Design of Biofuels (Biodiesel and Bioethanol) Production Facility for Renewable Energy Generation

…Lets not be cruel, use alternative fuel

IPRO 316

SPRING 2009

Faculy Advisor: S. Parulekar

1. Team Information

Our group consists of primarily Chemical Engineering students, and we also have a few Biology and Computer Science majors. The entire group is working on developing a chemical process for the production of biofuels. We will work through the semester to plan, coordinate, and design a chemical process to produce biofuels that is streamlined, time-efficient and cost-effective. Current biofuels of interest are bioethanol and biodiesel.

2. Team Purpose and Objectives

IPRO 316 strives to conduct research and develop a process to produce economically a biofuel from widely available renewable resources for widespread usage throughout the world.

Objectives:

- Research renewable biofuels, with emphasis on:
  -Sustainability of its basic components,
  -Economic feasibility, and
  -Resulting environmental impact.
- Develop a process for a biofuel meeting our objectives, improving upon current methods of production, by using homogenous and heterogeneous catalysis under extreme or supercritical conditions in order to improve yield, reaction time, and economic practicality.
- Design a reactor for biofuel production using software such as Matlab and Hysys for the process, and scale-up the reaction process accordingly to three different capacities.
- Perform an economic analysis of the process.

3. Background

3.1. INTRODUCTION

The world energy market is rapidly approaching a crossroads. As fossil fuel resources become sparser and fuel prices skyrocket, everyone is looking for the next best energy source. But not only does it need to be affordable, it also has to be safer for the environment and sustainable. There are many options being looked at including solar, wind and fuel cells, but there is one alternative that seems feasible in the immediate future: biodiesel.

3.1.1The History of Biodiesel

The technology needed to produce biodiesel has been around for over 100 years. The actual process will be described in greater detail later but it is called transesterification and essentially it thins vegetable oil. Scientists E. Duffy and J. Patrick conducted the process as early as 1853. The first real appearance of using vegetable oil as fuel came at the 1990 world fair in Paris when inventor Rudolph Diesel, inventor of the diesel engine, demonstrated the engine on peanut oil.

While pure vegetable oil is not considered biodiesel but rather a biofuel, this event still showed how the diesel engine could have been run on eco-friendlier biofuels from the beginning. Vegetable oil could be used in diesel engines until the 1920's when the engine was altered to use the thinner residue of petrol diesel. Even though the technology was there for biodiesel, it was largely abandoned as petrol diesel was cheaper and more widely availably as a result of government subsidies. Mid 1970 fuel shortages lead to renewed interest in biodiesel but interest in it has never been higher than it is currently as the result of global warming and rising fuel costs. In fact many fleets in the U.S. have switched to biodiesel but biodiesel consumption still only amounts to less than 1% of total diesel fuel consumption in the U.S.

3.1.2 The Benefits and Drawbacks of Biodiesel

Biodiesel is most commonly produced from vegetable oil, but can also be made from used vegetable oil (UVO) and animal fats. It is a cleaner burning alternative fuel to petrodiesel, as it can be used in diesel engines with little to no engine modification. Biodiesel is better for the environment in terms of emissions and can help the United States reduce its dependency on foreign oil as it is produced from crops which are grown domestically. Biodiesel is also better for diesel engines- it helps to lubricate the engine and eliminates debris buildup in the engine. Perhaps most importantly, however, biodiesel is safer for humans. It is less toxic than, biodegradable, and has higher flashpoint than regular petrodiesel so it is less likely to accidently combust. It also takes less energy to create a gallon of biodiesel than it does to make a gallon of petrol diesel because crops are produced with solar power.

There are, however, several drawbacks for biodiesel. While most harmful emissions are reduced compared with petrol diesel, biodiesel does have higher NO_x emissions. It also acts like a solvent so when it is used in old diesel engines it may initially cause the fuel filter to clog as old deposits from the petrol diesel are released. Engines run on fuels with high concentrations of biodiesel or pure biodiesel also have a slight decrease in fuel economy and power as well. All of this combined with the fact that the cost of a gallon of biodiesel is usually higher than the cost of a gallon of petrol diesel result in a very slow shift from diesel to biodiesel. Thus, biodiesel isn't widely availably yet, especially as a pure B100 fuel. This is another reason why the price of it is high right now even though the EPA estimated the cost of pure biodiesel to only be $1.95 to $3.00 per gallon.

3.1.3 The Current Use of Biodiesel in the US

As of January 25, 2008 there were 171 companies invested in the development of biodiesel manufacturing plants and marketing biodiesel. 19 of those focused on the U.S. The annual production capacity worldwide is 2.24 billion gallons per year, however actual production from October 1, 2006 to September 30, 2007 was only 450 million gallons. 60 companies have plants under construction, which should be completed in twelve to eighteen months and three plants are actually expanding. This is a potential capacity of an additional 1.23 billion gallons of biodiesel to be produced per annum.

3.2. ENVIRONMENTAL BENEFITS OF USING BIODIESEL

Biodiesel is being touted as a promising source of energy in the future largely because it is more environmentally friendly than petro diesel. The reason for this is primarily due to the fact that the production of biodiesel, as well as its subsequent combustion, contributes to a lesser extent towards atmospheric carbon dioxide (CO_2). In this sense, biodiesel will work towards decreasing the rate at which carbon dioxide is emitted, but not towards reducing what is already trapped in the atmosphere.

3.2.1 Biodiesel CO_2 Emissions

Biodiesel serves to decrease the amount of carbon dioxide emissions into the atmosphere compared to petro diesel. This is based on the premise that the carbon dioxide emissions from biodiesel come from 'recycled' carbon that was already in the atmosphere.

The calculation to determine the amount of carbon dioxide emitted from the use of biodiesel is a difficult and somewhat arbitrary process. The problem lies in the regulation of the assumptions made of the various factors, and oftentimes precise figures of data are not available for calculation. Some examples of factors that must be taken into consideration are the carbon dioxide emissions coming from the feedstock, the transport of feedstock to the factory, and the process of converting the feedstock to biodiesel, all of which are difficult to quantify.

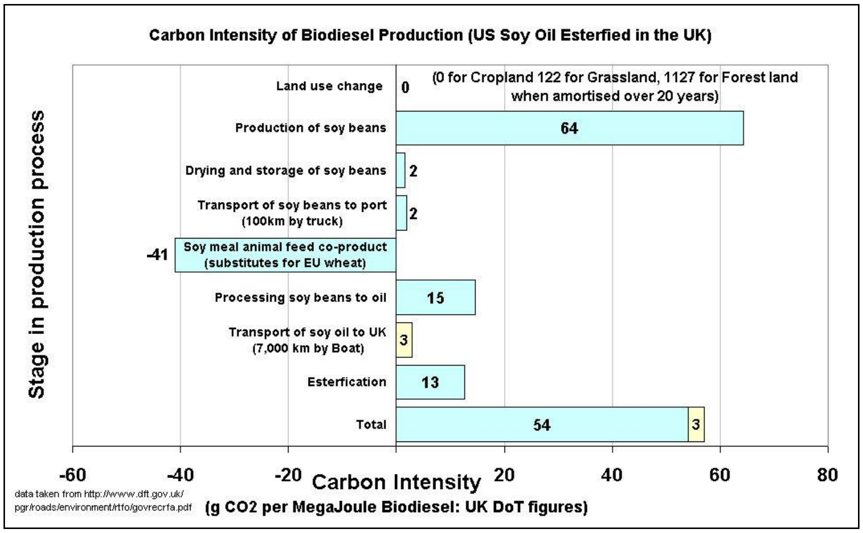

Figure 1. The carbon intensity during different parts of the biodiesel production processes[1]

3.2.2 Other Environmental Effects of Biodiesel

While biodiesel lowers the amount of carbon dioxide emissions, it has varying levels of the other kinds of gasses it lets off into the environment. Biodiesel reduces carbon monoxide emissions by up to 50% and benzopyrenes by 70% simply through its recycling of the carbon dioxide already present in the air.[2] Biodiesel also reduces the tailpipe carbon dioxide emissions by 20%.

Another problem associated with the combustion of petrodiesel is the particulate matter that is let off, which is considered a human health hazard. Biodiesel significantly reduces the particulate matter that is emitted from its combustion by up to 47% compared to petrodiesel.[3]

Over its life cycle commercial biodiesel is more renewable and less greenhouse gas intensive than petroleum-based diesel; however, it emits more pollutants related to agriculture and electricity generation. Biodiesel is known to increase nitrogen oxide (NO_x) and sulfur oxide (SO_x) emissions by 25%. Life cycle NO_x emissions are 13.5% greater for commercial biodiesel than for petroleum-based diesel, and 4.36% greater for recycled biodiesel than for petroleum-based diesel.

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[1] http://www.dft.gov.uk/pgr/roads/environment/rtfo/govrecrfa.pdf
[2] http://www.renewable-green-energy.co.uk/article/5947/is_biodiesel_good_for_the_environment_
[3] http://www.biodiesel.org/pdf_files/fuelfactsheets/emissions.PDF

4. Team Values Statement

A. Team members are expected to show up for all meetings and classes on time. All work must be completed on time to make sure the team stays on track. Everyone must communicate with the other members of the team and the sub-teams to avoid problems. iGroups should be used effectively, including e-mail and the calendar feature to make sure that everyone in the team is up to date and all information is being shared. To promote team progress, reasonable goals should be set for individual members and the entire group, critical thinking should be encouraged, and everyone's ideas and opinions should be respected and taken into account as much as possible.

B. In order to maintain these values, the group will be structured so that there is a chain of command to follow. This will help with addressing any problems with projects, among individuals, within sub-teams, and the entire team. At the beginning of every meeting, attendance will be taken, as to make sure that everyone is participating. Any scheduling issues should be discussed with team or sub-team leaders beforehand. Team members should hold each other accountable for missed work or meetings. By addressing any concerns right away, conflict and miscommunication will be avoided.

5. Methodology/Brainstorm/Work Breakdown Structure

5.1 Definition of Problem

The overall goal of IPRO 316 is to research a specific biofuel, such as ethanol and biodiesel, develop a process design for the production of that biofuel from feedstock to product and perform an economic analysis of the design. The first stage of the project involves the research of different biofuels currently being studied. The team will then decide on a specific plant-based fuel to focus on. More detailed research will be required to learn about the challenges associated with the production process of the chosen biofuel. Various process models that could possibly be used produce the chosen fuel will be developed and optimized throughout the semester. Toward the end of the semester, final optimization changes will be made to the selected process and an economic analysis will be conducted. The team will also employ a high standard of ethics.

5.2 Work Breakdown Structure

In order to solve the problem, the members of this IPRO team must develop a better understanding of the problem and biofuel technologies currently being used, apply this knowledge to develop various process models for a specific biofuel and carry out an economic analysis of the selected process.

Stage 1: Research

During this stage, the team members will focus on gaining a deeper understanding of the current biofuel technologies. This will be accomplished by dividing the IPRO team members into sub-teams. Currently, the team is divided into two research teams, one focusing on ethanol and the other on biodiesel. The teams will create mini-presentations of their findings and present them to the rest of the IPRO team. The research will be conducted mainly using research articles from the internet, but team members are encouraged to contact companies which are currently involved in producing biofuels.

Stage 2: Detailed Research and Process Design

During this intermediate stage, more research will be on the specific biofuel chosen, and the team will need to learn of any challenges and issues associated with the chosen biofuel. Preliminary design will also begin at this point based on the detailed research and estimates of economic viability. Aspen's HYSYS will most likely be used to develop possible designs of the production process of the biofuel. The work at this stage will again be carried out using sub-teams. The students with experience with process design and HYSYS will be in charge of the design models, while the necessary literature-based research will largely be done by CHE 296 students. The stage 2 sub-teams are yet to be determined.

Stage 3: Design Optimization and Economic Analysis

Near the end of the semester, the team should have decided on the best process model and will look at ways to optimize it. When the design is near completion, an economic analysis will be carried out to determine the approximate cost of a specific sized biofuel production plant. Again, the work on this stage will be completed using sub-teams, and the determination of these sub-teams will come later, likely after the midterm review.

In each stage, the sub-teams are most likely going to be reorganized. However the sub-teams are divided, all members of the team are encouraged to be involved with all of the sub-teams. The whole team will meet twice a week at the designated time, and each sub-team will report its progress. This will help keep the entire team up-to-date on the work of each of the sub-teams because interaction and good communication skills are important for a project like this.

5.3 Organization of Files and Data

In order to ensure that our work is properly recorded and documented, we will ensure that the iGroups online system is used to its full potential. We will upload all the files containing work done, and organize them into folders so that they are easy to access. This will allow all members of our team, 24 in total and therefore larger than most IPROs, to find relevant information quickly. This will also minimize the overlap of work being done, and make sure that everyone is working on tasks that will further the project. In addition, we hope this method of archiving our work will make it easier for future IPROs to access our information, and therefore allow them to move forward on the project instead of repeating the same tasks we did.

5.4 Generation of IPRO Deliverables

Most of the IPRO deliverables are conveniently divided into specified sections, and each section of each of the IPRO deliverables will be assigned to one member or a small group of team members. However, some exceptions will need to be made. For example, the final presentation will be different because the structure will depend on the progress the team has made, but the work involved in creating the final presentation will be divided among the team members. Finally, a small group of team members will edit individual sections, combine them and edit the document as a whole.

6. Expected Results

A. The first activity of the team will be to research different biofuels and bio-refining processes. A desired biofuel and raw materials will be chosen and then the team will work to design a full scale processing plant. Hysys provides an excellent process modeling environment where such a design can be created. The economics of the process will be used to pick the technology used for the bio-refining and to optimize the operating conditions.

B. To design a processing plant we will rely heavily on research from other institutions. The data that will be used will specify typical operating conditions for bio-refining. This data and process design optimization will create plant operating conditions such as temperature, pressure, and flow rates.

C. This project will create an initial model and rough economic estimate for building a bio-refining plant.

D. With a greater understanding of bio-refining, our presenting team members can educate the public on the benefits of biofuel.

E. A working Hysys model of the processing plant will be created.

F. The challenging aspect of our project is that a clear objective is not defined. We will first have to decide on the biofuel and then work to develop a process. Designing a new process is difficult without good information from research. It may be difficult to find the needed processing conditions for new technology in literature. Engineering assumptions must be made to scale the process up from lab bench scale to a processing plant scale.

G. The final report will provide a stepping stone for the next IPRO team's efforts in research and design. The ultimate goal of such an environmental IPRO is in reducing the World's consumption of fossil fuels. Continued research and dedication will achieve this goal.

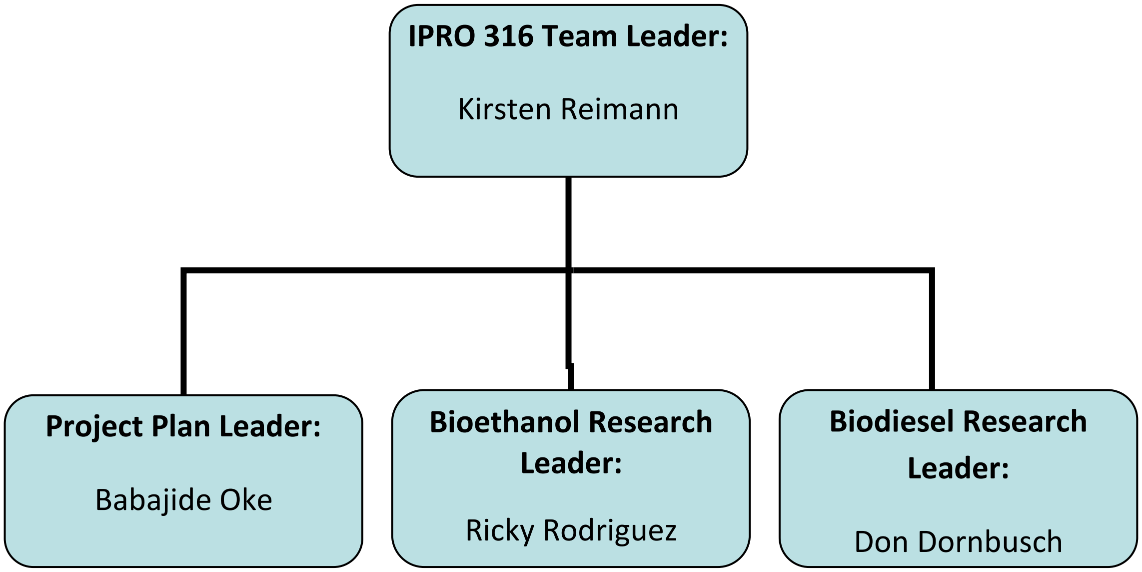
7. Project Budget

Event	Cost	Description
Get to know you Pizza Party	$150	Costs cover pizza, pop, paper products for 25 people.
Field Trip to ADM	$	Cost covers driving to and from ADM. The mileage for the round trip is 350 miles. Archer Daniels Midland Company 4666 Faries Parkway Decatur, IL 62526

8. Schedule of Tasks and Milestone Events

Please see Appendix for Gantt charts.

9. Individual Team Member Assignments



Hierarchy of the Team Leader and Sub-team Leaders

Sub-teams:

- Project Plan

  Sub-team Responsibilities:

  -Completion of the Project Plan by February 6th, 2009.

  Members and their responsibilities:

  -Ryan Attard: 2.Team Purpose and Objectives.
  -Kelsey Camp: 5. Methodology/Brainstorm/Work Breakdown Structure.
  -Omaditya 'Goldey' Khanna: 1.Team Information; and 3. Background.
  -Daniel Kim: 1.Team Information; and 3. Background.
  -Babajide Oke (Sub-team Leader): 10. Designation of Roles; assign tasks; and ensure that all tasks within the sub-team are completed on time.
  -Nicole Parks: 4. Team Values Statement.
  -Kirsten Reimann (Team Leader):6. Expected Results; 7. Project Budget; 8. Schedule of Tasks and Milestone Events; assign tasks to sub-teams; and ensure that all tasks and deliverables within the team are completed on time.
  -Jesse Reinhardt: 9. Individual Team Member Assignments.

- Bioethanol Research
  Sub-team Responsibilities:

-Research various designs for bioethanol production.
Members and their responsibilities-

-Calvin Kirtley – Research bioethanol processes.
-Joel Meno – Research bioethanol processes.
-Ricardo Rodriguez (Sub-team Leader) – Research bioethanol processes; assign tasks; and ensure that all tasks within the sub-team are completed on time.
-JongHwa Song – Research bioethanol processes.
-Deepthi Veliyathuparambil – Research bioethanol processes.

- Biodiesel Research
  Sub-team Responsibilities:

-Research various designs for biodiesel production.
Members and their responsibilities-

-Abdalmohsen Alhassan – Research biodiesel processes.
-Pierre-Paul Amegasse – Research biodiesel processes.
-Don Dornbusch (Sub-team Leader) – Research biodiesel processes; assign tasks; and ensure that all tasks within the sub-team are completed on time.
-Corey Hawker – Research biodiesel processes.
-Ryan Kyle – Research biodiesel processes.
-Hector Rodriguez – Research biodiesel processes.
-Piotr Sajdak – Research biodiesel processes.
-Emmanuel Sakla – Research biodiesel processes.
-Christopher Wiseman – Research biodiesel processes.

10. Designation of Roles

As agreed upon by members of the team the following members have been assigned to the following roles:

Meeting Roles

Minute Taker: Kelsey Camp

Agenda Maker: Kirsten Reimann

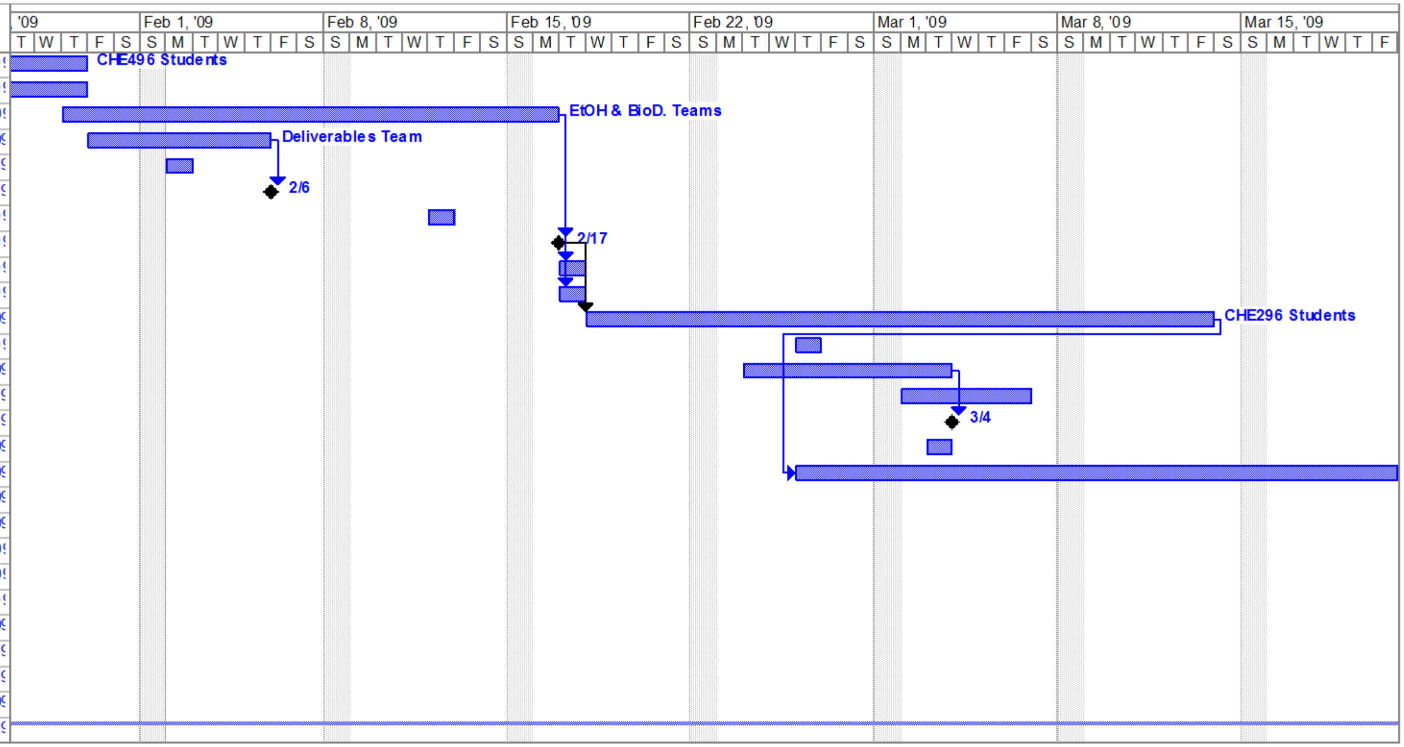
Time Keeper: Kirsten Reimann

Status Roles:

Master Schedule Maker: Kirsten Reimann

iGroups: Kelsey Camp

ID	Task Name	Duration	Start	Finish
1	CHE296 Members Selected	3 days	Tue 1/27/09	Thu 1/29/09
2	Set up initial Team Structure	3 days	Tue 1/27/09	Thu 1/29/09
3	Research Biofuels	16 days	Thu 1/29/09	Mon 2/16/09
4	Work on Project Plan	6 days	Fri 1/30/09	Thu 2/5/09
5	EtOH & BioD. Research Present	1 day	Mon 2/2/09	Mon 2/2/09
6	Project Plan Due	1 day	Fri 2/6/09	Fri 2/6/09
7	Ethics Seminar in Class	1 day	Thu 2/12/09	Thu 2/12/09
8	Biofuel Decission	1 day	Tue 2/17/09	Tue 2/17/09
9	Define Objective & Approch	1 day	Tue 2/17/09	Tue 2/17/09
10	Restructure of Team	1 day	Tue 2/17/09	Tue 2/17/09
11	Research on chosen Biofuel	21 days	Wed 2/18/09	Fri 3/13/09
12	IPRO Communication Seminar	1 day	Thu 2/26/09	Thu 2/26/09
13	Work on Midterm Presentation	7 days	Tue 2/24/09	Tue 3/3/09
14	Midterm Project Review	5 days	Mon 3/2/09	Fri 3/6/09
15	Midterm Presentation	1 day	Wed 3/4/09	Wed 3/4/09
16	Mid-term Peer Reviews	1 day	Tue 3/3/09	Tue 3/3/09
17	Design Process	28 days	Thu 2/26/09	Thu 4/2/09
18	Economics of Process	14 days	Sat 3/21/09	Tue 4/7/09
19	Communication & IPRO Day Tips	1 day	Fri 4/17/09	Fri 4/17/09
20	Work on Abstract	7 days	Mon 4/20/09	Mon 4/27/09
21	Work on Poster	10 days	Thu 4/9/09	Mon 4/20/09
22	Work on Presentation	14 days	Tue 4/14/09	Wed 4/29/09
23	Work on Final Report	14 days	Wed 4/22/09	Thu 5/7/09
24	IPRO Day	1 day	Fri 5/8/09	Fri 5/8/09
25	Final Report Due	1 day	Fri 5/8/09	Fri 5/8/09
26	End Peer Reviews	1 day	Tue 5/5/09	Tue 5/5/09
27	Take Minutes and Attendence	91 days	Tue 1/20/09	Fri 5/8/09



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