2017 Pacific Southwest Section
Meeting: Tempe, Arizona Apr 20
Paper ID #20700

Life Cycle Assessment of Paper Versus Electronic Assignment Submission

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Life Cycle Assessment of Paper Versus Electronic Assignment Submission in Cal Poly's Materials Engineering Department

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Abstract

Both hard and soft copy submission of assignments make an impact on the environment to produce the final product in terms of energy consumption and carbon emissions; an investigation was conducted as to which method is less environmentally impactful. Student disposition towards each assignment submission method was also investigated because it is associated with learning efficacy. A survey was conducted in the California Polytechnic State University's (Cal Poly's) Materials Engineering Department to determine the contributing components to the environmental impact of paper and electronic assignments, as well as the students' disposition towards each of them. Contributing components are man-made products used by a student to complete one homework assignment and they were chosen based on the pre-defined project scope and the survey results. They were then analyzed using life cycle assessment (LCA). Under the specifications discussed in this report, paper assignment submission results in 1.30 MJ of energy consumed per assignment, while an electronic assignment consumes 0.633 MJ of energy. The global warming potential (GWP) of paper assignments was 57.6 g CO_2 and of electronic assignments was 32.6 g CO_2. The largest contributing components of each submission method were subjected to a sensitivity analysis, which showed that the results are strongly dependent on the length of the assignment and the time it takes to complete the assignment.

Introduction

Many effective education systems require submission of a student's work as a method of evaluating a student's understanding of the material. Currently, the main option for showcasing a student's knowledge is physical: a paper hand-in assignment. Alternatively, a student might be asked to submit an assignment online. Questions have been raised about the environmental impact of these assignment submission methods [1]. Many professors and teachers also want to give students assignments in the form that will enable students to retain the information in the assignment with greater effectiveness. Thus, learning efficacy is a secondary quantitative objective of this project and its dependence on assignment submission method was investigated.

Paper is often associated with the demolishing of forests and thus can be viewed as having a significantly negative environmental impact [2]. Similarly, electronic assignment submission requires at least one of many electronic devices, which are recognized to contain rare earth metals and involve significant amounts of processing for extraction once their devices are no longer in use [3, 4]. They also operate on electricity, which furthers their energy consumption once manufacturing is complete. Thus, it is difficult to determine which method is more environmentally impactful simply by looking at life cycle phases qualitatively (what materials are used, processing, etc. This project uses life cycle assessment (LCA) to quantitatively evaluate the environmental impact of paper versus electronic assignments.

Methodology

Environmental Impact

One method of quantitatively determining environmental impact is LCA. This approach sums energy consumption and other environmental considerations (such as carbon or sulfur emissions) over the different stages of a product's life to determine its overall environmental impact. The five life cycle phases of an LCA are materials extraction, manufacturing, transportation, use, and disposal/end of life [5, 6]. In the application of homework assignments, energy consumption and global warming potential (GWP) were used in this project as measures of environmental impact. GWP is a relative measure of how much heat a greenhouse gas traps in the atmosphere. GWP was done on a 100-year basis in this study. This study used a single assignment as a basis for both the energy consumption and GWP calculations.

One of the most critical aspects of an LCA is determining its scope [5]. Contributing components to this LCA are man-made products used by a student to complete one homework assignment, and selection of the components helps to determine the scope of the LCA. Electronic assignments in this study are considered to be submitted through PolyLearn, which is the California Polytechnic State University's (Cal Poly's) learning management system software that stores and manages course content and activities online. Whether or not individual components are included in the LCA can play a large role in its outcome. What to include in the LCA is dependent in part on the time a product is used in relation to its lifetime. In this study, a survey was conducted in Cal Poly's Materials Engineering Department (MATE) to determine the fractions of the lifetimes of the components used to complete a homework assignment, and whether or not to include a component in the LCA based on the size of its contribution to an assignment. Possible components that had a "long lifetime," or ones that had an excess of ten years of use such as furniture or buildings were not included because one homework assignment would use an extremely small fraction of their lifetimes. Humans as LCA components were not included as they are assumed to have a small contribution to the energy consumption and GWP of the final product and are impractical to measure. Table 1 shows the components of each assignment submission method that were considered; ones shown in bold were selected on the basis of the scope considered above as well as the survey results. Assignment components that were identified by at least 70% of survey respondents' answers were included as part of the LCA for the assignment. The components that were considered but not selected were done so on either the basis of long lifetime or low survey response percentage.

A survey of students in Cal Poly's Materials Engineering Department was taken in order to quantify some of the information about the "use" portion of the components' life cycles as well as to help in deciding what components to include in the LCA. Twenty-four percent or 51 of the total number of students in the Materials Engineering Department (209) responded to the survey. The survey also served as a way to measure learning retention (see Learning Efficacy below). The survey was conducted in compliance with Cal Poly's Human Subjects Research Board (HSRB) standards [7]. These standards include informed consent, minimized risk, no benefits to survey respondents, equitable selection of survey respondents, confidentiality, respect of vulnerable subjects (disadvantaged, disabled, etc.), and a debriefing.

Table 1. Components that were considered for both assignment submission methods. Bold type indicates that the component was chosen for the LCA.

Paper Submission Method	Electronic Submission Method
Paper	**Laptop** (various sizes)
Mechanical pencil	Desktop
Wooden pencil	Keyboard
Black pen	**Mouse**
Graphing calculator	Speakers
Lamp/light bulb	USB drive
Computer	Headphones
Large eraser	Earphones
Rulers	**PolyLearn servers**
Binder	
Scientific calculator	

In order to achieve an accurate and meaningful representation of assignments in Cal Poly's Materials Engineering curriculum, students in their second year and beyond were asked to voluntarily participate in the survey. This means that the survey participants were actually representative of over 30% of Materials Engineering majors if the freshman class is not included. They were asked to consider assignments pertaining to the Materials Engineering major and technical elective classes. The full survey is shown in Appendix A. Questions 5 – 12 of the survey refer to a typical assignment from a technical course. Questions 14 – 17 of the survey focus on learning efficacy, where survey respondents are asked about their preferred method of submitting a given assignment (shown in Appendix B), and whether the assignment submission method affects retention of information from the given assignment.

One consideration that was not part of the survey was Cal Poly's online submission method, PolyLearn. Servers are required that are dedicated to the development, testing, and implementation of PolyLearn. Server considerations for PolyLearn can be found in the section titled “Global Warming Potential (GWP) and Energy Consumption of Cal Poly’s PolyLearn Servers.”

Component Assumptions

Data for the materials extraction, manufacturing, transportation, and end of life phases were either taken from previous data in the literature [10, 11, 12, 13] or were calculated using reasonable considerations as described below [10, 14]. The fraction of the lifetime and the “use” phases of components such as laptops and servers were determined as averages from the survey and used to compute the energy consumed by these components during assignment creation. Individual responses from the survey are not available in compliance with Cal Poly’s Policy on Human Subjects Research [7].

Global Warming Potential (GWP) and Energy Consumption of a Graphing Calculator

No LCA was readily available for a graphing calculator, so it was modeled as being similar to a laptop, but scaled down to reflect a calculator’s smaller size and lower power rating. A TI-84 Plus graphing calculator (very common in the current generation of college students based on the survey) is 14.0% of the mass of the laptop in question [10] and contains 12.6% of the volume of the same laptop. Other graphing calculators are also similar in size, both in mass and in volume when compared to a laptop in this way. Since the mass fraction and the volume fraction of the TI-84 Plus graphing calculator with respect to the Dell Inspiron 2500 laptop are similar, an average of the mass fraction and the volume fraction (13.3%) was used as the scaling factor to estimate the energy consumption and GWP of a graphing calculator in comparison to a laptop. The survey suggests that graphing calculators last for a relatively long time (in excess of six years) so they are not likely to be a large contributing component to the inventory of energy consumption and GWP in the LCAs for assignments. The power rating of a graphing calculator is unlikely to be near that of a laptop, so the validity of 13.3% of a laptop’s power as an estimate of a graphing calculator’s power was investigated. 1 amp is considered to be extremely high for a graphing calculator [15, 16] and they usually operate on four 1.5 V batteries, so an upper limit estimate of 5 W as a power rating was used. This corresponds to 12.5% of the laptop’s power rating. This suggests that it is reasonable to model a graphing calculator as scaled-down version of a laptop.

Global Warming Potential (GWP) and Energy Consumption of a Writing Implement

The survey also suggested that a mechanical pencil should be included as a contributing component to a paper assignment. No LCA for the energy consumption of mechanical pencils was available; however an estimate could be made from a U.S. government census of the industry as a whole [14] with respect to energy consumption. The total value of the mechanical pencils was divided by the total value of the purchased energy in the form of electricity for mechanical pencil production to find the average amount of energy consumed during the production of a pencil. The value of the pencils was taken from the 2002 U.S. government census. No value for the GWP of mechanical pencils was available in the literature, either. However, the amount of energy consumed during the production of a mechanical pencil can be used to estimate the GWP for a mechanical pencil. The energy (in kW-h) used in producing a mechanical pencil can be converted into g CO_2 using the average U.S. CO_2 emission rate from the EPA's Annual Report on GHG Output Emission Rates [17]. This is a low estimate because this estimated value is only the GWP associated with manufacturing of the pencils and does not include the GWP of the pencils' other life cycle phases.

Global Warming Potential (GWP) and Energy Consumption of Cal Poly's PolyLearn Servers

Michael Haskell of Cal Poly's Information Technology Services (ITS) Department provided information for the servers used to develop and maintain PolyLearn, which is a resource used for many online assignments. Cal Poly utilizes a total of 17 servers with 58 CPUs, all of which are Intel Xeon E5-2680 v2s [18]. Some details on the three environments that Cal Poly uses to maintain PolyLearn can be found in Appendix C. Specifications for this product indicate that the thermal design power is 115 W [19]. It is assumed that this is the average power the processor is dissipating. Intel had an LCA done on a similar server, known as a PowerEdge in compliance with ISO 14040 and 14044 [20]. Both energy consumption and GWP were calculated using a basis of 20944 students enrolled at Cal Poly [21]. Therefore, each student is using 0.081% of one of these servers (number of servers divided by the number of students) each time they complete an assignment on PolyLearn.

Global Warming Potential (GWP) and Energy Consumption of Other LCA Components

Laptop LCA data was incorporated directly from an LCA done as a collaborative study across several universities [10]. A joint study between the U.S. Board on Agriculture and the National Research Council was used for paper LCA energy consumption data [11] while GWP information was found in an LCA done by the American Forest and Paper Association [12]. Mouse LCA data was taken from an LCA done as a dissertation in the UK [13]. It should be noted that although many institutions follow the same procedures for conducting a LCA, the procedure for defining the scope of the LCA differs between parties [5, 6]; what one party chooses to include in their analysis may differ from another party looking at the same product. This will establish different final results.

Learning Efficacy

In addition to the quantitative impacts associated with the life cycle phases of LCA components, this project also focused on learning efficacy between the two assignment submission methods. In some studies, learning efficacy and retention rates have been linked to one's disposition towards a method of learning [8, 9]. In other words, if a student is more inclined to learn using a particular method, then they are more likely to benefit from using that method. This was studied using the survey by querying students about a hypothetical assignment from MATE 232 (Materials, Ethics, and Society). Then they were asked questions about which assignment submission method they were more inclined to choose and which assignment submission method they thought would result in greater retention of information. An example of the hypothetical assignment is shown in Appendix B.

Results

Environmental Impact

Assignment components that were identified by at least 70% of survey respondents' answers were included as part of the LCA for the assignment. Therefore the LCA components of paper assignments were 5.4 sheets of 8.5" x 11" paper, a graphing calculator (TI-84 Plus edition), and a mechanical pencil. For electronic assignments the LCA components included a 14" laptop and a mouse. It is important to note that nearly all laptops were within 2" of this size and a vast majority of students using laptops were using the 14" size. Students not using a laptop were generally using custom-built personal computers, which could be taken into account using sensitivity analysis. Although there have been verbal claims by students that many use the library desktop computers, the survey did not validate these claims. Table 2 shows the contribution of each of these components to the overall energy consumption and GWP of the respective assignment types.

Table 2. Energy consumption and GWP component breakdown for both paper and electronic assignment submission. Based on these initial results, electronic assignment submission appears to have a lower environmental impact in terms of energy consumption and GWP.

Paper Assignment Component	**Energy Consumed per Assignment (MJ)**	**GWP per Assignment (g CO_2)**
Paper	1.25	48.3
Graphing Calculator	0.0487	6.88
Mechanical Pencil	7.34 E-5	0
Total	***1.30***	***57.6***
Electronic Assignment Component	**Energy Consumed per Assignment (MJ)**	**GWP per Assignment (g CO_2)**
Laptop	0.617	31.1
Mouse	0.0160	1.51
Servers	4.18E-8	2.09E-4
Total	***0.633***	***32.6***

Learning Efficacy

Figure 1 shows the response from survey participants to the question of which assignment method (paper or electronic) they prefer. The response suggests that there is not a significantly strong preference for one assignment submission method over the other. Figure 2 illustrates what survey participants think of the importance of being able to choose which assignment submission method to utilize. The results indicate that most survey participants do not believe it is very important or only somewhat important to be able to select the method of assignment submission. Figure 3 is the response of survey participants to the question of which assignment submission method results in improved information retention. It suggests that survey respondents think that hard - copy submission is better or at least as good as electronic assignment submission for information retention. In order to comply with Cal Poly's HSRB policy on confidentiality, individual responses and any comments made by survey respondents are not available to the public [7].

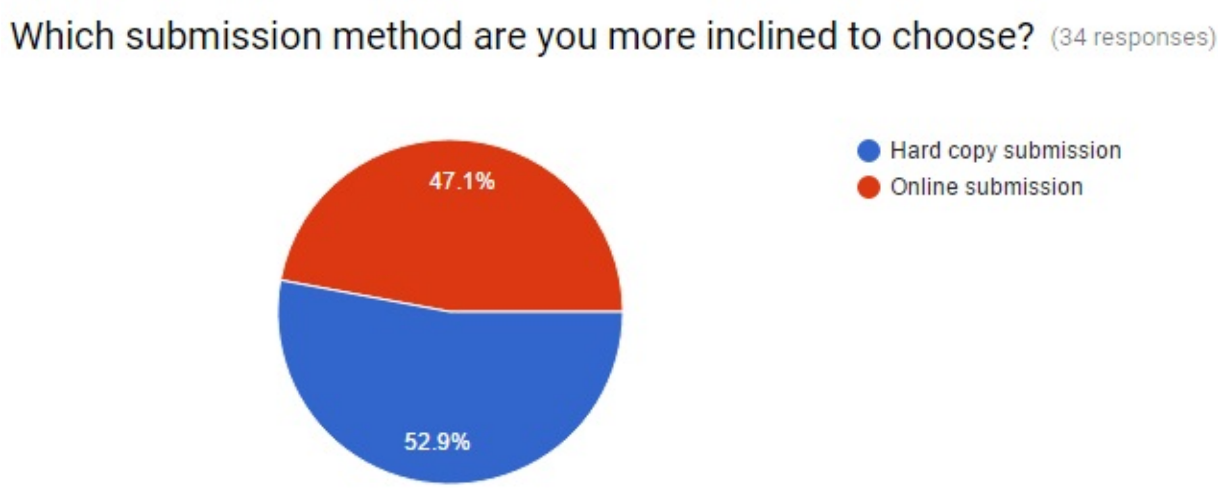

Figure 1. Results of survey of Cal Poly Materials Engineering students regarding which type of assignment submission method (paper or electronic) they prefer. Hard copy submission is chosen slightly more often as the preferred method of submission. If preference is an indicator of learning efficacy/retention as the literature suggests, then hard copy submission may be a better choice for learning efficacy/retention.

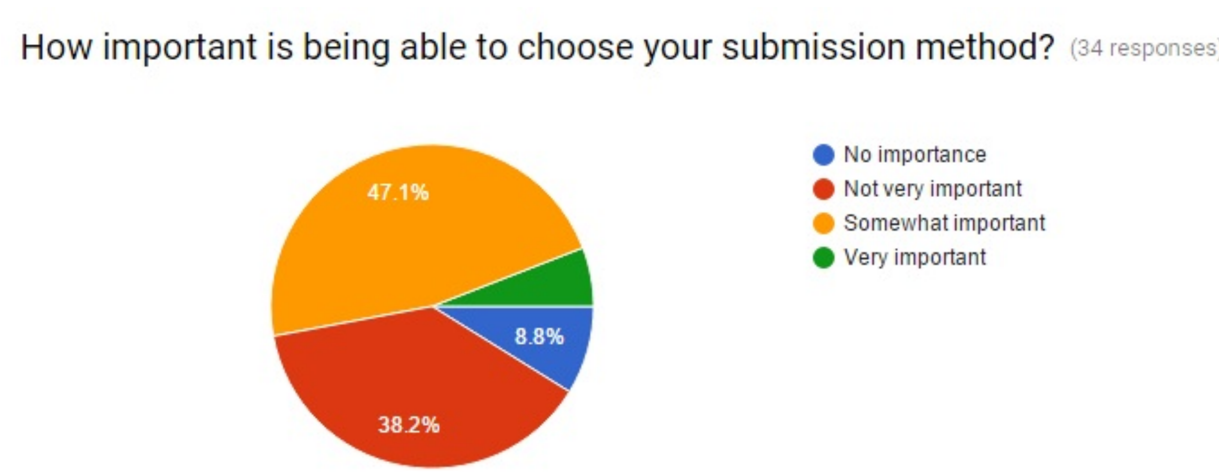

Figure 2. Results of survey of Cal Poly Materials Engineering students regarding how important it is to be able to choose between paper and electronic submission of assignments. Most survey respondents think that it is not very important or somewhat important.

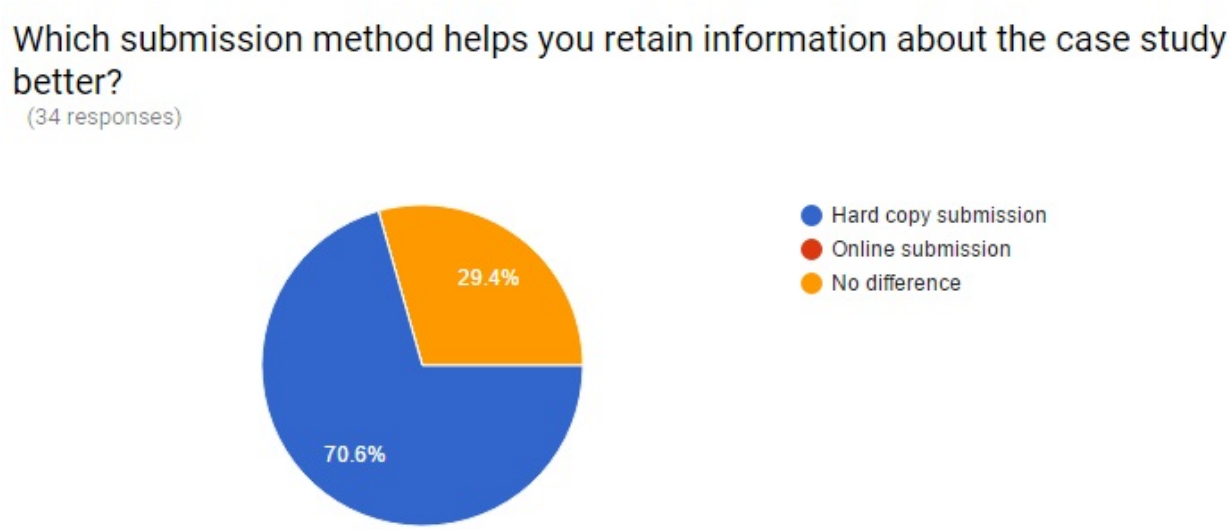

Figure 3. Results of survey of Cal Poly Materials Engineering students regarding which assignment submission method (paper or electronic) is more helpful for information retention. All participants in the survey indicated that hard copy submission is better than or at least as good as online submission in terms of information retention.

Analysis

Environmental Impact

A summary of the components contributing to energy consumption and GWP for each of the paper and electronic assignment submission methods is provided in Table 3 and an analysis of their contributions was performed. Paper and laptops are by far the largest contributors to energy consumption and GWP of their respective assignment submission methods. Components such as the mechanical pencil use in paper assignments could be considered inconsequential because it provides less than 0.01% of the total energy consumption of the assignment.

With over 95% of the energy consumption coming from paper and laptops in their respective assignment submission method, the amount of energy consumed and the GWP per assignment is highly dependent on the life cycle phases of paper and laptops. A summary of the contribution of each life cycle phase of these components in their respective assignment submission method's lifetime is provided in Table 4 for both energy consumption and GWP. In a paper assignment, the largest contributor is manufacturing while the largest contributor for electronic assignments is use. Following electronics use are the manufacture and transportation phases, which are minor but still non-trivial for electronic assignments.

The most environmentally impactful phases were then subjected to a sensitivity analysis to determine how relevant and meaningful the initial estimates of the energy consumption of a paper assignment and an electronic assignment are (1.30 MJ and 0.633 MJ respectively). Tables 3 and 4 have identified the most environmentally impactful life cycle phases to be the manufacturing of paper, the use of laptops, the manufacturing of laptops, and the transportation of laptops. The amount of energy consumed is also dependent on the time it takes to complete an assignment and the amount of paper used. These specific life cycle phases were subjected to a sensitivity analysis; a summary of the range of values for these life cycle phases and their effects on energy consumption and GWP are shown in Table 5. Factors are quantitative values that affect both the energy consumption and GWP of a life cycle phase (and transitively its component and the overall LCA of the assignment submission method).

Table 3. Percent contribution of components of electronic and paper assignment submission methods in terms of energy consumption and GWP. The laptop and the paper provide for most of the environmental impact in their respective assignment submission methods.

Paper Assignment Component	**Energy Consumption per assignment (MJ)**	**% Contribution to Total Energy Consumption per Assignment**
Paper	1.25	96.2
Graphing Calculator	0.0487	3.75
Mechanical Pencil	7.34 E-5	0.00565
Total	***1.30***	***100***
Electronic Assignment Component	**Energy Consumption per assignment (MJ)**	**% Contribution to Total Energy Consumption per Assignment**
Laptop	0.617	97.5
Mouse	0.0160	2.53
Servers	4.18E-8	6.60E-6
Total	***0.633***	***100***
Paper Assignment Component	**GWP (g CO_2)/ Assignment**	**% Contribution to Total GWP per Assignment**
Paper	48.3	83.9
Graphing Calculator	6.88	11.9
Mechanical Pencil	2.46	4.27
Total	***57.6***	***100***
Electronic Assignment Component	**GWP (g CO_2)/ Assignment**	**% Contribution to Total GWP per Assignment**
Laptop	31.1	95.4
Mouse	1.51	4.63
Servers	2.09E-4	6.41E-4
Total	***32.6***	***100***

Calculation of Minimum and Maximum Values of Energy Consumption and GWP

Laptop manufacturing, transportation, and power use minimum and maximum values were taken from the LCA of the Dell Inspiron 2500 laptop [10]. Values for laptop use and the amount of paper used were taken from the survey results. The values for paper manufacturing were taken from an LCA by the U.S. National Research Council and the Board on Agriculture [11].

Table 4. Energy consumption and GWP breakdown by life cycle phase for the major components (paper and laptops) of paper and electronic assignment submission methods respectively.

Life Cycle Phase	**Paper Energy Consumption (MJ/assignment)**	**Paper Energy Consumption (% contribution)**	**Electronic Energy Consumption (MJ/assignment)**	**Electronic Energy Consumption (% contribution)**
Raw Materials	0.0402	3.09	0.0361	5.70
Manufacture	1.15	88.5	0.111	17.5
Transportation	0.0311	2.39	0.0793	12.5
Use	0.000	0	0.333	52.6
End of Life	0.0778	5.98	0.0723	11.4
Total	***1.30***	***100***	***0.633***	***100***
Life Cycle Phase	**Paper GWP (g CO_2 / assignment)**	**Paper GWP (% contribution)**	**Electronic GWP (g CO_2 /assignment)**	**Electronic GWP (% contribution)**
Raw Materials	4.55	7.90	3.06	9.39
Manufacture	31.1	54.0	8.46	26.0
Transportation	2.00	3.47	6.28	19.3
Use	2.60	4.51	11.9	36.5
End of Life	17.4	30.2	2.96	9.08
Total	***57.6***	***100***	***32.6***	***100***

Sensitivity Analysis Results

Table 5 reveals that the largest contributing factors to the overall energy consumption of a paper assignment are the number of sheets of paper used. In electronic assignments, the largest contributor to energy consumption is the amount of time a laptop is used as well as the amount of power it uses. By combining the lower and upper bounds of the changes in energy consumption and GWP resulting from sensitivity analysis, a range of values is obtained (Table 5). For electronic assignments this yields a range of 0.202 MJ - 1.36 MJ consumed for an electronic assignment and a range of between 13.5 g CO_2 - 65.4 g CO_2 for GWP. Comparatively, a paper assignment consumes between 0.554 MJ and 2.57 MJ of energy and emits between 20.4 g CO_2 and 101 g CO_2 in GWP.

These ranges suggest that electronic assignments may be overall less energy intensive than paper assignments, although there is overlap in the ranges. If a professor were to consider both submission options for an assignment with environmental impact (energy consumption and GWP) in mind, he/she should take the following into account:

- Assignment Time: If the assignment is estimated to take longer than six hours to complete, then he/she should consider making it a paper assignment due to the energy consumption that occurs during the use of the laptop.
- Assignment Length: If the assignment is estimated to take more than five 8.5” x 11” sheets of paper to complete, professors should consider making it an electronic assignment due to the energy consumption and GWP that occurs from the manufacturing of paper.

Table 5. Sensitivity analysis that shows the maximum and minimum values of energy consumption and GWP for paper and electronic assignment submission. Lower values are the least environmentally impactful while upper values are the most environmentally impactful.

Factor	Energy Consumption Initial Value	Energy Consumption Minimum Value	Energy Consumption Maximum Value	Energy Consumption Lower Bound (MJ)	Energy Consumption Upper Bound (MJ)
Electronic	**0.633 MJ/assignment**			**0.202 MJ/assignment**	**1.36 MJ/assignment**
Laptop Manufacturing, MJ/laptop	1508	1315	2645	-0.014	0.084
Laptop Transport, MJ/laptop	1070	865	1215	-0.015	0.011
Laptop Power, W	40	20	52	-0.166	0.100
Laptop Use, hrs.	3.24	2	6	-0.236	0.527
Paper	**1.30 MJ/assignment**			**0.554 MJ/assignment**	**2.57 MJ/assignment**
Paper used, sheets	5.4	3	10	-0.556	1.07
Paper Manufacturing, MJ/kg	38300	32000	45000	-0.190	0.200
Factor	**GWP Initial Value**	**GWP Minimum Value**	**GWP Maximum Value**	**GWP Lower Bound (g CO_2)**	**GWP Upper Bound (g CO_2)**
Electronic	**32.6 g CO_2/ assignment**			**13.5 g CO_2/ assignment**	**65.4 g CO_2/ assignment**
Laptop Manufacturing, GWP (kg CO_2)/laptop	31.0	27.1	54.4	-0.300	1.80
Laptop Transport, GWP(kg)/laptop	83	67.1	83	-1.1	0.9
Laptop Power, W	40	20	52	-5.8	3.6
Laptop Use, hrs.	3.24	2	6	-11.9	26.5
Paper	**57.6 (g CO_2/ assignment)**			**22.9 (g CO_2/ assignment)**	**103 (g CO_2/ assignment)**
Paper used, number of 8.5” x 11” sheets	5.4	3	10	-30.4	41.4
Paper Manufacturing, MJ/kg	38300	32000	45000	-4.40	4.60

Learning Efficacy

Studies have shown that student disposition towards a certain method learning has a direct correlation to better retention of information [8, 9]. The survey results suggest that there is not a significant difference in preference of assignment submission methods. However, a substantial percentage of survey respondents believe that paper assignment submission is better for retention of information. Whether or not this assumption is true in practice, the belief that paper assignments are better for information retention than electronic assignments could be enough to make it seem true to students. This could mean that students are more likely to retain more information from using paper assignment submission [9].

Conclusions

Under the specifications of the scope of this LCA the amount of energy consumed for paper and electronic assignments is estimated at 1.30 MJ and 0.633 MJ and the GWP is 57.6 g CO_2 and 32.6 g CO_2, respectively. However, sensitivity analysis revealed that there is actually a considerable range of values for energy consumption and GWP for both paper and electronic assignment submission (including some overlap between assignment submission methods). Although there is not a significant difference in preference between paper and electronic assignment submission, survey respondents from among Cal Poly Materials Engineering students generally think that hard copy submission is correlated to better information retention. This belief may make paper submission of assignments better than electronic submission of assignments for greater information retention. In general, it is acceptable to state that electronic assignment submission is less environmentally impactful but it may not always be the case depending on laptop use and assignment length.

References

1. Bonham, Scott, Robert Beichner, and Duane Deardorff. "Online Homework: Does It Make a Difference?" *The Physics Teacher* 39 (2001): 293-96. *North Carolina State University Articles*. North Carolina State University, University of North Carolina, May 2001. Web.
2. "Environmental Impacts of the Paper Industry." *Clean Water Action Council*. Clean Water Action Council, n.d. Web. 18 May 2016.
3. Ramirez, Ainissa. "Where to Find Rare Earth Elements." *NOVA NEXT*. PBS, 2 Apr. 2013. Web. 18 May 2016.
4. Connelly, Neil G. *Nomenclature of Inorganic Chemistry IUPAC Recommendations*. Cambridge, UK: Royal Society of Chemistry, 2005. Web.
5. "ISO 14040 Environmental Management - Life Cycle Assessment - Principles and Framework." *International Standard* (1997): n. pag. International Organization for Standardization. Web. 18 May 2016.
6. "ISO 14044 Environmental Management - Life Cycle Assessment - Requirements and Guidelines." *International Standard* (2006): n. pag. International Organization for Standardization. Web. 18 May 2016.
7. "Policy for the Use of Human Subjects in Research." *- Research and Economic Development*. Cal Poly Research and Economic Development, n.d. Web. http://research.calpoly.edu/HS-policy. Accessed 18 May 2016.
8. Brophy, Jere. *Motivating Students to Learn*. 2nd ed. Mahweh: LAWRENCE ERLBAUM ASSOCIATES, 2004. Web. 18 May 2016.
9. Committee on Increasing High School Students' Engagement and Motivation to Learn, Board on Children, Youth and Families, Division of Behavioral and Social Sciences and Education, and National Research Council. *Engaging Schools: Fostering High School Students' Motivation to Learn*. N.p.: National Academies, 2003. Web. 18 May 2016.
10. Deng, Liqiu, Callie W. Babbitt, and Eric D. Williams. "Economic-balance Hybrid LCA Extended with Uncertainty Analysis: Case Study of a Laptop Computer." *Journal of Cleaner Production* 19.11 (2011): 1198-1206.
11. Denison, Richard A. "LIFE-CYCLE ASSESSMENT FOR PAPER PRODUCTS." *Wood in Our Future: The Role of Life-Cycle Analysis: Proceedings of a Symposium*. Environmental Defense Fund, 1997. Web. 18 May 2016.
12. Gaudreault, Caroline. "Printing and Writing Papers Life Cycle Assessment." *NCASI*. American Forest and Paper Association, 3 Dec. 2010. Web. 18 May 2016.
13. "Conduct A Life Cycle Assessment." UKessays. November 2013. All Answers Ltd. 18 May 2016.
14. Bureau, U.S. Census. "Pen and Mechanical Pencil Manufacturing. "*Economic Census Manufacturing Industry Series* (1999): n. pag. *Census*. U.S. Census Bureau. Web. 18 May 2016.
15. Giovinazzo, Paul. "The Fatal Current." *Bulletin* 2.13 (1987): n. pag. *Electrical Safety*. New Jersey State Council of Electrical Contractors Associations, Inc. Web. 18 May 2016.

16. Kuphaldt, Tony R. "Electrical Safety." *Lessons In Electric Circuits*. Vol. 1. N.p.: Design Science, n.d. N. pag. *Electrical Safety*. Design Science, 2001. Web. 18 May 2016.
17. *eGRID2012 GHG Annual Output Emission Rates* (n.d.): n. pag. 2012. Web. 1 June 2016.
18. "PolyLearn - Server Information." Private communication from Michael Haskell. 2 May 2016. E-mail.
19. "Intel® Xeon® Processor E5-2680 (20M Cache, 2.70 GHz, 8.00 GT/s Intel® QPI) Specifications." *ARK Product Launch*. Intel, n.d. Web. 18 May 2016.
20. Stutz, Mark. "Carbon Footprint of a Typical Rack Server from Dell." *Carbon Footprint of a Typical Rack Server from Dell* (2011): n. pag. Dell. Web. 18 May 2016.
21. Saavedra, Mauricio F., Patricia Van Belleghem, Kathleen Agostini, and Garry Smith. *Cal Poly Fact Book*. San Luis Obispo: California Polytechnic State U., 2015. *Overview of Publications and Reports: Fact Book*. Cal Poly Institutional Research, 2016. Web. 18 May 2016.

Appendix A: Assignment Submission Survey

Thank you for participating in this survey for the senior project “Life Cycle Analysis of Paper versus Electronic Assignment Submission in Cal Poly Materials Engineering.” Your answers today will help shape any conclusions or recommendations I have for the improvement of our department. However, environmental aspects that the title suggest are only part of the project. The second portion of the survey will be aimed at determining a motivational difference between the two methods of submitting assignments. What’s a life cycle analysis? Life cycle analysis is a method of looking at a product’s complete life cycle, from raw materials to final disposal. It includes five major phases: Raw Materials, Manufacturing, Transportation, Use, End of Life.

What I’ll be asking you to do today will help me with the inputs for the “Use” phase. Your answers will be kept anonymous through the use of Google Forms if you are utilizing the online option; I will not be able to differentiate one set of answers from any of the others.

You will be asked to:

--Provide information about how you do your assignments

--Provide your thoughts on how you would do a hypothetical MATE 232 (Materials, Ethics, and Society) ethics case study worksheet. Here is the scope of the project: the goal is to look at the tools that you utilize from the start of an assignment to the finish, but any human--related function items should not be considered. You do not need to include items with a very long lifetime such as large furniture or buildings in your description.

Example: A student who normally eats while doing their paper assignment at their home desk should not include eating or the desk itself in the responses to follow. However, they should include that they always use a graphing calculator and a mechanical pencil. You will be asked questions regarding typical paper or electronic assignments in MATE or MATE technical support courses. A paper assignment is defined as a handwritten assignment that is physically submitted to a professor or grader. An electronic assignment is defined as an assignment that is completed using an electronic device and submitted via the internet (PolyLearn, email, etc.).

If you have questions, comments, or concerns regarding the project, please contact Patrick McDonnal at pmcdonna@calpoly.edu.

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT, "Life Cycle Analysis of Paper versus Electronic Assignment Submission in Cal Poly Materials Engineering" A research project on the environmental impact differences between paper and electronic assignment submission is being conducted by Patrick McDonnal, a student in the Department of Materials Engineering at Cal Poly, San Luis Obispo under the supervision of Dr. Jean Lee. The purpose of the study is to gain relevant and meaningful data to incorporate into the life cycle analysis that the project is focused on.

You are being asked to take part in this study by completing the following survey. You will first be asked about the demographics of your past assignment submissions. Then, a hypothetical situation will be given and questions inquiring about your disposition towards assignment submission methods will be asked. Please be aware that you are not required to participate in this research and you may discontinue your participation at any time without penalty. You may also omit any items on the survey you prefer not to answer. There are no risks anticipated with participation in this study. Your responses will be provided anonymously and your decision whether or not to participate will have no effect on your status at Cal Poly. Potential benefits from this research include a better understanding of how different assignment submission methods affect the environment and the students completing the assignments.

If you have questions, comments, or concerns regarding the project, or would like to be informed of the results, please contact Patrick McDonnal at pmcdonna@calpoly.edu. If you had concerns regarding the manner in which this study is conducted, you may contact Dr. Michael Black, Chair of the Human Subjects Research Committee at (805) 756-1508, mblack@calpoly.edu, or Dr. Dean Wendt, Dean of Research, at (805) 756-1508, dwendt@calpoly.edu. Moving beyond this page indicates that you give your informed consent to participate in the project. Please keep a copy of this form for your records and thank you for your participation in this study.

1. Please indicate your expected date of graduation.

2. Please indicate your major. If other please elaborate.

3. Please estimate the percentage of MATE and MATE required technical support courses that have required mostly paper submission of assignments.

4. Please estimate the percentage of MATE and MATE required technical support courses that have required mostly electronic submission of assignments.

5. In a typical paper assignment for a MATE or MATE required technical support course, please estimate the number of pages (not sides) of paper that you would use to complete the assignment.

6. In a typical paper assignment for a MATE or MATE required technical support course, please estimate the number of hours that you would use to complete the assignment.

7. Please indicate the location at which you would typically complete a paper assignment. Example: Kennedy Library third floor.

8. Please give information about items you need to complete paper assignments for MATE or MATE required technical support courses here. Please estimate the lifetime of these items in parentheses as well. Examples: wooden pencil (3 months), lamp (5 years), textbook (6 years), graphing calculator (8 years).

9. In a typical electronic assignment for a MATE or MATE required technical support course, please estimate the number of hours that you would use to complete the assignment.

10. Please indicate the device that you would use to complete a typical electronic assignment for a MATE or MATE required technical support course. Example: 13" Vaio-Z laptop purchased in 2015.

11. Please indicate the location at which you would typically complete an electronic assignment. Example: Kennedy Library first floor.

12. Please give information about items you need to complete electronic assignments for MATE or MATE required technical support courses here. Please estimate the lifetime of these items in parentheses as well. Examples: USB drive (6 months), keyboard (5 years), mouse (4 years), speakers (8 years).

13. Other relevant information, questions, comments, and concerns. Please write any relevant information here that you feel was not covered or that you would like to voice.

The following questions pertain to a hypothetical assignment in Materials, Ethics, and Society (MATE 232). Please read through the situation and use this information to answer the questions. You are assigned an engineering ethics case study, and given a worksheet where you are asked to provide the following information about the case study:

The important facts of the case study:

The primary stakeholders, their priorities, and what is at stake for them.

Any laws, rules, or customs that may have been violated.

You are asked on the worksheet to come up with an action that could prevent such an ethical dilemma from reoccurring in the future. You will be expected to support your solution with evidence from the information above as well as logical reasoning. This response will be about the length of a single paragraph. Hypothetically you will be tested on the information in this assignment in the future. You are given the choice of how to prepare and submit this hypothetical worksheet:

Hand writing your responses to the worksheet questions and submitting hard copy of the worksheet, or typing your responses to the worksheet questions and submitting the worksheet electronically through PolyLearn.

14. Which submission method are you more inclined to choose?

15. Why?

16. How important is being able to choose your submission method?

17. Which submission method helps you retain information about the case study better?

Appendix B: MATE 232 Hypothetical Assignment

MATE 232
Ethics Case Study: Volkswagen Emissions Scandal

Name:_______________________________________

1. What are the salient facts of this case?

2. List the primary stakeholders, each stakeholder's top priorities, and what's at stake for each stakeholder.

Stakeholder	Stakeholder's Top Priorities	What's at Stake

3. Are there any laws, rules, or customs being violated?

4. What resources and limitations are there to help solve the dilemma?

5. Please answer this question before you enter into your discussion group. What do you think is the single most effective action that can be taken to prevent this kind of emissions scandal from happening again in the auto industry? Justify your answer.

6. Please list the names of the people in your discussion group (last name, first name)

7. Did any member(s) of your discussion group persuade you to change your answer to question 5? If so, what did you change your answer to and why? If not, explain why you were not persuaded to change your answer.

8. What conflict resolution skill(s) did you use during your group discussion?

Appendix C: PolyLearn Server Information

PolyLearn has 3 environments to allow for application development, testing and production. Production is the environment that the campus uses. Below is a list of the servers used to support PolyLearn in each environment.

Development:

2 Moodle application servers (each 2 GB of RAM, 1 CPU Intel(R) Xeon(R) CPU E5-2680 v2 @ 2.80GHz)

2 Moodle database servers (each 6GB of RAM, 2 CPU Intel(R) Xeon(R) CPU E5-2680 v2 @ 2.80GHz)

Testing:

3 Moodle application servers (each 2 GB of RAM, 4 CPU Intel(R) Xeon(R) CPU E5-2680 v2 @ 2.80GHz)

3 Moodle database servers (each 16GB of RAM, 4 CPU Intel(R) Xeon(R) CPU E5-2680 v2 @ 2.80GHz)

Production:

5 Moodle application servers (each 8 GB of RAM, 4 CPU Intel(R) Xeon(R) CPU E5-2680 v2 @ 2.80GHz)

2 Moodle database servers (each 16GB of RAM, 4 CPU Intel(R) Xeon(R) CPU E5-2680 v2 @ 2.80GHz)