A Feasibility Study on the Life Cycle of 30% and 100% Post Consumer Waste and Virgin Paper

Source: Paper Task Force < http://www.edf.org/content_images/pap_WasteworkPaper.gif >

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CHBE 484 Life Cycle Analyses of 30%, 100% Post Consumer Waste and Virgin Paper
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April 18, 2008

ATTN: Ms. Brenda Sawada, Ms. Victoria Wakefield, Dr. Xi Tony Bi

Dear Ms. Brenda Sawada, Ms. Victoria Wakefield, Dr. Xi Tony Bi:

RE: A Feasibility Study on the Life Cycle Analyses of 30%, 100% Post Consumer Waste and Virgin Paper

Paper is a universal tool used everywhere around the world and its demand continues to increase tremendously year after year. Due to these increases, environmental impacts are becoming a major issue. Thus, through conducting life cycle assessments we hope to identify the origins linked to these concerns and solutions to reduce or eliminate the impacts.

The purpose of this report is to conduct a feasibility study by comparing the life cycle analyses between 30% post consumer waste, 100% post consumer waste and virgin paper. In regards to our Green Engineering Course, this paper will provide a life cycle assessment focused mainly on manufacturing in terms resource consumption, waste, emissions and economics.

The project timeline was from March 14 to April 18, 2008. We are confident this report will meet your expectations. If you have any question or concerns regarding this paper, please do not hesitate to contact us.

Sincerely,

Angie Tai, Charles Borromeo, Opttie Tsoi
CHBE 484 Life Cycle Analyses of 30%, 100% Post Consumer Waste and Virgin Paper

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1.0 Scope

This paper compares the feasibility and life cycle assessment for 30% post consumer waste paper, 100% post consumer waste paper and virgin paper. The scope of this project only focuses on the life cycle within the manufacturing process. It is assumed that for raw material acquisition and production shipping will ultimately be identical in for all three paper cases and will not play a significant role in this study.

2.0 Introduction

3.0 Background

Paper has been used as far back as the Egyptian times. It has been used over the centuries as the carrier of knowledge. Today, paper is still in use and our consumption has doubled since the 1960s (“A New Way to Buy Paper”). The production of pulp and paper is considered to be one of the world’s largest industries.

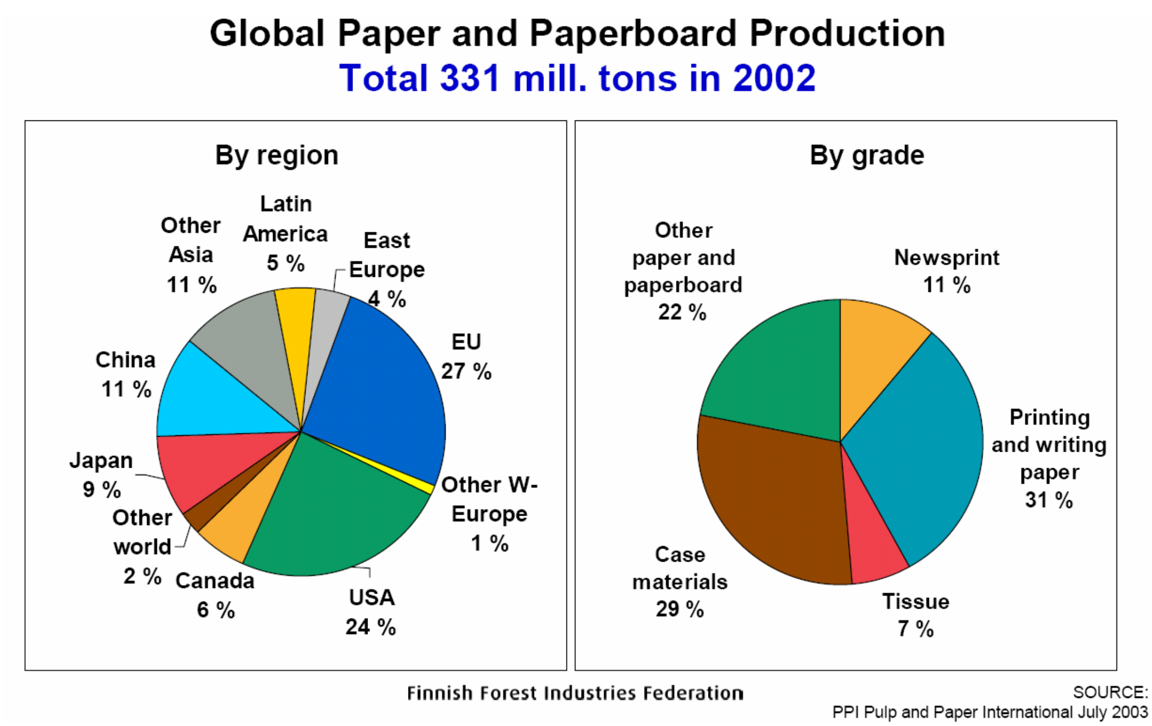

Figure 1: Global Paper Production

Source: Olsen, James. "Introduction to Mechanical Pulping and Papermaking." Lecture Notes. UBC. 12 Apr 2008 <http://origin.mech.ubc.ca/~chbe401/Topic%201%20Introcution.pdf>.

With increasing paper demand and consumption, environmental concerns over the lifecycle of paper has arisen. As with any other production processes, paper making utilizes energy, consumes natural resources, and produces various emissions (i.e. air emissions, wastewater, and solid wastes). In an effort to reduce the environmental impact of paper production, various means have been employed such as the development of cleaners and more efficient technologies; this includes process optimization, and fiber recycling.

Recycling of fiber is mainly classified into three: internal mill waste, pre-consumer waste, and post-consumer waste. Internal mill waste mainly utilizes substandard or defective paper products made within the paper mill and reintroducing them back into the manufacturing system. Pre-consumer waste mainly consists of processing waste, which is generated outside the pulp mill and is recycled before it is used by a consumer ("Pre-consumer Waste"). Post-consumer waste (PCW) is fiber from used paper which includes newsprint, paper from office waste, and magazine papers, to name a few ("Paper Terminology"). This paper will only deal with the post consumer waste content in paper and virgin paper.

4.0 Raw Materials

The main raw material of paper is pulp fibers which basically come from wood. Other sources of fiber include internal mill waste, pre-consumer waste, and post-consumer waste.

Virgin paper, or 0%PCW paper, mainly uses wood as a source of fiber. A ton of paper, consisting of around 200,000 sheets, typically requires about 24 trees[1] (Paper Task Force). 30% post-consumer waste paper uses approximately 17 trees and 100% post-consumer waste paper doesn’t use any trees.

[1] Uncoated virgin printing and office paper basis

5.0 Paper Manufacturing[2]

There are two paper production techniques used widely in industry: mechanical and chemical. In our life cycle analysis, the type of paper production that would be used is chemical, which is required to make regular copy/printing paper.

The production of paper is generally comprised of 5 steps. These steps include: debarking, chipping, pulping, bleaching, and the paper machine.

5.1 Debarking

The purpose of this stage is for decomposing the bark into fine fiber. The debarking step mainly removes the bark from the tree. A drum debarker, a large spinning and rotating drum, is usually used to carry out this process. As the drum spins, the logs rub against each other and, as a result, remove the bark.

Therefore, since virgin paper utilizes more wood in comparison to PCW paper, the energy utilized is highest for virgin paper because it has a higher loading of wood. For 30%PCW paper, the energy used would be less than that of virgin paper and 100%PCW paper will rank superior at this stage since it does not require any wood from trees. Similarly if “wet oxidation debarking” (Kindsigo et al) was used at this stage, the degree of water

[2] Paper production process is based off CHBE 401 Pulp and Paper course notes

consumed will follow a similar trend, with 100%PCW ranking superior. Furthermore, 100% recycle paper also proves to be more feasible since it will not require the purchasing of debarking equipments and will not have any emissions.

5.2 Chipping

In this step, the debarked logs are cut into small chips. Chippers, as they are usually called, use large rotating knives to cut the logs down into chips. This step is only required if debarking occurs. Thus, 100%PCW will again be most preferable at this stage of analysis since it does not require this step.

5.3 Pulping

Pulping is the process where separation between the lignin from the cellulose[3] and hemi-cellulose[4], contributes to 40%-45% of the wood weight. This process also removes the “tree oils and resins” from the wood ("Fact files: The pulping process | Pro Carton Design."). There are two main pulping processes: chemical and mechanical pulping.

3.3.1 Chemical or Kraft Pulping

[3] From Webster’s dictionary: polysaccharides that are found in plant wall cells
[4] From Webster’s dictionary: similar to cellulose but possesses a less complex structure

This type of pulping produces long pulp fiber lengths, which improves paper quality. In this process, the wood chips are "cooked" in a solution of sodium hydroxide and sodium sulphide. This process is highly efficient in removing lignins and resins in softwoods. More than 95% of the chemicals used for pulping are recovered for re-use.

In spite of the process' high chemical recovery and efficiency in producing high quality pulp, the release of hydrogen sulphide and mercaptan family of sulphides can cause the smell of rotten eggs. Hydrogen sulphide is highly toxic and may be fatal since it will cause asphyxiate and mercaptan may cause "anemia and coma" ("Chemical Sampling Information: Methyl Mercaptan"). In addition, cellulose fibres that are lost during the chemical pulping can be discharged with the wastewater and may cause a build up of fiber beds around wastewater pipes. This fiber build up may cause environmental problems.

Overall, this manufacturing step will be required for all three types of paper, and the amount of chemical solutions utilized at this step will be the same.

3.3.2 Mechanical Pulping

In mechanical pulping is a process that forces debarked logs against a grinding stone or a metal disk to produce pulp. This process usually produces a higher percentage of usable pulp but the pulp quality is considerably lower compared to the pulp produced from the Kraft process. As a result, paper produced from mechanical pulping is lower compared to chemical pulping. Up to 95% of the wood is converted into usable pulp, as compared to around 40% to 50% for the Kraft process.

Paper produced from the process is used mainly for newsprint, telephone books, and etc.

5.4 Bleaching

Bleaching is considered to be one of the most important steps. This step is used to purify and clean up the pulp by removing the lignin which affects fiber purity. Chemical pulp mills typically use chlorine gas and chlorine dioxide as bleaching agents. These chemicals are highly toxic and pose a severe health risk by acting as a mutagen, carcinogen and may be fatal ("Treecycle Recycled Paper: About Recycling and Recycled Paper."). On the other hand, mechanical pulp mills use peroxide. There is paper process that excludes this stage which aids in reducing the “organochlorine compounds to the sludge” (UBC Sustainability Office).

This part of the process is only required for the paper types that have wood content, which are 30%PCW and virgin paper. Therefore, the most preferable paper choice is 100%PCW since it does not require such a step, does not has one fewer step that would contribute to cost, emissions, water and energy consumptions.

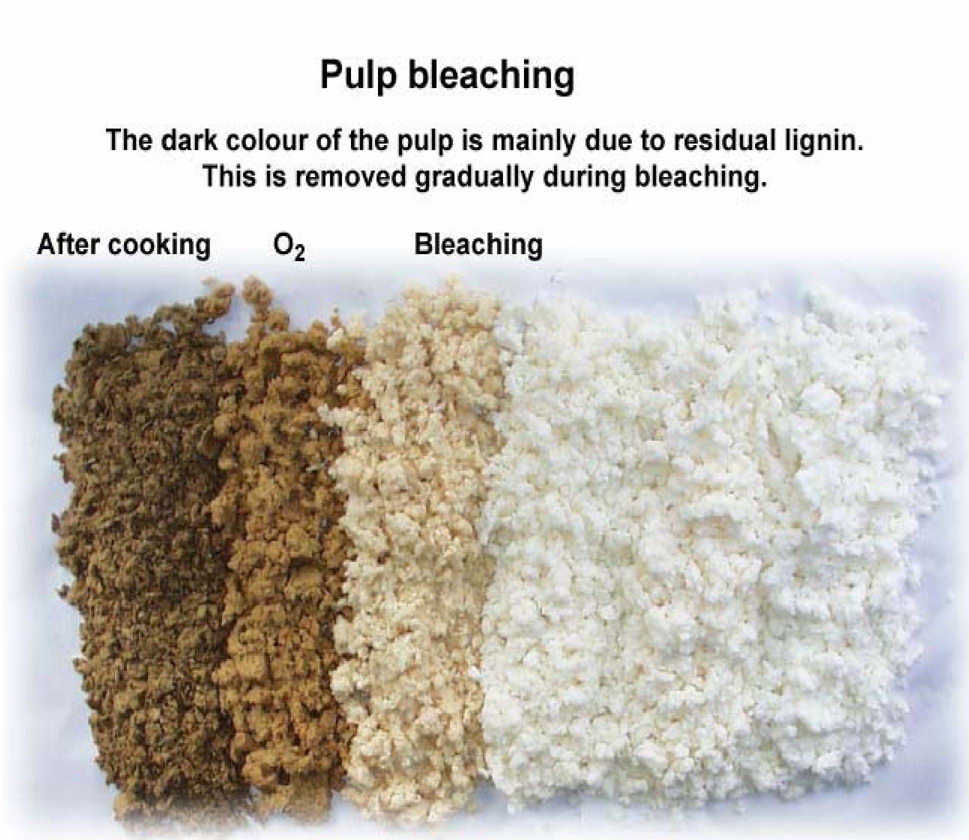

Figure 3: Pulp Bleaching

Source: Lee, Quak Foo. "Pulp Production and Paper Making." Advance Chemical Technology Center. Department of Chemical and Biological Engineering. 12 Apr 2008 <http://www.chmltech.com/pulppaper.htm>.

5.5 Paper Machine

The paper machine primarily consists of four sections: stock preparation, press section, dryer section, and after-dryer section/rolling. This stage in the process will be required equally among by all three paper types.

3.5.1 Stock Preparation

In this section, the wood fiber mixed with water and minerals. The water is drained out and a web of paper is formed.

3.5.2 Press Section

This section is a primary drying step. The paper web is squeezed between rollers. After this section, the water content of the paper is typically around 40% to 50%.

3.5.3 Dryer Section

Further removal of water is achieved in this section. A water content of around 2% to 6% is typical after this section.

3.5.4 After-dryer Section/Rolling

In this section, further drying is done and the paper is wound up into a giant roll.

Based on superiority of each paper type on the step stages in the process provided above, three being most preferable to one being least, the results indicate 100% being most economical in terms of manufacturing since it requires less stages, less maintenance and so less potential sources of emission sources. The results are summarized below in Table 2.

Table 1: Manufacturing Ranking

Rank	**Virgin**	**30% PCW**	**100% PCW**
Debarking	**1**	**2**	**3**
Chipping	**1**	**2**	**3**
Chemical Pulping	**1**	**1**	**1**
Bleaching/De-inking	**3**	**2**	**1**
Paper Machine	**1**	**1**	**1**
Total	**7**	**8**	**9**

It is important to note that this rank does not include the actual emission amounts per stage or energy consumption. Both these factors will be assessed in the subsequent sections.

6.0 Resource Consumption

In this section of the life cycle analysis, the energy and water consumption and emissions released are defined and assessed. Minimal information was attained on water consumption and its dependency at various recycles rates, and so only 30%PCW paper's water usage will be discussed in this section with total water consumption comparisons conducted in section 5.0 Environmental Impacts.

It was found that both the energy consumed and emission amounts vary tremendously at different operating conditions; mainly the recycling rates. The trends were adapted from a study done by Paper Task Force ("White Paper No. 10A") using 1 ton of air dried paper as the basis.

6.1 Energy

The total amount energy required to produce a ton of air dried paper decreases with increasing recycling rates. Table 2, shown below, shows a summary of the energy requirements for the different types of paper.

Table 2. Energy Requirements for Different Paper Types

	Paper Type				% reduction from base case (virgin)		
	Virgin	20%	30%*	100%	20%	30%*	100%
Total Energy (Btu / air dried product)	36.8	33.5	31.85	20.3	8.97	13.45	44.84
Purchased Energy (Btu / air dried	17.2	17.8	18.12	20.3	-3.49	-5.35	-18.02

product)							
Energy Generated by plant (Btu/ air dried product)	19.6	15.7	13.73	0	19.90	29.95	100.00

*Based on linear regression

As shown in the table above, 100% recycled paper has the greatest reduction in total energy required with 44.84% and with an energy requirement of 20.3 Btu per ton of air dried product. However, the amount of purchased energy (or energy taken from the grid) increases by 18.02%. This would indicate that with increasing recycling rates the dependence of energy from the grid, which is mainly electricity produced from carbon-intensive fossil fuels, increases.

Assuming a linear relationship between 20% and 100% recycled paper, the estimated reduction of energy and energy required for 30% recycled paper would be approximately 13.45% and 31.85 Btu per ton of air dried product, respectively. In addition, the amount of purchased energy increases by 5.35%.

6.2 Water

Limited information was available for water consumption. Based on material provided from the sustainability office and supply management, it shows 100%PCW will save approximately

7000 gallons of water in comparison to virgin paper (UBC[5]) "Recycling - It Adds Up!."). Since 30% also contains recycle content, overall virgin paper is the least sustainable paper group and the least preferably.

6.3 Emissions

Using the same study and techniques from the Energy Section, the following table was derived.

Table 3. Air Emissions for Different Paper Types

Air Emissions (lb/ ton of air dried product)	Paper Type				% reduction from base case (virgin)		
	Virgin	20%	30%*	100%	20%	30%*	100%
SO2	26.60	26.40	26.25	25.40	0.75	1.32	4.51
NOx	14.10	13.70	13.52	12.20	2.84	4.11	13.48
Particulates	11.70	10.70	10.25	6.90	8.55	12.39	41.03
CO2 - total	10200.00	8850.00	8175.00	3450.00	13.24	19.85	66.18
CO2 – fossil fuel	2850.00	2950.00	3022.62	3450.00	-3.51	-6.06	-21.05
Hazardous air pollutants	2.20	1.80	1.60	0.20	18.18	27.27	90.91
VOC's	5.40	4.70	4.37	2.00	12.96	19.07	62.96
Total reduced sulfur	0.34	0.27	0.24	0.00	20.59	29.41	100.00

*Based on linear regression

From the table above, air emissions is greatly reduced as the recycle rate increases. However, CO_2 emissions from fossil fuels increase as the recycle rate is increased. This trend is expected considering that as the recycle rate is increased the purchased

[5] The basis was provided by the website "Recycling - It Adds Up!." (refer to Works Cited)

energy, electricity produced from carbon-based fossil fuels, increases.

7.0 Environment

7.1 Environmental Impacts

In this section, life cycle energy use and environmental releases of virgin paper, 30% recycled paper and 100% recycled paper is compared as shown in table 4 below.

The data is obtained from *The Paper Calculator*, which is based on research done by the Paper Task Force. The paper, *Lifecycle Environmental Comparison: Virgin Paper and Recycled Paper-Based Systems,* is a peer-reviewed study of the lifecycle environmental impacts of paper production and disposal in 1995.

The underlying data is updated regularly and industrial data was very limited to us to provide adequate comparisons. The previous emissions data provided previously assumes a linear relationship to determine 30%PCW emissions but this assumption may not be entirely valid. Thus, it is assume that this will be the main basis of our comparison on the overall life cycle energy use and environmental releases for all three types of paper.

This quantitative analysis is based on three complete systems:

(1) acquisition of virgin fiber, manufacture of virgin paper, followed by landfilling;

(2) acquisition of virgin fiber, manufacture of virgin paper, followed by incineration; and
(3) manufacture of recycled paper, followed by recycling collection, processing and transport to the site of remanufacture.

Detailed definitions are described in Appendix Table 1A

For the presentation of data for virgin paper, the two systems are reduced to “virgin production plus waste management”, which is a weighted average of the “virgin production plus incineration” systems.

In the comparison, some important activities involved in the virgin fiber-based systems were omitted due to lack of data (Duke University, 1995):

- acquisition of virgin fiber from forests, including energy (and associated wastes) involved in planting, site preparation and stand tending activities, and production, use and disposal of forest chemicals (fertilizers and pesticides); only energy required for tree harvesting, for transport of logs or chips from the forest to the mill, and for debarking and chipping of logs is included, as well as its associated air and water releases and solid waste:
- releases to the air and water from MSW landfills, except for carbon dioxide and methane emissions;
- releases to the air from incinerators, except for carbon dioxide, sulfur oxides, nitrogen oxides and particulates; and
- releases from ash landfills.

Air emission and waterborne waste from both production stages and waste treatment are also included and as defined as follows (Duke University, 1995):

- for air: hazardous air pollutants (HAPs), volatile organic chemicals (VOCs) and total reduced sulfur (TRS); and
- for water: biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, adsorbable organic halogens (AOX) and effluent quantity/water use.

Table 4: Summary of lifecycle environmental impacts and equivalents their percentage difference

	Virgin Paper	30% Recycle	100% Recycle	**Difference %** (Virgin Paper is differed with 30% Recycle Paper by)	(Virgin Paper is differed with 100% Recycle Paper by)	(30% Recycle Paper is differed with 100% Recycle Paper by)
Wood Use	3 tons	2 tons	0 tons	0	100	100
Total Energy	56 million BTU's	52 million BTU's	44 million BTU's	7	15	15
Greenhouse Gases	5,690 lbs CO_2 equiv.	5,058 lbs CO_2 equiv.	3,582 lbs CO_2 equiv.	11	29	29
Wastewater	19,075 gallons	16,450 gallons	10,325 gallons	14	37	37
Solid Waste	2,278	1,941	1,155	15	40	40

pounds	pounds	pounds			

From table 4, it is observed that the virgin paper always have a higher consumption of wood and energy. In addition, it produces more emission of greenhouse gases, higher discharge of wastewater and higher amount of disposal of solid waste. Therefore, the option of "recycled production plus recycling" saves more energy, consumes less material and generates less waste compared to the option of "virgin production plus waste management".

Furthermore, it was found that one "mature tree" (UBC TREK Program Centre) is able to remove 13lbs/year of CO_2. Assuming for every tree saved by producing PCW rather than virgin paper, that amount of CO_2 will be absorbed from the emissions released, the reduction in greenhouse gas emissions are provided below.

Table 5: Green House Gas Reduction

Basis: 1 Tree = 13 lb/year CO2 Absorbed			
PCW	**Virgin**	**30%**	**100%**
Trees Consumed	24	17	0
Trees Saved (assume virgin paper as basis)	0	7	24
CO2 Absorbed (emissions eliminated)	0	4967.00	3270.00
New Total Emissions released	5690	**91.00**	**312.00**
% Reduction	0.00%	98.20%	91.29%
%Reduced relative to Virgin Paper	0.00%	**98.40%**	**94.52%**

As shown above in Table 5, it is obvious that most environmentally sound paper type for production would be 30%PCW paper achieving the highest reduction out of the three types and lowest overall emissions.

7.2 Environmental Concerns

In the section previous section, it is clear that virgin paper is consuming more energy, more material and is generating more waste than recycle paper. The acquisition of virgin fiber can decrease biodiversity, lead to erosion or even deforestation. For instance, there will be fewer trees to absorb carbon dioxide, which is a major contributor to global warming. Furthermore, without recycling, solid and liquid waste generated is sent to land-filling or incinerating leading to leachate and toxic air emissions. Although 100% post consumer waste recycle paper is not feasible in the long run, government and publics should always recycle papers to reduce the environmental impacts.

Waste water, leachate and run-off can contain toxic substances that can potentially pollute other fresh water sources and farmlands. High Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) effluent consume the dissolved oxygen in water. Aquatic lives can be suffocated because of insufficient dissolved oxygen. Heavy metals ions such as lead and nickel can lead to metal poisoning. Lead poisoning can damage nervous cells which cause blood and brain disorders. Dioxins from the bleaching process are carcinogenic. Also, it can causes chloracne, an extreme skin disease (International Chemical Safety Cards).

7.3 Paper Assessment Applicable to UBC

From UBC data[6], the comparison between 100%PCW is much more sustainable than virgin paper since it saves more energy, water and trees. 100%PCW also reduces environmental impact since it releases lower emissions and frees up landfill space. The comparison between 100%PCW and virgin paper is summarized in the following table.

Table 6: 100% PCW Comparison to Virgin Paper

Relative to Virgin Paper (annual basis)	Amount Saved by Using 100% PCW (based on Paper Reduction Plan)
Trees	17
Water	7000gallons
Air Pollution (lbs)	60
Energy (kWh)	4100
Landfill Area (yd^3)	3

** The above values were provided by the UBC's sustainability office**

8.0 Economic Analysis (unwritten)

SUPERIOR QUALITY
Unisource Canada guarantees that their 30% post-consumer recycled paper is the same quality as virgin. In the last few years, a lot of fine-tuning has taken place with recycled paper. Quality issues that may have been a concern just a few years ago have been resolved. Departments like Geography, Computer Science and the President's Office as well as businesses like UBC Supply Management and Copyright in the SUB have all been using 30% post-consumer recycled paper from Unisource for sometime and have not had any complaints.

Prices as of June 2007

[6] The basis UBC relies on is from the "Recycling - It Adds Up!" (refer to Works Cited)

price/1000 sheets	8.5x11	8.5x14	11x17
Husky recycled white	$ 6.80	$ 8.70	$ 13.66
Econosource virgin white	$ 6.12	$ 8.11	$ 12.75

Assuming that on average, a department uses 200,000 sheets a month, this is the difference in cost and the number of trees used when Husky is purchased instead of Econosource:

Husky	Econosource
$6.80 (1000 sheets) x 200 = $1360/ month	$6.12 (1000 sheets) x 200 = $1224/month
$1360/month x 12 months = $16, 320/year	$1224/month x 12 months = $14, 688/year
16.8 trees/month	**24 trees/month (requires 86.4 more trees per year)**
Husky v. Econosource yearly cost difference:	$1632.00

Figures courtesy of Paul Kilpatrick. Source: http://www.conservatree.org/learn/EnviroIssues/TreeStats.shtml

9.0 Conclusion

10.0 Recommendations

All recommendations are for improving the quality of the data. The majority of our uncertainties are all due to the limited availability of released data. It would be more accurate to conduct a feasibility study with the contributions from the stages of raw material acquisition, packaging deliver and product use to have a more thorough outlook on the long term impacts. It is also recommended that the different paper grades should be investigated on to address the better paper grade rather than recycled content, since a large amount of energy and water consumption is depending on the process. It may also be good to analyze treatment technology and capture methods to assess the amount and type of waste produced can be reduced efficiently. Thus, a comparison between wastes produced to waste treated can be considered. It was found based on analysis that mechanical pulping requires less energy then chemical. It is also recommended that data analysis will be focused on Canada to increase the reports applicability to UBC.

11.0 Limitations in Assessment

There were several limitations due to the data used to conduct our life cycle analysis that one must be aware of. A lot of the information in the entire life cycles was not available or recorded. Emissions released during packaging, delivery and raw material acquisition stages were unattainable or not released by industrial resources. It was assumed that the major contributing factor would be within the process steps and so our scope was quite limited. Most importantly, to produce pure 100%PCW paper is impossible, because recycled lignin will degrade and shorten over time (Moll et al).

The majority of the numeric information that was used in our analysis was provided by one single, though accredited, organization which was the Paper Task Force of the Environmental Defense Fund. This organization is a volunteering based group comprised of businesses that uses a lot of paper ("A New Way To Buy Paper"). Therefore, there is limited assurance of the accuracies of the values. Possible biases are present by this source since this paper force was based on values applicable to the United States of America. The environmental impact numbers were provided by the Paper Task Force group through the correlation from a collection of paper studies. However, some of the papers date back to 1992 and the paper demand and technology have improved tremendously since then.

There is much more green technology with better production techniques with less pollution that companies have implemented. However, different technologies have different efficiencies, and so the feasibility of a certain paper type changes depending on the available or in service technology. Furthermore, it depends on the abundance and renewable nature of the raw materials. For now it may be most feasible to use 30%PCW paper, but if future advancements and the priorities are valued differently, an alternative paper type may be preferable.

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13.0 Appendices

Table 1A: Three systems provided by *Lifecycle Environmental Comparison: Virgin Paper and Recycled Paper-Based Systems*

Virgin Production plus Incineration:	- harvesting of trees, transporting of logs (or chips) to the mill, debarking and chipping, and manufacture of pulp and paper using virgin fiber; - waste collection and transport; placement in the landfill; generation of leachate, and leachate management, treatment and disposal; generation of landfill gas, and possible recovery and utilization of such gas (energy production); and land use issues.
Virgin Production plus Land-	- harvesting of trees, transporting of logs (or chips) to the mill, debarking and chipping, and manufacture of pulp and paper using virgin fiber;

filling:	- waste collection and transport; possible pre-processing at the incinerator (e.g., refusederived fuel vs. mass-burn facilities); the incineration process and management of air emissions; energy generation; ash management (storage, transport) and disposal; and generation of ash leachate, and leachate management, treatment and disposal.
Recycled Production plus Recycling:	- material collection (curbside collection, commingled or source-separated; drop-off or buy-back centers; commercial collection); transport; pre-processing at material recovery facilities (MRFs); residuals management and disposal; and transport of processed recovered material to the remanufacturing site; - Remanufacturing of pulp and paper using recovered fiber.

Table 2A: Summary of lifecycle environmental impacts and equivalents

	Virgin Paper	30% Recycle	**Difference** (Virgin Paper – 30% Recycle)		100% Recycle	**Difference** (Virgin Paper – 100% Recycle)	
Wood Use	3 tons	2 tons	1 tons	**7 trees**	0 tons	3 tons	**24 Trees**
Total Energy	38 million BTU's	33 million BTU's	5 million BTU's	**<1 homes/year**	22 million BTU's	17 million BTU's	**<1 homes/year**
Purchased Energy	18 million BTU's	19 million BTU's	-1 million BTU's	**<1 homes/year**	22 million BTU's	-3 million BTU's	**<1 homes/year**
Sulfur dioxide (SO_2)	26 pounds	26 pounds	<1 pounds	**<1 18-wheelers/year**	26 pounds	<1 pounds	**<1 18-wheelers/year**
Greenhouse Gases	5,690 lbs CO_2 equiv.	5,058 lbs CO_2 equiv.	632 lbs CO_2 equiv.	**<1 cars/year**	3,582 lbs CO_2 equiv.	2,108 lbs CO_2 equiv.	**<1 cars/year**

Nitrogen oxides (NOx)	18 pounds	17 pounds	1 pounds	**<1 18-wheelers/year**	14 pounds	4 pounds	**<1 18-wheelers/year**
Particulates	12 pounds	11 pounds	2 pounds	**<1 buses/year**	7 pounds	5 pounds	**<1 buses/year**
Hazardous Air Pollutants (HAP)	2 pounds	2 pounds	<1 pounds		<1 pounds	2 pounds	
Volatile Organic Compounds (VOCs)	6 pounds	4 pounds	1 pounds		2 pounds	4 pounds	
Total Reduced Sulfur (TRS)	<1 pounds	<1 pounds	<1 pounds		0 pounds	<1 pounds	
Wastewater	19,075 gallons	16,450 gallons	2,625 gallons	**<1 swimming pools**	10,325 gallons	8,750 gallons	**<1 swimming pools**
Biochemical	6	6	<1	**<1**	6	<1	**<1**

Oxygen Demand (BOD)	pounds	pounds	pounds	**homes/year**	pounds	pounds	**homes/year**
Total Suspended Solids (TSS)	10 pounds	9 pounds	<1 pounds	**<1 homes/year**	7 pounds	3 pounds	**<1 homes/year**
Chemical Oxygen Demand (COD)	92 pounds	73 pounds	19 pounds	**<1 homes/year**	28 pounds	64 pounds	**<1 homes/year**
Adsorbable organic halogens (AOX)	<1 pounds	<1 pounds	<1 pounds		0 pounds	<1 pounds	
Solid Waste	2,278 pounds	1,941 pounds	337 pounds	**<1 garbage trucks**	1,155 pounds	1,124 pounds	**<1 garbage trucks**

Source: Duke University, Environmental Defense Fund, Johnson & Johnson, Mcdonald's, The Prudential Insurance Company Of America, and Time Inc.. "No. 3: Lifecycle Environmental Comparison - Virgin Paper and Recycled Paper-Based Systems." Paper Task Force 1 (1995). 19 Mar. 2008 <http://www.edf.org/article.cfm?ContentID=1635>