBC is $6 million. This value was inputted into the spend-based modelling tool to determine the emissions impact of the different waste-management strategies.

- For the reuse scenario, total lifecycle GHG emissions for the $6 million spend input were estimated to be 1,807 of tonnes CO_2e. This means that by producing $6 million worth of office furniture X tonnes of CO_2e are emitted.
- For refurbishment, total lifecycle GHG emissions were slightly higher, at 1,831 tonnes of CO_2e. This figure accounts for the emissions created in manufacturing the initial furniture products, and refurbishing them all once.

- For recycling, total lifecycle GHG emissions were estimated to be 3,057 tonnes of CO_2e. These are the emissions from manufacturing the initial $6 million worth of furniture, sending it all to be recycled, and producing an equal amount replacement furniture using the recycled materials.
- For disposal, total lifecycle GHG emissions were notably higher than previously considered scenarios, at 3,897 tonnes of CO_2e. This figure accounts for the production and disposal of $6 million worth of furniture, as well as the production of an equal amount of furniture to replace that which is disposed of.

While these values are approximations, their relative magnitudes are reflective of the findings of other material lifecycle GHG studies, with landfilling producing more than twice the total emissions of the reuse option.

For all end-of-life scenarios considered, the upstream emissions are considerably higher than downstream emissions. For example, in the disposal scenario upstream emissions are estimated at 3,615 tonnes of CO_2e, whereas downstream emissions are estimated at 282 tonnes of CO_2e. Transportation accounts for around 10% of upstream emissions, whereas material processing and manufacturing makes up almost 90% of upstream emissions. This is considering the average distance from all UBC office furniture suppliers and is an overestimate of the transportation footprint for furniture purchased from suppliers in Vancouver. It is likely that for some of the office furniture on campus, material processing and manufacturing makes up more than 90% of upstream emissions.

Although these values are approximate, they make a strong case for furniture reuse, as all downstream emissions are avoided, and no replacement items are necessary so upstream production emissions are half that of disposal.

Using the alternative waste-management scenario portion of the tool, emissions savings can be calculated for furniture sent to different end-of-life paths. Assuming that the baseline strategy for dealing with the $6 million worth of furniture at the end of its useful life is landfilling 100% of it, the emissions savings for reuse, refurbishment, and recycling can be computed.

- If 25% of the furniture is reused and the rest is sent to landfill, an estimated 522 tonnes of CO_2e are avoided.
- If 50% of the furniture is reused and the rest is sent to landfill, emissions savings double to 1,044 tonnes CO_2e.
- If 50% of furniture is reused and the remainder is recycled rather than landfilling, an estimated 1,465 tonnes of CO_2e are avoided.
- If 100% of the furniture is reused on campus, emissions savings are estimated to be 2,089 tonnes CO_2e.

Considering alternative emissions factors from various sources, the spend-based emissions calculated by the modelling tool are on the low end of the possible range. Lifecycle GHG emissions from producing and disposing of $6 million worth of furniture could actually be as high as 5,425 tonnes of CO_2e. While the emissions calculated by the modelling tool can be taken as a rough estimate, it is important to also keep in mind the discrepancies in emissions factor data when considering the total impact of furniture disposal.

4.2 Weight-Based Results

The previous UBC SEEDS project on office furniture reuse estimated that 400 tonnes of furniture was disposed of by UBC in 2018. This value was inputted into the weight-based portion of the modelling tool to determine the lifecycle GHG emissions associated with this quantity of furniture, and to calculate the value of emissions that could have been saved had disposal not occurred.

- The approximate lifecycle GHG emissions of 400 tonnes of landfilled furniture is equal to 1,718 tonnes of CO_2e.
- Had 50% of this furniture been reused and the rest sent to landfill, an estimated 460 tonnes of CO_2e would have been avoided.
- Had 50% of this furniture been reused and the rest of it recycled, an estimated 646 tonnes of CO_2e would have been avoided.
- Had 100% of this furniture been reused on campus, an estimated 921 tonnes of CO_2e would have been avoided.

While there are limitations to the emissions calculated in this model, the outcomes present a clear trend of increasing emissions savings for increasing material diversion from landfill.

4.3 Comparison with UBC GHG Inventory

Since 2006, UBC has conducted an annual GHG inventory which tracks and reports scope 1 and 2, and some components of scope 3 emissions. In this section emissions savings calculated for waste-management scenarios in section 4.1 and 4.2 are compared to other emissions sources at UBC to help quantify their impact on the universities carbon footprint.

The 2018 UBC GHG inventory, the most recently available version of the document, calculates the total emissions from scope 1 and 2, and campus paper use to be 37,491 tonnes of CO_2e [16]. For the approximate annual furniture spending amount of $6 million, 3,897 tonnes of CO_2e are produced if 100% of that furniture is sent to landfill at the end of its useful lifetime. This is equal to just over 10% of the total campus emissions from scope 1 and 2 sources, and paper.

The emissions associated with annual furniture spending are almost as high as the 4,128 tonnes of CO_2e produced annually by direct natural gas use in ancillary buildings on campus [16].

If just 25% of the $6 million worth of furniture are reused rather than landfilled then 522 tonnes of CO_2e are saved. This emissions savings is almost as much as the 648 tonnes of CO_2e produced annually by gasoline usage in UBC’s fleet.

If 100% of this furniture is diverted from landfill by reuse, then 2,089 tonnes of CO_2e are saved. This emissions savings is more than 1.5 time the total annual emissions from electricity production for core campus buildings (1,443 tonnes of CO_2e) [16].

In comparison with other scope 3 emissions, the lifecycle GHG emissions based on annual furniture spending data are lower than most other categories that are reported on. The annual emissions from business flights are 15,710 tonnes of CO_2e, and the annual emissions from commuting are 40,821 tonnes of CO_2e [16].

While furniture-associated emissions are lower than some other scope 3 emissions – even when it is assumed that all furniture is sent to the landfill – they are still significant. Diverting material from landfill via furniture reuse on campus could lead to a considerable amount of avoided emissions. If UBC truly hopes to become a net zero emissions and zero waste campus, then furniture material waste and waste-related emissions must be addressed.

5.0 Limitations of Study

This study is the first at UBC to aim to quantify GHG emissions from office furniture, and to calculate the potential emissions savings by diverting surplus furniture from the landfill. As such, there is a lack of accurate data specific to UBC furniture and processes. Many assumptions and approximations had to be made and relied upon to create the accompanying modelling tool, and emissions factors from several different sources were compiled and considered.

Limitations of the study are outlined as follows:

- Emissions factors and data used in the modelling tool are obtained from several sources. No one source contained all the emissions factors necessary for this analysis, and as such data was used from a range of sources. Data from different sets should not be used together for calculations as it was likely calculated by different methods and considers different assumptions. While most data sources explain their basic methodology, none go into specifics about how exactly certain factors were calculated. Some studies specify that their methods for emissions factor derivations are confidential (ie. DEFRA). Other studies calculated their emissions factors with the use of paid software or data sets that were unable to be accessed for this project. Furthermore, many factors are from different parts of the world and are given in different units (US mass based factors are given in tonne emissions/short ton material, UK spend based factors are given in kg emissions/ £ spent) which must be converted.

- Emissions factors for recycling are based on assumptions about how much recycled material is lost in the process of collection, sorting, and remanufacturing products. Refurbishing factors are based on assumptions about how much material is used in the repair of products relative to their initial production. Both of these are somewhat approximate and could use further investigation to obtain more accurate data.

- The spend-based furniture emissions factor used in this analysis was chosen because it is from a dataset which also provided mass-based factors, and thus allowed for a comparison of the two production emissions values. However, it was initially in units of British pounds spent, and had to be converted to Canadian dollars using a currency exchange rate. The spend-based emissions factor is also a universal factor for furniture, not intended specifically for office furniture. The source does not explain what materials or data were considered in its calculation. It may account for materials that are not a significant component of office furniture (ie. textiles, foam cushions).

- Because the spend-based furniture manufacturing factor and the weight-based furniture manufacturing factor likely make different assumptions and consider different materials, they probably should not be directly compared. However, for this analysis there was not a clear way to determine a better mass to spend conversion factor.

- Given the limitations of the mass to spending conversion factor, the entire spend-based sheet is quite approximate. Emissions factors are usually in units of mass and had to be converted to spend units for most of the end-of-life processes considered in this study. There is a lack of available spend-based data that has already been computed by a reputable source. Furthermore, the price of office furniture is variable, and subject to factors that do not correlate to GHG emissions (ie. brand). Overall, this is not the best way of looking at emissions. This method is included in this study as a rough estimate of emissions for cases where spend data is the only information available to the tool's user.

- For the recycling and landfilling scenarios considered in this study, the assumption that all material that gets recycled or disposed of will be replaced by an equal amount of new material is not necessarily accurate. For the spend-based analysis, replacing a given number of furniture items will likely cost more in the future than the initial cost due to inflation. This assumption also fails to take into account that when furniture is disposed of due to renovations, it is likely to be replaced with different quantities and types of furniture.

- The assumption that reuse and refurbishment prevent new furniture items from being produced is not necessarily accurate either. For example, as new buildings are constructed on campus, new furniture will be required to fill them. Reusing existing surplus furniture has the potential to mitigate some, but likely not all, of this demand for new furniture.

- For material inputs in furniture production, it is inaccurate to consider that 100% of materials are from virgin sources. Some furniture used on campus is likely to be made from a mixture of virgin and recycled inputs. However, there is no current data on recycled composition of furniture at UBC, so that was not considered in this study.

Despite these limitations, this study has created an approximate method for quantifying lifecycle GHG emissions for various office furniture materials and end-of-life processes and allows for the calculation of emissions savings when certain waste-mitigation strategies are chosen over disposal for surplus furniture. It serves as a starting point for the universities accounting of scope 3 emissions from furniture production and waste, and can be improved as more accurate data and methods become available.

6.0 Conclusion

This study has demonstrated that the lifecycle emissions associated with furniture production and waste at UBC are quite significant, and there is great potential for solid waste and emissions savings by diverting furniture from landfill. While results are approximate, for every case considered the lifecycle GHG emissions from the reuse scenario were the lowest, followed by refurbishing, recycling, and finally landfilling. UBC's annual furniture spending of $6 million equates to roughly 3,897 tonnes of CO_2e if

100% of that furniture is eventually sent to the landfill. However, over half of these emissions can be saved by furniture reuse.

Additionally, studies have shown that scope 3 emissions can account for over 75% of an entity's total GHG emissions [17], making it critical for UBC to calculate, track, and report on scope 3 missions – part of which should include working to improve the calculation of furniture-related emissions to make them more accurate.

Based on the results of this study, the following recommendations are being made to UBC:

- When different departments around campus purchase new furniture, they should be required to track both their spending and the type and quantity of furniture that is being purchased. This would give more accurate data on annual furniture procurement, as well as allow for better calculation of a mass to spend conversion factor for emissions calculations.

- A case study should be conducted as a follow up to this project in which a set of campus furniture (ie. from a renovation project) could be counted, weighed, and have its material composition estimated, in order to allow for better calculation of weight and spend-based furniture emissions factors.

- Another follow up study to this project could be to reach out to UBC office furniture suppliers for more specific data on the material processing and product manufacturing GHG emissions. Additionally, an LCA software could be used to assist with determining emissions factors for various materials and lifecycle processes. These are both things that were meant to be covered in this study but could not be completed due to time frame limitations.

- The modelling tool should be expanded to consider more material types and products (ie. scientific equipment), to gain better insight into the total emissions impact of material and waste on campus.

- In terms of reducing furniture waste on campus, the university should implement a centralized furniture reuse program such as the one suggested in a prior SEEDS study on office furniture reuse [3].

- The university should implement more sustainable purchasing practices such as a policy to encourage purchasing second hand furniture, furniture with higher recycled material content, items with longer warranties (as this usually indicates they are built to last), and items from suppliers that offer local refurbishing/repair programs.

While this study is quite approximate, and more data is needed to better quantify the GHG impact of furniture at UBC, it serves as a preliminary investigation into GHG emissions savings from furniture reuse. Many sources agree with the finding that diverting more material from landfills allows for greater emissions savings. Especially in the case of items such as office furniture, which are durable, have a steady long-term value, and are unpowered, creating no emissions in the use stage of their lifecycle. Reuse has shown promising results in mitigating production emissions from new furniture products [13].

If UBC is committed to achieving its net zero emissions and net zero waste production targets, it must begin to account for, and reduce, emissions associated with furniture production and waste.

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