IPRO 302

CO_2 Mitigation: A Techno-Economic Assessment

Project Plan

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Sponsor: Sargent & Lundy

Team: Asma Mustafa
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1.0 Objectives

The objective of this IPRO is to research and compile information on potential future CO_2 environmental regulations, current CO_2 mitigation technology, and CO_2 sequestration techniques. In addition to this, research will be conducted to find the chemical processes associated with each technology. The results will include an analysis of the items listed above as well as a high-level technical and economic comparison of the CO_2 mitigation technologies.

2.0 Background

A. Sponsor:

Sargent & Lundy is sponsoring IPRO 302. For more than 100 years, this company has provided comprehensive consulting, engineering, design, and analysis for electric power generation and power delivery projects worldwide. With a large, highly experienced staff solely dedicated to the energy business, it has the ability and expertise to take on the smallest tasks as well as the largest projects.

B. Problem: Carbon dioxide (CO_2) is a major pollutant in the utility industry and a desire to find the most economical method of CO_2 mitigation is of keen interest. Work is currently being done by both governmental bodies and private institutions to determine best possible method to move forward with CO_2 mitigation. Sargent & Lundy is currently working with the utility industry to formulate optimal CO_2 mitigation strategies and would like to work with our IPRO team to create a further understanding of potential CO_2 mitigation technologies.

C. Technology/Science: The main focus of this IPRO is to research solutions to modify coal-based powered plants in order to reduce CO_2 emissions. The majority of this project is research-intensive and involves finding information on the following technologies: oxy-combustion pulverized coal-fired boilers, conventional pulverized coal-fired boilers, and Integrated Gasification Combined Cycle (IGCC); as well as current and future environmental regulations and sequestration techniques. The three main areas from which this research will be conducted from are: newspapers, technical journals and patents. Research will also be conducted on pulverized coal plants and Acid Gas Removal Systems (AGR).

D. Prior Work: This problem is new based on the potential environmental laws and problems. Over the past several years, there have been modifications to power plants, based on productivity and the price of upkeep. Currently, there are two IGCC power

plants, which are considered by some to represent an improved technology compared to the standard pulverized coal plants. These new plants are considered successful because they run at a higher efficiency.

E. Issues: The obvious moral issue coupled with this research is the effect that CO_2 emissions have on the environment. One of the largest challenges facing our research is finding storage or use for the excess CO_2 that could be potentially harmful to the environment. There are several ethical issues regarding the sale of excess material from the plant that can be used in other materials. Another challenge that we face is how to upgrade the current power plants so that they can provide efficient and clean energy in the future.

F. Business/Societal Costs: There are two prominent issues regarding cost: the expense of modifying existing power plants (PC, IGCC) and the problem of how to expand and adapt to the energy needs of this country in the next twenty to thirty years. Obviously implementing a solution to reduce CO_2 emissions to every plant in America will be expensive. These additional costs may be passed on to consumers. The cost to implement such technology will have to be at the minimum point possible in order to have a robust energy industry.

G. Implementation: The research done in this first semester of the IPRO will provide the basic framework for the second semester of this project. The next IPRO group will select a CO_2 mitigation technology based on the results of the work from the first semester, for an in-depth analysis of all aspects of installing the chosen technology on a conventional pulverized coal-fired boiler (CFB), an integrated gasification/combined cycle (IGCC), and an oxy-combustion pulverized coal-fired boiler (O_2CFB).

H. Research:

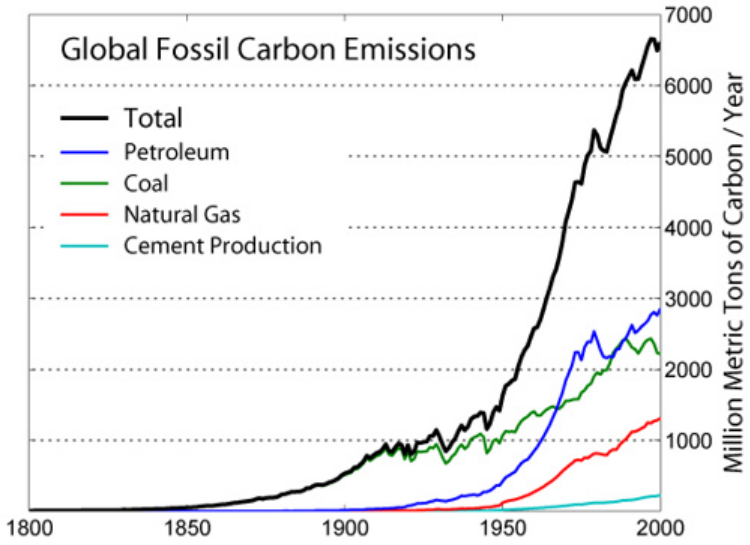
Global Warming

Since 1910, the Earth's temperature has been rising at a considerable rate. According to the World Meteorological Organization, the Earth's maximum temperature was attained in the 90's. Based on this and other pieces of evidence, there is a consensus between many scientists that global warming is a real problem.

This increase is believed to come from carbon dioxide (CO_2) emissions, as temperature has been rising since the invention of the auto-controlled steam engine. Coal, oil, and natural gas have powered our economies for years. Hydro-power and nuclear power are comparatively minor contributors to energy needs.

Today, the amount of carbon dumped globally into the atmosphere corresponds, on average, to one ton per person on the planet each year. Carbon dioxide is a greenhouse gas that keeps heat radiation from escaping the Earth. It follows that an increase in carbon dioxide within the atmosphere would produce a rise in temperatures at ground level. CO_2 emissions have increased 1.3 times over pre-industrial levels. Numerical experiments using climate models have shown that doubling of carbon dioxide produces a temperature

rise between 1.5 and 5 degrees Celsius, so a warming of between 0.5 and 1.7 degrees Celsius should have been seen. A small increase has been seen, but not what has been predicted.



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Based on the statistical facts that have been obtained, CO_2 emissions are becoming more of a serious problem. In order to comply with future government regulations and the health of our planet, people should start taking the preliminary steps to control these emissions. Whether or not CO_2 emissions are causing global warming is somewhat inconclusive, since the projected data from the models is not matching up with what is actually happening. In order to ascertain whether or not this is true, more conclusive research must be conducted.

CO_2 Mitigation Technology

Figure 1 Pulverized Coal System - Without CO_2 Mitigation

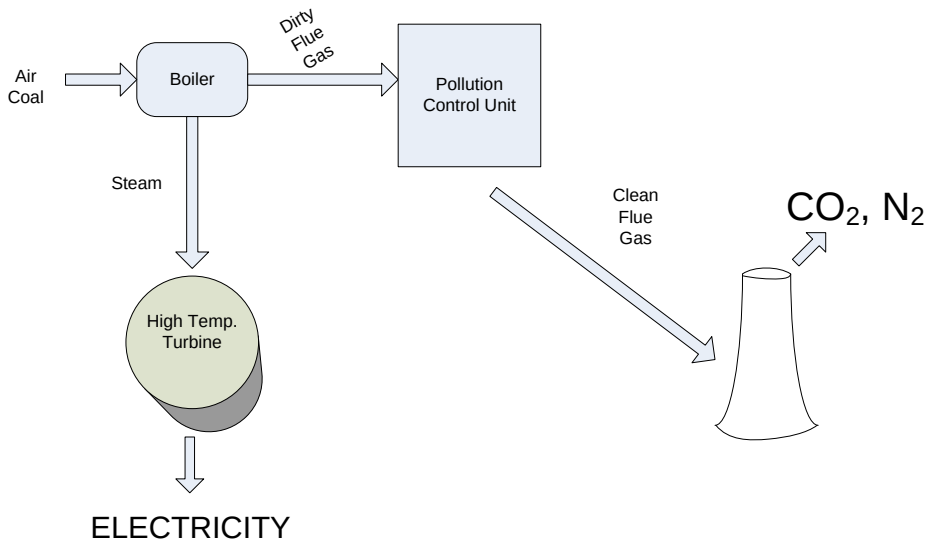
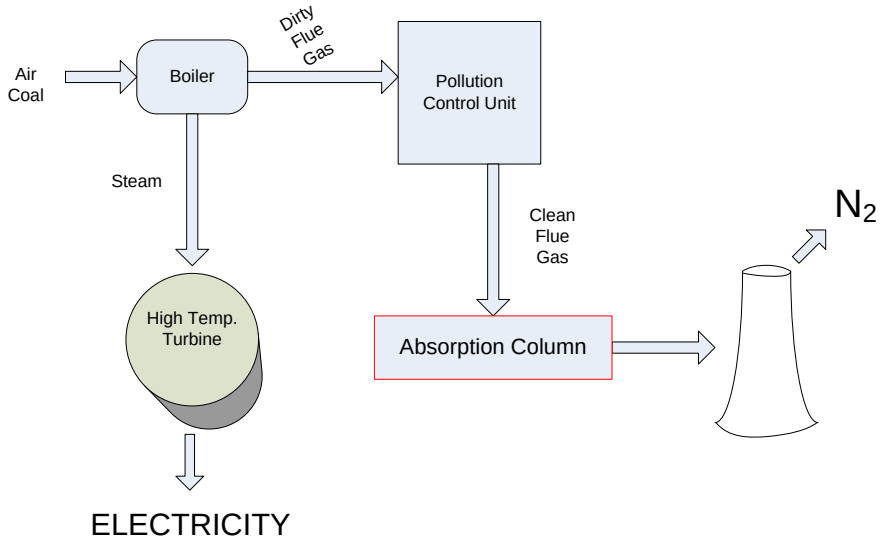


Figure 2 Pulverized Coal System - With CO_2 Mitigation



Pulverized Coal-Fired (PC) Plant

On an industrial scale, the PC boiler combusts coal with large quantities of air. These boilers are lined with water jackets that capture an immense amount of heat from the combustion reaction to create steam. Steam from this boiler can then be used to drive a

conventional high temperature turbine. The turbine converts mechanical energy from steam power into electrical energy.

After heating water to produce steam, exhaust gases are then cleaned of particulate matter such as nitrogen and sulfur in a pollution control unit. Without CO_2 mitigation technologies in place, this consists of particulate removal stages such as a desulphurization stage, catalytic-converter stage, and a feathered-filter stage. Once the pollutants are removed and collected, they are often sold for profit. After these pollution control stages, the remaining exhaust gases, including CO_2, are released into the atmosphere through the stack. This approach is followed in a traditional PC power plant without CO_2 mitigation technology. For PC power plants that are retrofitted with CO_2 separation technologies, a large absorption column is added to separate the CO_2 gas from the exhaust gases.

Figure 3 IGCC - Without CO_2 Mitigation

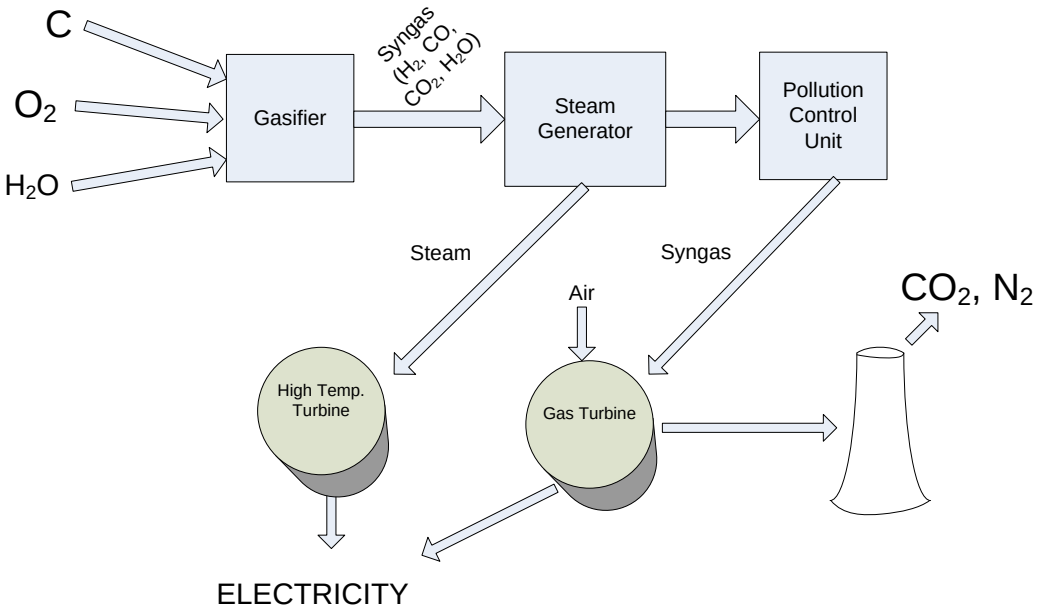
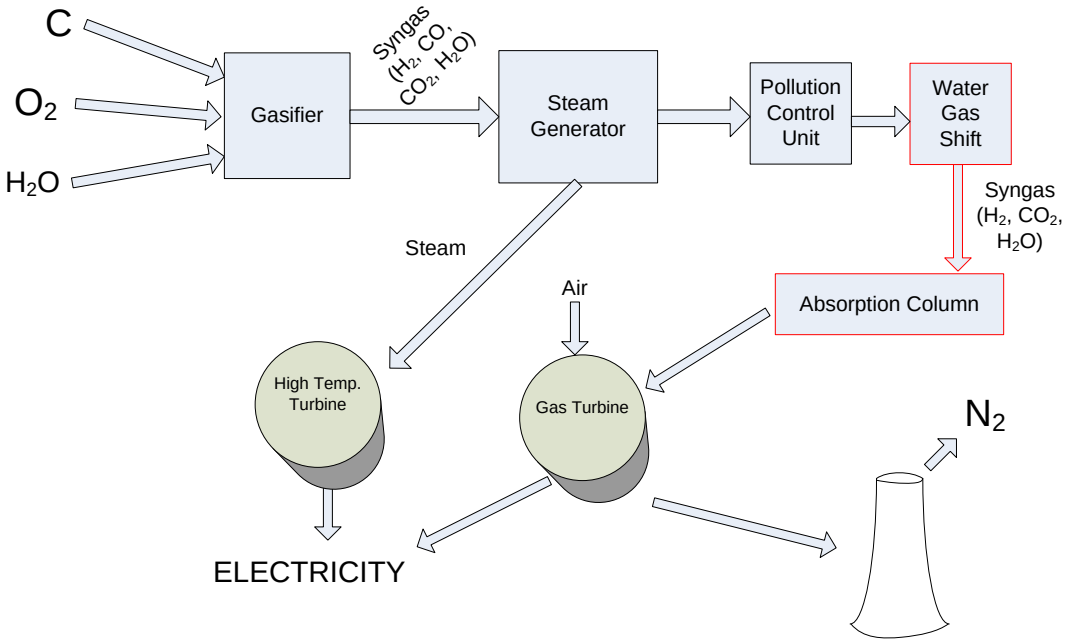


Figure 4 IGCC - With CO_2 Mitigation



Integrated Combined Coal Gasifier (IGCC)

Through incomplete combustion, coal and air become reduced to syngas composed mainly of hydrogen (H_2), carbon dioxide (CO_2), carbon monoxide (CO), some water and particulate gases. This combustion reaction releases heat, which is then used to create the

steam that powers the steam turbine. This turbine converts mechanical power into electrical power. After some pollution control stages, the syngas can directly fuel a gas turbine, which extracts additional electric power. The syngas then goes through pollution control units to remove particulate matter.

In a modern IGCC power plant containing CO_2 minimization technologies, the syngas is processed in order to maximize the capture of CO_2. Carbon monoxide is converted to carbon dioxide in a *water-gas shift reactor* prior to the absorption-column catalyst stage. This reaction occurs so the carbon monoxide left in the system does not react with the air in the turbine to form carbon dioxide. CO_2 can then be directly separated from the syngas using an *absorption-column* catalyst. A major advantage of using IGCC over PC is that the syngas can be stripped of most of its carbon content prior to combustion in the gas turbine. As a result, IGCC requires a much smaller absorption-column unit. Two current European IGCC plants are located in Puertollano and Buggenum.

Other Technologies

Methyl diethyl amine (MDEA), Rectisol, Selexol, and Sulfinol technologies have been developed to separate acid gases, including hydrogen sulfide and carbon dioxide, from feed gas streams. Eco 2 and chilled ammonia are two techniques for capturing CO_2.

3.0 Methodology/Brainstorm/Work Breakdown Structure

A. Problem: The goal of this IPRO is to research potential future CO_2 environmental regulations, current CO_2 mitigation technology, and CO_2 sequestration techniques.

B. Solving the Problem: To accomplish the necessary research, the team broke up into three groups, each focused on a type of source: newspapers, patents, and technical journals. Within the source groups, each person is focusing on a particular topic, but is not limiting their research to just that topic. Miri Park, Da Hye Lee, and Ellen Kloppenborg are concentrating on the conventional pulverized coal-fired boiler and oxy-combustion pulverized coal-fired boiler approaches. Asma Mustafa, George Vrana, and Jarrod Godfrey are looking at the integrated gasification/combined cycle process. Martin Kolodziej, Vernell Robinson, and John Enverga are studying the current and future regulations and sequestration techniques.

Each week, members will research on their chosen topic and report to the group. This information will then be compiled and used in the written reports and presentation. It is reasonable for our team to accomplish these tasks within a semester.

C. Testing: No testing will be done by this IPRO.

D. Documentation: Each member will submit a short report on their findings each week. The reports will be compiled and the information from them will be used to form the midterm and final reports, as well as a report for Sargent & Lundy.

E. Analysis of Test Results: No testing will be done, so analysis will not be completed.

F. IPRO Deliverables Report: The IPRO report will be generated using the individual reports from team members that are submitted throughout the course of the project.

4.0 Expected Results

A. Expected Activities of Results: The research done in this first semester of the IPRO will provide the basic framework for the second semester of this project. The next IPRO group will select a CO_2 mitigation technology based on the results of the work from the first semester for an in-depth analysis of all aspects of installing the chosen technology on a conventional pulverized coal-fired boiler (CFB), an integrated gasification/combined cycle (IGCC), and an oxy-combustion pulverized coal-fired boiler (O_2CFB).

B. Expected Data of Results: Information will be found on current and future regulations, sequestration techniques, and technology that can be installed on a conventional pulverized coal-fired boiler, integrated gasification/combined cycle, and an oxy-combustion pulverized coal-fired boiler.

C. Potential Products: The coal-fired powered plant may be retrofitted or altered based on the technology research that our team completes.

D. Potential Outputs: Reports will be generated from this IPRO.

E. Expected Deliverables: Two final reports will be generated from this IPRO: one for the IPRO office and one for Sargent & Lundy.

F. Solving the Problem: It is expected that our research will be beneficial to Sargent & Lundy's future decision on how to mitigate CO_2 emissions.

G. Incorporation: The research done during this semester will provide the basis for the design that will be created next semester. This design will be given to Sargent & Lundy, which will then determine the implementation of this project.

5.0 Project Budget

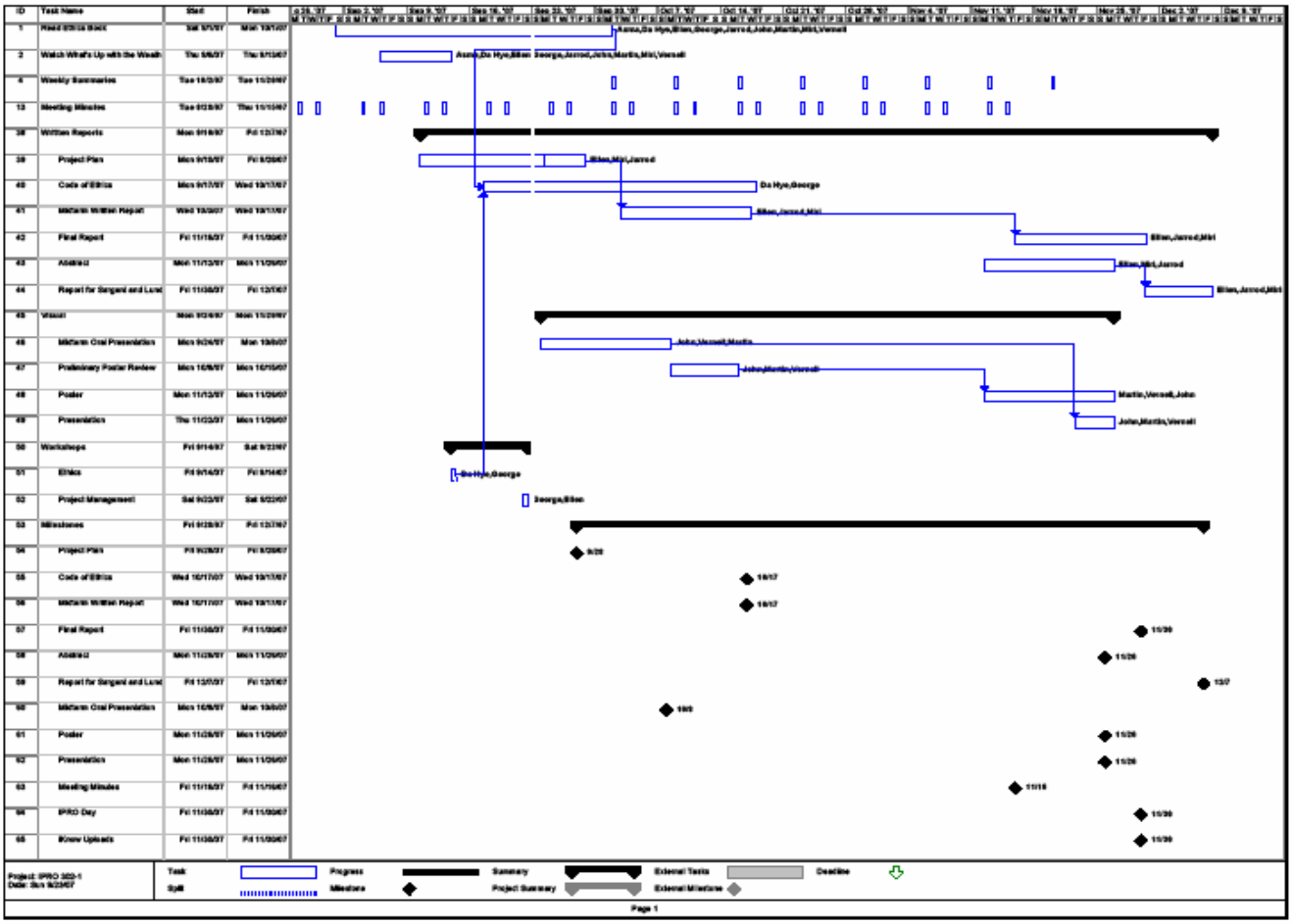
A. Itemized List

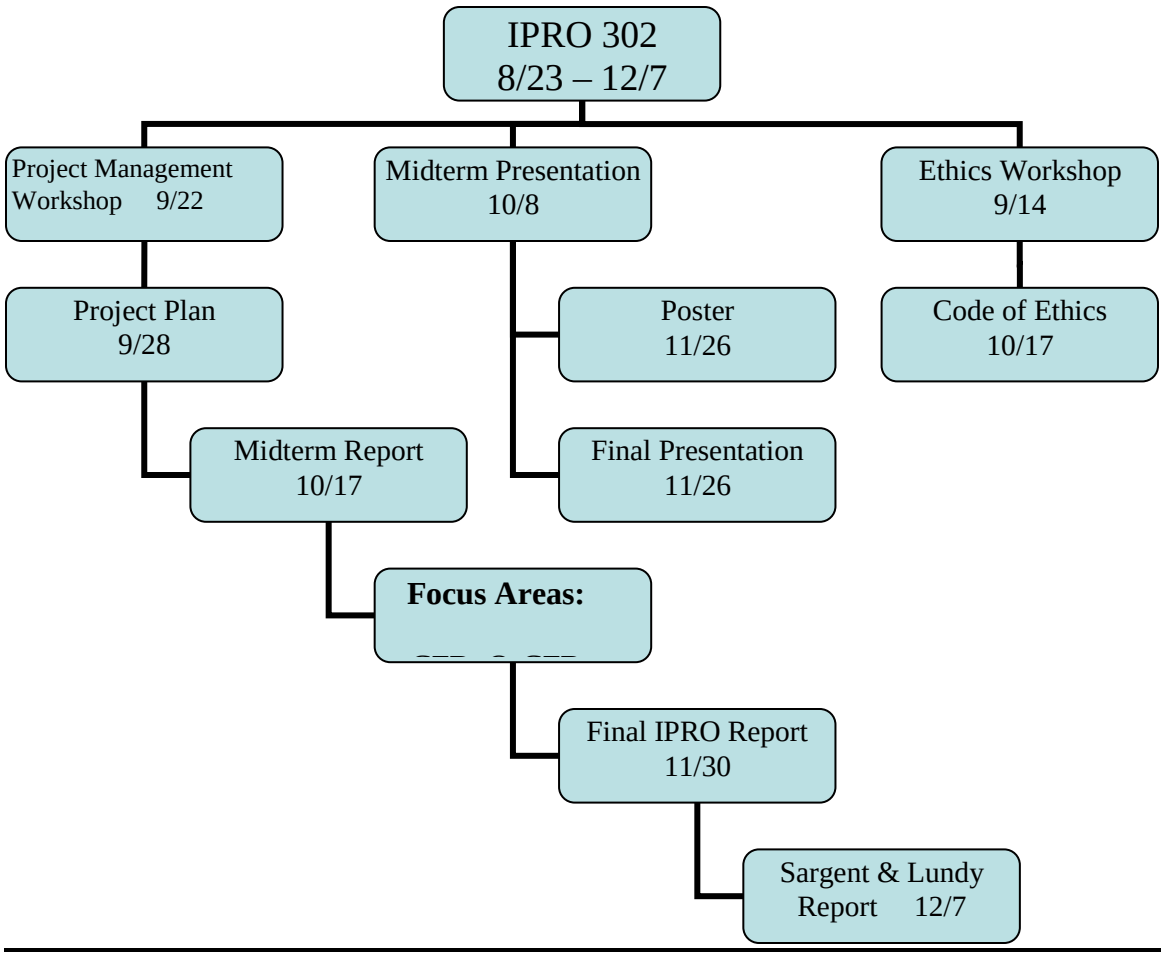
Item	Amount
10 DVDs	$9

These DVDs were used to share information with team members.

6.0 Schedule of Tasks and Milestone Events

A Gantt chart for our team can be seen below.





Task Name	Duration	Start	Finish
Read Ethics Book	41 days	Sat 9/1/07	Mon 10/1/07
Watch What's Up with the Weather Movie	10 days	Thu 9/6/07	Thu 9/13/07
Meeting Minutes	472 days	Tue 8/28/07	Wed 11/21/07
Project Plan	23 days	Mon 9/10/07	Fri 9/28/07
Code of Ethics	39 days	Mon 9/17/07	Wed 10/17/07
Midterm Written Report	19 days	Wed 10/3/07	Wed 10/17/07
Final Report	19 days	Fri 11/16/07	Fri 11/30/07
Abstract	19 days	Mon 11/12/07	Mon 11/26/07
Report for Sargent and Lundy	10 days	Fri 11/30/07	Fri 12/7/07
Midterm Oral Presentation	19 days	Mon 9/24/07	Mon 10/8/07
Preliminary Poster Review	10 days	Mon 10/8/07	Mon 10/15/07
Poster	19 days	Mon 11/12/07	Mon 11/26/07
Presentation	19 days	Thu 11/22/07	Mon 11/26/07
Ethics	1 day	Fri 9/14/07	Fri 9/14/07
Project Management	1 day	Sat 9/22/07	Sat 9/22/07
Project Plan	0 days	Fri 9/28/07	Fri 9/28/07
Code of Ethics	0 days	Wed 10/17/07	Wed 10/17/07
Midterm Written Report	0 days	Wed 10/17/07	Wed 10/17/07
Final Report	0 days	Fri 11/30/07	Fri 11/30/07
Abstract	0 days	Mon 11/26/07	Mon 11/26/07
Report for Sargent and Lundy	0 days	Fri 12/7/07	Fri 12/7/07
Midterm Oral Presentation	0 days	Mon 10/8/07	Mon 10/8/07
Poster	0 days	Mon 11/26/07	Mon 11/26/07
Presentation	0 days	Mon 11/26/07	Mon 11/26/07
Meeting Minutes	0 days	Fri 11/16/07	Fri 11/16/07
IPRO Day	0 days	Fri 11/30/07	Fri 11/30/07
iKnow Uploads	0 days	Fri 11/30/07	Fri 11/30/07

7.0 Individual Team Member Assignments

A-B. Team Members

Asma Mustafa – Asma is the team leader for IPRO 302, and will also be working on the newspaper team for this project. She is a biomedical engineering student whose accomplishments include being an air traffic controller and a proud parent of two. Asma has leadership and organizational strengths and is skilled in project management. She was also the assistant team leader on her last IPRO.

John Enverga – John is a fourth year student who is active in the biomedical, chemical, and physical science department. He was born and raised in Chicago, Illinois. John is proficient in mathematics and has a genuine interest in science and technology. John enjoys traveling various places and has found that he has a fascination with nature. John is often a leader in lab groups where he offers valuable insight and skill. He enjoys the Internet, video games and reading in his spare time. John will be working on the newspaper and presentation teams.

Jarrod Godfrey – Jarrod is a fourth year computer science major. Originally from Seattle, he was an Information Systems Technician in the United States Navy. While serving in the military, he primarily worked with system networking and data communications. His current studies include software engineering, object oriented program design and relational database management systems. Jarrod's interests include tennis, running and film. His current tasks on the IPRO are the written report team and the patent team.

Ellen Kloppenborg – Ellen is a third year chemical engineering major, specializing in process design and operation and polymer science and engineering. She is currently the president of AIChE, is working as a teaching assistant in the Introduction to Chemical Engineering class, and is researching thermal conductivity in polymers. Additionally, Ellen plans retreats and coordinates women's mentoring for InterVarsity Christian Fellowship. Previously, Ellen worked for UOP in the hydroprocessing group, was a member of an IPRO team that designed an ethanol plant, and served as the treasurer of AIChE. She is originally from Iowa and enjoys playing her violin. On this IPRO, Ellen is a member of the written report and technical journal teams.

Martin Kolodziej – Martin is a senior electrical engineering major with a previous degree in audio, acoustics and vibrations. He obtained technical and organizational skills while working as a consultant in vibrations and environmental noise control for a leading technology firm, SMW, Inc. His skills include project management, visual communication and technical writing. Martin has interests in analog and digital electronics, and his hobbies include technology, programming and music. He is on the presentation and newspaper teams.

Da Hye Lee –Da Hye is a fourth year student in the Chemical and Biological Engineering department. She is from South Korea, and her academic interest is in chemical biology. Her experience includes research in the area of olefin refinery design and optimization. Her skills consist of document organization and data retrieval. She enjoys tennis, jogging, and exquisite cuisine. Da Hye considers patience one of her strengths. She is in the ethics and patent groups and is taking the meeting minutes.

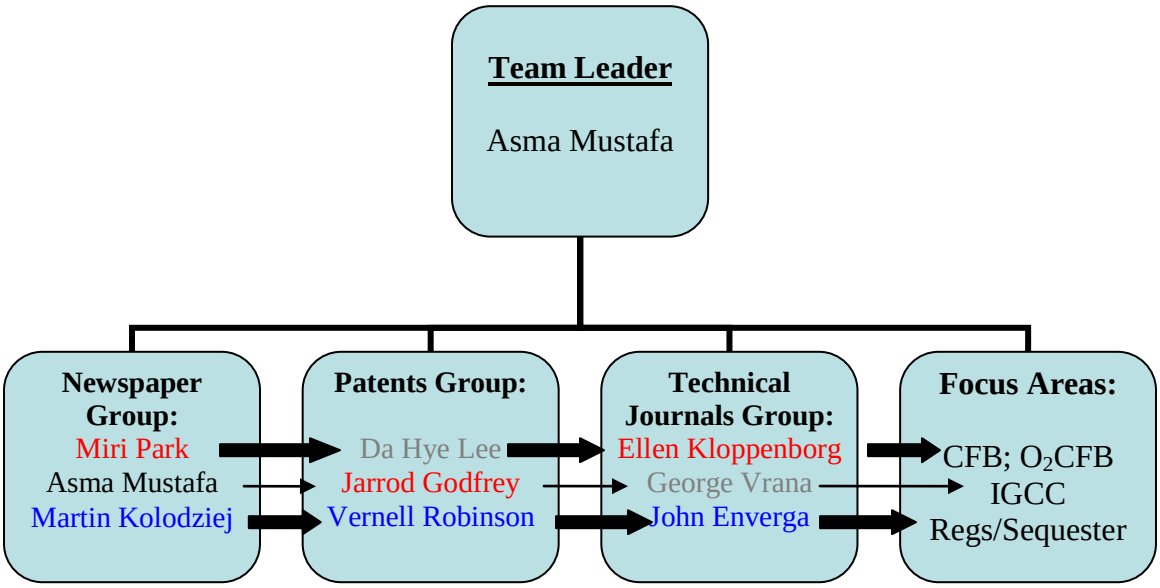
Miri Park – Miri is a senior in the Chemical and Biological Engineering department. She lived in Boston, but is originally from South Korea. Miri's academic interests include new advances in the biological and biomedical fields. In addition she is interested in hydrogel technology. In her recent IPRO, she conducted research on the design and optimization of an olefin refinery. Miri serves as a Bible study group leader at her church, works at the Academic Resource Center in Galvin Library and was a Korean interpreter at New England Medical Center. Her hobby is playing the flute. Miri will be working on the written report and newspaper teams this semester.

Vernell Robinson – Vernell is a business administration major with an emphasis in marketing. He is originally from Temple, Texas. Vernell has completed four years of his B.A. and is currently working on his final semester. He has a genuine interest in sports and management and is interested in becoming a personal trainer in the future. Vernell is currently working at the University of Chicago Comer Children's Hospital researching pediatric trauma medical records and entering them in an electronic governmental system. He was involved in varsity basketball prior to his final semester and enjoys being involved in different cultural activities. Vernell has strong computer and social skills and will be working on the patent and presentation teams.

George Vrana – George is majoring in electrical engineering and already holds an Associate of Science degree. Originally from Canada, George is a member of the Royal Conservatory of Music in Toronto. He has extensive musical background and has taken lessons in music theory, piano, voice and classical guitar. In addition, he won awards in various musical festivals for both solo and ensemble performance throughout Ontario. He gained valuable experience with CAD, as well as project management and public speaking skills, while working for a major manufacturing company of automated packaging machinery. His other hobbies include competitive tennis, water-skiing, alpine-skiing and snowmobiling. George is on the ethics and technical journal teams.

C-F. Sub Teams: There are two different sets of sub teams for this IPRO, one based on the source of the information and another focused on a particular type of IPRO deliverable. The first group is broken up into researching using newspapers, patents, and technical journals. Each group will look up information on all of the main topics using their source and report on their findings to the whole group. The second set of sub teams consists of the presentation team, the written report team, and the ethics team. The presentation team will prepare the midterm and final presentations and the poster. The written report team will write the project plan, midterm report, final report, and abstract. The ethics team will attend the ethics workshop. They will then present this information

to the whole group and lead them in developing the code of ethics. Members picked their teams based on their strengths or interest in learning in these areas.



Presentation team (Blue): John Enverga, Martin Kolodziej, Vernell Robinson
Written report team (Red): Jarrod Godfrey, Ellen Kloppenborg, Miri Park
Ethics team (Grey): Da Hye Lee, George Vrana

G. The sub teams function independently; the sub team leadership duties are shared among members. Everyone will be finding information and presenting it to the class. The team leader's role is to make sure that everything is being completed in a timely fashion.

8.0 Designation of Roles

A. Meeting Roles

Minute Taker: Da Hye Lee will be taking the minutes for the IPRO meetings.

Agenda Maker: As team leader, Asma Mustafa will be creating the agendas for the meetings.

Time Keeper: Asma will make sure the meetings go according to her agendas.

B. Status Roles

Weekly Timesheet Collector/Summarizer: Asma will be making sure that timesheets are submitted and will be preparing a summary report.

Master Schedule Maker: Jarrod Godfrey will be serving as the Master Schedule Maker for this IPRO.

iGROUPS: Ellen Kloppenborg will be managing iGROUPS.