Department of Chemical Engineering Capstone Design Project Summaries

1. Renewable Energy of wind and solar on Petroleum Refining (Green Refinery)

Students: Shahab Niktash, Juno Song and Dan Baldissera
Supervisor: Professor Ali Elkamel

The goal of the project is to design a “green” refinery with the integration of renewable energy on the existing petroleum refining unit, which can ultimately reduce cost and improve energy efficiency. The group has set up the project goal to save maximum 10 % of energy consumption of a certain refining process unit. To better comprehend the scope of the project, an extensive amount of research on the basic design, energy consumption, and economics on oil refinery has been made. Moreover, a detailed economic analysis on renewable energy technologies will be necessary in order to get a rough idea on the overall cost.

The project is environmental friendly as sustainable energy will be used on the operation of oil refinery, generating less environmental and ecological constraints. Moreover, the oil industry is growing steadily over the last few decades and this steady growth in the industry will create more job opportunities and put less economic constraints. However, the integration of solar and wind energy in the process of oil refining will create some geographical constraints as an ideal location for this project would provide sufficient amount of solar and wind energy. Thus, information on the amount of solar and wind energy in Sarnia, our location candidate, was reviewed and studied.

2. Electrical Thermal Outerwear Feasibility

Students: Taqee Ahnaf, Eun-Sue Cha, Sylvia Cung, Jiahua Ou Supervisor: Zhongwei (John) Chen

The objective of our project is to test the feasibility of implementation of flexible batteries in outerwear to generate heat at a reasonable cost. The main constraints are power capacity, physical size, weight and safety. We expect to determine the feasibility of our electrical thermal outerwear design through simulating gloves and jacket. This will be completed through thermodynamic modeling and battery research.

The project began with research in the field of flexible batteries and industrial outerwear, simultaneously . Various companies were contacted and some showed interest in further pursuing the idea of the project. This indicated that there is a market for this product and affirmed needs posed by customers. Technical research is also being done to further understand the scope and workings of flexible battery technology. Once again,

companies and research facilities were contacted to get an idea of the current market, which is still in progress. Theoretical modeling of heat distributions within gloves and jackets using Comsol is currently being conducted to determine thermal values and set objectives. Simple electrical circuit models are also being made in order to roadmap for prototypes. Depending on research and availability of materials, prototypes may be fabricated for testing in the lab.

3. Building bio-filter system to control polluted air using solar power

Students: Sung-Jun (Paul) Yu, Hyemin (Hazel) Park, Jiyoung Hah
Supervisor(s): Prof. Ali Elkamel, Prof. Jason Grove, Prof. Zarook Shareefdeen

The objectives, expected outcomes and approach taken. if you have some preliminary results it would be good to include them. I think that this can be easily put together from information presented in the Status Report, however, please do not include information on the actual progress of the project.

The overall goal of this project design is to build a lab-scale bio-filter system with solar power to control air pollution and odor. This should provide guidelines for industrial applications, and tools for education and research.

In order to accomplish the ambitious goal of the project, the following individual objectives will be achieved. Design a bio-filter system with humidifier and adsorber to control the pollutants, and odorous compounds, build a lab scale bio-filter system, implement an effective solar power system to the design, optimize and characterize the system through testing various air pollutants and odorous compounds, perform economic analysis of the design, and analyze the impacts on the environment and safety.

4. The feasibility of Multilateral Wells in primary production in the Lloydminster area

Students: Ahmed El-Moustehy, Jim Duong, Daniel Cho, Jeongwan Hong
Supervisor: Ai El Kamel

This project proposes an in-depth analysis of the current multilateral wells, perform reservoir modeling for multilateral wells, and design a development plan that Husky Energy should pursue based on the reservoir characteristics. The objectives of this project are:

Preform extensive economic analysis of current multilateral wells compared to equivalent horizontal wells.
Model bottom hole simulations on HYSYS to match current wells and provide alternative

technologies for more efficient and effective completion strategies
Model different types of reservoirs on CMG, to provide production data for HYSYS simulation. This is used to test the effectiveness of the bottom hole designs

The first design objective is essential for our project to provide us with a basis of how Husky Energy expects the wells to perform. Husky Energy has drilled a total of eight multilateral wells to date, and would like to see which one of these wells are considered successful based on their key performance characteristics. These will be the constraints for this project when designing the wells. A comparison between multilateral wells and horizontal wells is being performed because the reservoirs that are considered for horizontal wells are also good candidates for multilateral wells. If the multilateral wells show that they have better production in the reservoir compared to their horizontal counterparts, then multilateral wells have potential to replace these horizontal wells.
The second design objective requires the team to produce bottom hole simulations on HYSYS as a series of pipes with the proper resistance to flow as would be experienced in the bottom hole casings. Since in the wellbore, they use casings with perforations to allow the flow of oil, the same can be modeled in Hysys. The oil and water flowrates will be obtained from the reservoir simulations, and based on the results, a pump can be sized and design a surface facility for Husky Energy. Surface facilities usually consist of gas knockouts drums to remove any entrained gas in the oil and also a water knockout drum to remove any water. Since all of the large scale multilateral and horizontal well pads are tied in to a pipeline, these have to be considered in this design as well.

The final phase consists of running a number reservoir models that will feed production data to the HYSYS models so that sizing of an appropriate pump and surface facility can be completed. The reservoir models will also involve some sensitivity analysis such as how the production rate is affected by increase in bottom water or if the reservoir is exceptionally gassy.

5. Design of History-Matching and Forecasting Analytical Tool for SAGD

Students: Bryan A. Nerger and Kevork Lochkajian
Supervisor**:** Jason Grove

There are three main objectives of the Capstone Design Project. The first objective is to evaluate the feasibility of current SAGD recovery techniques. These evaluations will be performed based on oil recovery and production rates, energy and water requirements, capital and operating costs, and environmental and social impacts. Secondly, an innovative SAGD performance modelling approach will be used and verified with history matching of publically available operations data for SAGD. The aim of modelling is to develop a better understanding of SAGD process operations and enable more accurate predictions for future forecasting. Lastly, using new insights from modelling, recommendations will be made in order to improve both economic and environmental aspects of current and future SAGD operations.

The first step to solving the aforementioned problem will be evaluating the economic and environmental feasibility of current SAGD projects. The feasibility study will provide a baseline for future work and will largely involve the use of publically available data as well as knowledge and experience gained from past co-op terms. Economic analysis will be conducted using the Ulrich and Vasudevan method, literature analysis, and available heuristics. Environmental analysis will be evaluated based on compliance with existing provincial and federal regulations. After the feasibility study, a typical SAGD process will be modelled. The starting model equations will be obtained from literature and based on past co-op experience. Modelling results will provide production and emissions data and will be validated using a technique known as history matching, whereby model outputs are compared to actual SAGD outputs and model parameters are adjusted to ensure the best fit between the model and historical data. After validation, the model outputs will be used in economic and environmental calculations in an iterative procedure such that the ideal operating conditions can be found. Note that ideal operating conditions are defined as providing the maximum profit while minimizing the environmental impact wherever possible. Finally, based on these findings, practical design recommendations will be made regarding the current and future state of SAGD recovery operations.

The overarching goal of this design project will be to improve economic and environmental aspects of both current and future SAGD recovery processes. Therefore, the end project deliverable will be a set of design recommendations that could be used for a typical SAGD process in order to improve operation. These recommendations will be presented along with the modelling methodology and additional economic and environmental analysis. Ultimately, the design project will focus on a specific SAGD operation, but the methodology will be widely applicable to any SAGD process with the available operation data. Therefore, if successful, the project has significant potential to address major concerns regarding the future sustainability and prosperity of the Canadian oil sands and Canadian economy as a whole. It is expected that the design project will likely be ready for immediate application upon its completion.

6. In-Situ of Mixing of Oil Sands Free Water

Students: Gareth Price Kayleigh Kuindersma Matthew Craig
Jacob Drouillard
Supervisor: Frank Gu

The goal of the project is to design a feasible method for mixing free water (top one meter) from large oil sand tailings ponds with minimal energy input to expedite remediation of the water. As of 2010 the tailings ponds in Alberta Canada occupied 176 km^2, and it is anticipated that they will double in size by 2020. Clearly there is a need to remediate these ponds so the water can be recycled safely and the expansion of the ponds can be minimized. Due to their large size and remote location it is necessary to treat the tailings on site to minimize transportation and handling costs. Several

technologies have attempted treatment, but have had difficulties treating the entire pond in a reasonable time frame due to mass transfer limitations within the ponds because of their stagnant nature.

It is therefore necessary to develop a novel method to mix a large body of tailings water which will greatly aid with decreasing the remediation time required. This will allow companies with operations in the Alberta oil sands to the ability to recycle process water more efficiently, decreasing the amount of new water that needs to be added to the process. Water is usually sourced from the local environment, such as the Athabasca River, which creates great strain on natural water resources. Additionally, remediating the ponds will decrease the amount of toxins that are currently seeping into the groundwater from these stagnant tailing ponds. As discussed, there are large environmental and economic benefits to speeding up the remediation of the Alberta tailings ponds.

In this project we will develop a reliable process for mixing large amounts of water (4000 tons) with little or no energy input. Having completed an extensive literature review it has been determined that the slow rotating paddle wheel used in the fishery industry offers the most feasible method of achieving the project objectives. A pilot scale mixing pond has been constructed to test the paddle wheels, which have been designed and 3D printed. Experimental trials have begun, based on conductivity measurements and the addition of NaCl to the tank filled with DI water. The results of these 24 hour trials with differing paddle wheel designs will be compared to diffusion trials (no agitation) to illustrate the level of mixing the paddle wheels can achieve. This information will provide a basis for the full scale design. Energy requirements for the full scale application can be estimated, along with the time savings for water remediation.
This is a smaller project in a much larger program to reduce the size and impact of oil sands tailings ponds in Alberta. If successful it will be integrated with other technologies both upstream and downstream to solve the problem. Environmental controls, such as seepage prevention, and overflow protection are important to the overall project but are not in the scope for this project.

7. Feasibility Study on Blowline Design Improvements in a Pet Food Facility

Students: Keziah Chan, Alyssa Lombardi, Ishraq Habib
Supervisor: Christine Moresoli

The objective of this project is to determine if there are feasible design alternatives that will improve the blowline system in terms of increased product flow rate at the Guelph plant of the global pet food manufacturer Royal Canin. The blowline is used to transport a variety of raw ingredients in small and large quantities from various dosing stations and is currently considered a bottleneck in the process. In addition to limited product flow rate, the inefficient blowline design results in temporary blockages and constriction of the pipeline by permanent build-ups.

In an effort to limit the bottleneck and other issues, we will generate various design alternatives and evaluate them using, first, an AutoCAD model of the existing plant layout for general compatibility and, second, an Excel mathematical model to determine the potential product flow rate change. In addition, we will consider the capital and installation costs of each design alternative, as well as implementation factors such as duration of installation.

Based on the results from the above analysis, as well as considering the existing blowline design, a decision matrix will be used to determine the best design to optimize the blowline efficiency in Royal Canin's Guelph plant. It is expected that there is a design alternative which improves the blowline efficiency over the existing system. This design will then be recommended to Royal Canin for consideration to be implemented.

8. Utilizing Organic Waste for Starch Recovery and Biogas Production in order to Enhance Green Initiatives and Raise Bottom-Line Production Economics

Students: Nick Butson, Andrew Holmes, John Catton, Gavin Letourneau
Supervisor: Wayne Parker

Our Client (Industry Partner) is a food processing plant in Manitoba, Canada, which makes frozen potato products. A significant amount of wet waste is produced by the plant daily. Wet waste is in the form of a slurry mixture, including raw, cut and whole off-spec potatoes and peels. The disposal method for this waste is to have it shipped away from the facility to local farmers for cattle feed. Approximately $300,000 a year is spent on this diversion effort, mainly on trucking costs. Ideally, Simplot would like to eliminate this cost of removal by processing and utilizing the raw material on site for various purposes.

To reduce, or eliminate, the disposal fees incurred by our Client, the wet waste needs to be re-purposed at the plant. On-site, the waste material can be used as a feed to generate a high- quality potato starch stream or as a feed source to the anaerobic digester on-site to produce biogas. This report has been generated to investigate these methods to determine the most economically viable and efficient technique for waste disposal. Each of the options will be evaluated separately on an economic viability basis.

Based on our analysis of the possible solutions, the most economical method is the integration option, to process the wet waste using the starch recovery system and then subsequently send the effluent waste from the system to the anaerobic digester. Utilizing these two process methods greatly reduces the amount of waste that needs to be transported from the plant. The organic waste potatoes are converted into valuable potato starch, which can be sold to various companies, as well as into biogas which can then be used in the plant for their boilers to create steam, lowering the usage of natural gas for the facility. This particular solution, also, has the added benefit of being a "green" technology initiative as it reduces greenhouse gas emissions by having less

transportation of waste and produces energy through biotechnological techniques.

Overall, the project will reduce the cost of transporting the wet waste by 60%. Only uncooked, non-gelatinous starch containing potato can be processed via starch recovery and anaerobic digestion methods and thus the remaining 40% of wet waste that includes potato peels and fried potato product will still need to be trucked at cost from the plant. The obvious incentive of currently existing starch recovery equipment provides an attractive option which can handle the additional load required for processing this waste stream without further capital investment in equipment.

9.

Students: Madison Connors, Manuel Furtado, Shawn Simmons, Alex
Supervisor: Jason Grove

The objective of this project is to create a nitrogen rich modified atmosphere in order to reduce the rate of ripening in fresh produce. This apparatus can be used as a stand-alone unit or in conjunction with a standard residential refrigerator. The modified atmosphere will flow through an intrinsically sealed container which houses the produce, as opposed to being stagnant or periodically purged.

The group expects to test a number of different combinations of nitrogen rich atmosphere, altering both flow rate and nitrogen purity in order to determine which combination optimizes both ripening reduction and cost effectiveness. From there, equipment will be sized and priced and energy requirements will be determined. Although nitrogen will be provided via cylinder in the lab, it is expected that a membrane gas separator will be implemented for use in the apparatus. As such, this will need to be sized and priced in addition to pumps and other equipment. Although the group is not expecting to produce a physical prototype of the unit, we will provide a virtual mock-up.

10. Bitumen Froth Treatment Alternative Using Ionic Liquid

Students: Carla Marie Moday, Muhammad Rohail Siddiqui, Lydia Terisno, Natasha Mukaram Peer
Supervisor: Professor Flora Ng

The objective of this design project is to eliminate the use of diluent in Oil Sands extraction through the design of a more cost effective and inherently safer alternative process for froth treatment producing pipeline transportable bitumen. The project will aim to investigate alternate methods of froth treatment. The ensuing product should meet the feed specification of a primary upgrading reactor, which will produce pipeable crude oil that can be directly transported to refineries with the capability to handle heavy crude oil.

Research being conducted on cleaning oil spills on beaches using ionic liquids has shown notable promise. The approach employed is that discussed by Professor Paul Painter at Penn State University[1] to extract bitumen from oil sands. Two ionic liquids are being explored, these are: 1- butyl-2,3-dimethyl-imidazolium tetraflouroborate (bmmim[BF4]) and Choline Chloride+Urea. The feasibility of this project is being investigated using these two methods. Small scale experiments are being conducted for proof of concept and determination of technical feasibility. A design of experiments has been set up to evaluate the effect of different ratios of bitumen to ionic liquid and state of ionic liquid (fresh or recycled). The process is also being modelled in Aspen Plus to test for scalability and to perform an economic cost/benefit analysis once technical feasibility is established.

Preliminary results from experimentation shows that separation using bmmim[BF4] occurs at a faster rate and more distinct phases are observed as compared to the Choline Chloride+Urea mixture. Therefore, the group expects that the process employing bmmim[BF4] will produce more effective results when scaled up to industrial standards. The results obtained from

experimentation will be used to refine the model in Aspen Plus.

[1] Painter,P.; Williams, P.; Mannebach, E. *Energy Fuels* **2010**, 24, 1094-1098.

The overall objective of this project is to reduce the cost incurred by the Petro- Canada Lubricants Wastewater Treatment Plant (WWTP) when purchasing Bioplus, a supplemental organic feed, from an external vendor. Bioplus is used as a feed product for the wastewater treatment microbes. The cost of purchasing Bioplus must be reduced by recovering sugars and other organics from a wastewater stream produced at Suncor's Bio-ethanol facility. The sugars will be recovered through reverse osmosis. Scope changes made during the fall 2014 semester include a change in feed stream. The feed now comes from the overhead of an evaporator train; the Suncor contact/client has advised against the use a pre-filter as no solids are present in the new feed.

11. Feasibility Study of PVA/PVA-m CNT Membranes for Ethylene Glycol Dehydration

Students: Zhuoyuan Fan Do Yeon Lee Wesley Marr Raymond Tran
Supervisor: Professor Xianshe Feng

The goal of our design project is to evaluate if an alternative ethylene glycol dehydration process is feasible in comparison to the conventional process used currently by Shell. We will be producing a scale up analysis of an ethylene glycol dehydration system using PVA-PVAm with embedded carbon nanotube (CNT) membranes and performing a cost comparison to current separation methods. We will also look at feasibility of a hybrid conventional/membrane process. The CNT membrane separation process will be modelled in Excel using empirical data extracted from work done by Yijie Hu and Professor Feng. This model will be integrated into Aspen in order to model a hybrid conventional/membrane dehydration process.

It is hypothesized that the CNT membrane system will have superior cost benefits due to the lack of heating required. For high purity applications, the separation capability of the membrane is relatively higher. Therefore, a hybrid system may prove to superior to both individual systems.

12. Improved Binder Mixing 0f Carboxymethyl Cellulose

Students: Benjamin Knapik Nicholas Koch Victor Kuang Davis Ly
Supervisor: Dr. Zhongwei Chen

Driven by increasing demands in both quantity and performance, a large scientific effort has been underway to improve binder performance in lithium ion batteries. An identified area of potential improvement is the mixing of carboxymethyl cellulose with de-ionized water. The resulting slurry is combined with other materials which make up the anode of a lithium ion cell.

Upon contacting water, CMC is prone to agglomeration despite its solubility, making a uniform dispersion highly difficult. The agglomerations result in bare foil spots in the anode layer, leading to suboptimal electrode performance. Better CMC dispersion in water is highly sought after. The objective of this design project is to improve the mixing process for CMC slurries and then to design a mobile mixer unit to meet the demands of our industrial partner.

Once this project is completed, it is expected that a mixer design that eliminates agglomerates will have been found, an analysis on the power consumption performed, and a cost analysis for the portable mixer conducted. The approach taken to achieve these goals involves laboratory mixing of CMC where factors such as blade geometry, agitator speed, and use of eductor will be optimized. Viscosity must be continually measured and a certain value maintained as it a constraint set by our industrial partner. Filtration of the CMC slurry will determine the success (whether agglomerates are still present) of the mixing. Additionally, COMSOL Multiphysics will be used to simulate flow patterns and determine areas of poor mixing.

13. The Application of Hydrogels for Oil/Water Separation

Students: Larkin Leach, Sahel Hassani, David Nissim, Carina Pai
Supervisors: Ali Elkamel, Chandra Mouli R. Madhuranthakam

The objective of this project is to explore the use of hydrogels as a mechanism for separating oil from water. Separating oil from water has always been an area of interest because of its need in industry. A challenging step for any industrial oil process is the separation of oil from water. Aside from the obvious use of separation in the oil industry, using this concept in treating waste water to remove residual oil is also a potential application. Currently, oil removing materials are used to filter oil from water however these materials have several limitations. The purpose of this project is to report on the separation properties of hydrogels with a mixture containing oil and water. Experimentation will be conducted to provide quantitative data regarding the degree of separation of oil from water using hydrogels. The properties of the hydrogel mixture will also be tested to produce data on optimum performance. The project will deliver these quantitative results and expects to conclude with a recommended hydrogel formulation for oil and water separation. In continuation of this project, a process can be designed for implementing the product at an industrial level. This design project will strive to produce a hydrogel for use in oil- water separation and report on the feasibility of hydrogels as an alternative to current techniques.

14. Integration of a Molten Salt Reactor for the Production of Gasoline and Diesel

Students: Saad Khan, David Wulff, Ajay Ramanujam, James Hsu

The objectives of the project are the following:

- To evaluate various fuels used in transportation to determine which ones would be the best options to produce via an integrated molten salt reactor.
- To evaluate various processes and methods for each fuel to be produced by the integrated design
- To estimate the options that provide the best economic value and high return on investment
- To design and simulate the processes for the selected fuels to estimate the conditions for optimal production
- To iterate the design and evaluate the safety and impact of the design
- To report on the findings of the integrated molten salt reactor in the production of the liquid fuels

Expected Outcomes

The expected outcome of this project is to design a process that is capable of utilizing the heat produced from the molten salt reactor to produce fuels. More specifically, the process must be able to make use of the heat generated from the molten salt reactor efficiently. An effective heat transfer process will be designed, which will allow the transfer of heat from molten salt reactor into the fuel production process. Another major requirement of the process is the ability to incorporate the fuel production process into the molten salt reactor. The fuels generated should also be of high market value, as well as high demand. In addition, it is expected the process to be cost effective, since this is one of the major consideration of design. The cost of fuel production through this process should be significantly cheaper than the traditional methods of fuel production. Furthermore, the process must also be able to meet environmental and safety regulations and standards.
One potential limitation to the design is that this project will not be focusing on designing the actual fuel production process (such as steam reforming, Haber process, gas shift reaction). These fuel production processes are already well studied and established. Therefore, the major focus of the project will be on designing a process that is able to integrate molten salt reactor into fuel production processes.

Approach Taken

The approach our team took with our project was to establish which fuels are best suited to production with a nuclear molten salt reactor. After decided this, we then focused on the different aspects of our proposed process that would require design. In both of the fuels we have chosen, diesel and gasoline, the main requirement is the design of a heat exchanger that will use the energy from the molten salt to heat the CH4, the water, or both. This approach to our project has allowed our team to be efficient with our time in deciding what and how to design for integration of liquid fuels with a molten salt nuclear reactor.

Preliminary Results

To design a process that is capable of utilizing heat produced from the molten salt reactor to produce fuels, optimization of the reactor and process units must be performed to determine the optimal conditions for the parameters. Capital cost analysis was performed for hydrogen, diesel and gasoline fuel production to determine the most profitable fuel. Capital cost including the contingency fee for the production of hydrogen and ammonia exceeded that of gasoline and diesel. Therefore, given the advantages from the cost benefit analysis, gasoline and diesel were the fuels to be focused. The reaction heat utilized from the molten salt at 700 ^{O}C was fed into the steam-reforming unit with a natural gas inlet to produce syngas, a by-product which is then utilized for the production of gasoline and diesel. The optimization of the steam reforming unit is to be performed using ASPEN Plus to determine the optimum conditions of parameters for the conversion of methane to syngas given the constraint of conserving the reaction heat for the gasoline and diesel production processes.

15. Scaling Algae Growth for CO2 Sequestration and Biofuels Project

Students: Kayvan Riazi Kermani; Saif Khan; Kumar Singh; Hameed Kadiri
Supervisor: Professor Ali Elkamel

The field of biofuels is progressively drawing more attention as a substitute for petroleum derived fuels in order to address issues such as: the ever depleting fossil fuel reserves; high production and energy costs; and global warming concerns facilitated by toxic industrial emissions.This project's objective is to simulate a biochemical plant design that utilizes industrial by-product CO_2 and microalgae for effective production of biodiesel.

The overall production process is divided into 4 stages namely: *Biomass cultivation*; *Lipid extraction*; *Esterification* and *Biofuel production*. Chlorella sp., the microalgae species selected for simulation due to its high lipid to biofuel ratio will be cultivated in a series of bioreactors and the lipid collected will be processed using a methodical bioprocessing approach yielding the desired product. Material and Energy balances are derived for each process unit using - MATLAB that employs a computer-based simulation to compute ordinary differential equations that systemically solve for yields; and Aspen Hysys to simulate the plant operation and analyze performance under a given set of operating conditions. In line with project deliverables, a process flow diagram (PFD) will be proposed to evaluate the economic feasibility for processing biodiesel from the algae biomass nourished from the sequestration of by-product CO_2 from industries.

Towards the goal to produce biodiesel in this study, the growth model of Chlorella algae was simulated. The simulation result shows that the microalgae concentration increased

from 0.8 (g/L) to 6.5 (g/L) during a fifteen days time interval. Similarly, the lipid content of the biomass increased from 0.058 (g/L) to 0.35 (g/L). The concentration of glycerin showed an expected decline from a value of 15.5 (g/L) to 1.2 (g/L). Further calculations will determine the ease of lipid extraction and biodiesel production.

16. Student Microbrewery Design

Students: Michael Kutcher Nolan Boronka Scott Boegel
Supervisors: Professors Marc Aucoin and Jason Grove

At the University of Waterloo, there is currently a lack of clubs specifically geared towards Chemical Engineering students. There is also a lack of educational information and equipment on campus relating to the brewing process – a common industry in Chemical Engineering.

This project seeks to address and solve these problems by creating a microbrewery design which could be feasibly built and operated on the University of Waterloo campus by a brewery club made up of Chemical Engineering students (overseen by professors). In addition to this club, the microbrewery would have the potential to be used as an aid in the teaching of a future technical elective focusing on the brewing industry.

In order to reach these goals, we will take into account: governmental regulations, environmental impact (energy efficiency and waste disposal), and economic feasibility (start-up and continuous costs) in order to come up with a detailed design and proposal for the campus microbrewery.

17. Reduction of cBOD Levels in Food Based Wastewater Treatment

Students: Amanda Kuk, Annamaria Reda, Evangeline Rose, Priscilla Chan
Supervisor: Mark Pritzker

The production process at the FritoLay manufacturing facility in Cambridge currently produces an effluent waste stream that generates high to extreme level of cBODs. The Region of Waterloo, where the plant is located, has set limits on the level of contaminants that are allowed in the effluent streams exiting the facility. When the waste water contaminant levels are above the specified limits, surcharges are incurred by the company. To avoid the surcharges, an effective waste water treatment (WWT) system must be installed in the plant. The current WWT system implemented consists of a rotary screen, clarifier, dissolved air floatation (DAF), and a centrifuge. Despite efforts to reduce the carbonaceous biological oxygen demand (cBOD) levels using various methods that have been found to be successful in other plants, the cBOD levels are still above the specified limits at the Cambridge location.

The objective of this design project is to develop an effective design that will reduce the cBOD levels in the FritoLay manufacturing plant's wastewater to eliminate, or greatly reduce these surcharges. The focus is on optimizing the current system to meet current flow rate demands or to install an additional system to help remove the cBODs. The selected design must be cost effective and easily adaptable to the current system.

The selected design will be modeled using wastewater software called BioWin. This model will be used to determine the best location and operating conditions of all equipment in the wastewater treatment facility. From the model, a facility layout and equipment specification will be developed. Finally, after the solution is finalized, a cost analysis for purchasing and installation will be performed to determine the feasibility of the project.

18. Wastewater Treatment with Microbial Fuel Cells

Students: Travis Green, Ellen Dannys, Andrew Wettlaufer
Supervisor: Dr. Ali Elkamel

Microbial Fuel Cell (MFC) technology has opportunities to supplement or replace traditional wastewater treatment methods as a safe, environmentally conscious alternative. MFCs use electrochemically-active bacteria in the anode chamber to oxidize substrates and separate electrons from protons. The separated electrons travel through the anode and external circuit and generate a current. At the anode, an effluent stream with a lower substrate composition is available, which can be discharged to a municipal sewer or, if required, treated further.

Literature on MFC technology currently focuses on the small-scale modeling and design of MFCs, however this finished project will provide a process design for the technology at an industrial size and an accompanying cost-benefit analysis. Final analysis will focus specifically on monetary and environmental impacts.

This project aims to provide a design and feasibility for the application of MFC technology to the brewery industry. The operation of lab-scale microbial fuel cells have been modeled to varying complexities and verified against experimental results. Using published data on the operation of a bench-scale MFC, a model has been expanded upon and used to demonstrate that MFC scale-up is feasible. In this model, chemical oxygen demand reductions greater than 95% have been achieved at wastewater flow rates of 84 L/h. This treatment system is likely able to generate enough electricity to power the auxiliary equipment needed, however further analysis is still needed to confirm. A final design for a wastewater treatment system for the brewery industry is proposed, and a financial justification will be presented to indicate feasibility of this technology in small breweries. The completion of this project will enable the next step of building a larger-scale MFC system to validate final results.

19. Feasibility of cracking technologies for heavy oil upgrader

Students: Ammar Mamajiwala, Jinqiang Li, Nicholas Crocker, Rahul Senwal, Shahrukh Khawaja
Supervisor: Dr. Ali Elkamel

The physical properties of heavy oil have always been its Achilles' heel. As a result of the high concentration of TAN, sulfur, and high viscosity, heavy oil has to be upgraded before it is refined. During the upgrading process, the large molecules that can't be distilled must be cracked to give lighter molecules. The cracking process produces heavy by-products in the form of coke, asphaltene, and vacuum residue. These by-products have little economic value but present great environmental risks.

The objective of this project is to evaluate the feasibility of cracking methods that can be used for a prototypical heavy oil upgrader in order to minimize energy consumption and maximize economic return. The five cracking technologies to be evaluated are:

- Delayed coking
- Flexi-coking
- H-oil coking
- LC refining
- Fluid coking

To complete the objective of this project, a simplified upgrading facility consisting of the basic units of distillation, primary upgrading (cracking), and secondary upgrading (hydrotreating) will be constructed.

The five cracking methods will be evaluated separately, where each technology is integrated into the upgrading facility and evaluated based on facility product yields and total energy consumption. The evaluation process will be aided by results from material and energy balances.

Additionally, the calculated results will be compared to similar upgrading facilities already in existence. Some examples of existing facilities to be used for comparisons are:

- Suncor Base Plant Upgrader (Delayed coking)
- Shell Scotford (Hydro conversion)
- Long Lake Upgrader (Deasphalter & gasifier)

20. Husky Sunrise Central Process Facility Heat Recovery Enhancement

Students: Daniel Mitcheltree, Abdelrahman Mohamed, Ammar Moosa, Brendan O'Neill
Supervisor: Dr. Ali Elkamel

The overall objective of this project is to study current major heat exchangers in the Central Processing Facility (CPF) of Husky Sunrise and identify if opportunities exist for heat recovery enhancement. This could involve changing the arrangement and number

of heat exchangers. Pinch Point Analysis (PPA) for the following operating cases will be conducted: Lift Gas and Electric Submersible Pumps (ESPs). Once this is complete an economic analysis will be performed on any desired changes to determine if these are economically feasible.

21. Campbell's Soup

Students: Eureka Choi, Caitlin Huber, June Hung, Chinmayee Rindani
Supervisor: Professor Moresoli

Currently a soup bar prototype is implemented at Ron Eydt Village at the University of Waterloo by Campbell's Canada. Our objective is to upgrade the pilot design to improve marketability to universities and other facilities. We will focus on the optimization of the soup bar layout, heating, refrigeration, and dispensing aspects to fulfill user needs and reduce production cost. We will be required to consider both the requirements of Campbell's as the manufacturer of the soup bar, as well the user needs and concerns determined through preliminary surveys.

Our expected outcome is to create a design that satisfies Campbell's needs and the consumer needs and generate a 3D model of this design. From the two preliminary surveys we conducted and Campbell's focus group it was concluded that consumers enjoy the idea of the soup bar but dispensing the food ingredients needs to be made easier.

Our approach to meet Campbell's expectations for a proposed upgrade to its current prototype involves three major steps:

- Identify criteria of items that can be upgraded such as layout, flow, refrigeration system, dispensing system
- Research and propose at least 2-4 alternatives to their current design problem
- Select and cost out optimal option including a 3D model of the design

22. Bioprocessing Plant Feasibility Study in Southwestern Ontario

Students: Michael Pan, Matthew Li, Abin Sebastian, Jimmy Chow
Supervisor: William A. Anderson

A proposal was put forward that a bioprocessing plant should be built in Southwestern Ontario to stimulate the local economy by creating a new source of income and jobs. The bioprocessing plant would also revitalize the agricultural economy of the region by generating new demand for agricultural products.

The overarching goal of this project is to study the feasibility of a bioprocessing facility

in Southwestern Ontario. The specific objectives are investigating the type of bio-product to be produced, and the technical and economic specifications of the proposed bioprocessing plant.

In the first portion of the project, levels of screening were conducted to identify the optimal feedstock, bio-product, and the plant location. In the second portion of the project, a model of the bioprocess plant will be produced to find preliminary estimations of energy and material flows. In addition, capital and operating costs will be calculated for the proposed bioprocessing plant.

23. Electric Vehicle Battery Sizing and Optimization

Students: Leigh James Corrigall, Ben George, Robert William Koller, Keith Norman Richard Pike, Joshua Weavers.
Supervisor: Aiping Yu

The purpose of this project is to model an electric vehicle, with a focus on the battery pack. The ultimate goal for the project is to design a battery pack that is cheap and lightweight, while still providing enough energy for the electric vehicle to travel a reasonable distance before having to recharge. The battery pack will consist of lithium-ion cells due to their high energy density and good rechargeability.

We will investigate commercially available lithium-ion batteries from different manufacturers, in terms of cost, voltage, capacity, weight, and power output. We will also gather information on electric motor options and vehicle configurations, and then select a specific set of parameters that we will use in our model. All this information will be combined in a MATLAB or Microsoft Excel simulation, that will determine the optimal battery manufacturer, and the optimal battery configuration that will provide the necessary capacity. In addition, we wish to explore other types of battery packs or chemistries, that when introduced, will further reduce overall vehicle weight and cost, without adversely affecting provided power or energy capacity.

Finally, we will compare other energy sources to our modelled electric vehicle, and state our model's advantages and disadvantages. We will also look at the research being performed with other battery configurations and chemistries, and discuss how these may change our model's design.

24. 3D Printing of Food for Dysphagic Patients

Students: Laura Boronka, Ashley Mathewson, Mykaela Rier
Supervisor: Christine Moresoli

In order to aid in the dietary habits of dysphagic patients the 3D printing of pureed foods has been suggested as a feasible solution. Dysphagia results in difficulties when swallowing thus restricting the foods that these patients are capable of eating which can

further result in malnutrition. The enjoyment of food is accomplished through texture, mouth feel and most importantly through the visual appearance. The solution to this problem would be to print pureed foods into solid shapes that are dissolvable within the mouth, visually appealing, and nutritious. This can be accomplished through the addition of thickeners and gels. Purees require a thickener improve cohesiveness and consistency. From research we determined that with additionally adding a hardener, the produced purees can make the purees 'printable', where they can be extruded and hold their shape, as long as they are odorless, tasteless, dissolves in the mouth, and are required in small enough proportion to not affect the nutritional value of the original foods.

In order to tackle this problem a build it yourself 3D printer (Rostock MAX™ v2 Desktop 3D Printer Kit) was purchased as well as an additional extrusion device DISCOV3RY PASTE EXTRUDER by Structur3D for the incorporation of food pastes within the printer. Through experimental testing the aim is to determine the properties necessary to produce solid food of which easily dissolves within the mouth thus aiming to solve the problems pertaining to dysphagic patients.

It is known that the rheological properties of the puree will affect both its print-ability and its thickness requirement for easy swallowing; therefore the formulation of the printable purees will require experimentation with additive. The final food puree formulations will need to meet the rheological, sensory, and textural requirements for this project.

As the printer is being assembled, and the paste extruder is being integrated we can learn formulation printer considerations from test printing different well-known materials. Additionally, we can evaluate the materials that have already been successfully printed using the same paste extruder and a similar 3D printer setup. These possible test materials include; Nutella, silicone, and drywall filler. Due to its availability Nutella was chosen as the test print material.

Design considerations will be explored for producing the puree foods commercially by looking at currently available commercial textured foods suitable for the elderly. We will then evaluate their composition and properties to see how they could be adapted/formulated for printing. From research into current dysphagic patient treatments in assisted living facilities it was found that companies producing purees are currently not providing any thickness or viscosity measurements on the purees, making consideration by staff necessary to ensure safety. Additionally, there is no standard across or within the facilities regarding practices to achieve the desired texture. Therefore, we will attempt to produce a consistent texture achievement with the formulations.

25. Reactor Modeling and Dust Management for a Solvent-free Protein Separation Process

Students: Michael Vitelli, Marco Quattrochiochi, Brendan Gentili
Supervisor: Raymond Legge

The focus of this project was on a novel protein separation method which does not employ the use of solvents – a high cost method that the protein separation industry currently uses. The first objective of this project was to model the reactor that separates proteins from a flour mixture that contains a combination of fat, carbohydrates, and proteins by electrically charging the particles. The model of this reactor was created in COMSOL and modified to match results that were found in bench-scale tests. The end-goal of this section of the project was to obtain a model that replicated real-life experiments and to then determine the ideal parameters that would yield the most efficient protein separation.

The second objective of this project was to create a health, safety, and environmental plan to manage the dust particles in the process. The flour that is fed into the process could potentially be an explosion hazard due to its small particle size and high concentration. Based on the literature reports, there is a legitimate threat of a dust explosion being created in this process. Systems are currently being designed to mitigate this risk of a dust explosion and to control the dust emissions to the atmosphere which are regulated by provincial law. The end- goal is to design a safe, efficient, and cost-effective dust management system that will meet government regulations.

The findings from this project will be applied to the pilot scale set-up that is currently being designed and built.

26. Post Combustion Carbon Capture Unit

Students: Richard Kwon, Jungho Kang, Hanmiroo Kim
Supervisors: Ali Elkamel Ahmed Shafeen

The overall objective of this project is to simulate a post combustion carbon capture unit with ionic liquid solvents
For many years Carbon dioxide emissions has been believed by many to be a major contributor to global warming. Approximately 85% of CO2 emissions come from energy production. As a consequence, development of innovative environmental control technologies is crucial in maintaining coal as a competitive and environmentally benign energy source. Current processes for CO2 capture available is based on amine-solvents, such as monoethanolamine (MEA). However these methods have environmental, social and economic drawbacks. Ionic liquid is a relatively new area of research among the scientific community and it has drawn much attention from researchers. This is mainly due to the fact that ionic liquids offer infinite number of possible structural construction; thus allowing it to be tailored to desired properties for any particular application.

By using simulation program such as Aspen Hysys, carbon capture process will be simulated with the ionic solvents and will be compared with other solvents to see how beneficial it is to utilize ionic liquid for carbon capture process.

27. SAGD WellPad Design at Low Pressure Casing Gas Line

Students: Gloriana (Yunan) Gao, Cristal Siao Tao Choi, Bonnie Nicolette Ng

Recent trends show that heavy oil producers in Alberta intend to increase oil production rate at lower average SOR (Steam Oil Ratio). With the aid of an electric submersible pump (ESP) at the wellbore, adequate hydraulics is generated to send the products up to the surface. This option results in a low-pressure casing gas when the emulsion is flashed at the ESP and creates a pressure gradient between the high emulsion pressure and low casing gas pressure at the surface. This complicates the mixing between the two products before transporting to the Central Processing Facilities (CPF).
Two options to solve the problem will be explored in this project, which includes the use of a compressor and a multiphase pump. The intent of adding these units is to reduce or even eliminate the pressure difference between the casing gas and emulsion before reaching the CPF. A computer- based simulation Aspen HYSYS software will be used to model both the compressor and multiphase pump process. The operating conditions will then be examined and optimized using simulated models and cost analysis will be conducted along with some industry guidance. By the completion of this project we will be able to provide a comparison of the two processes, which consist of: HYSYS design for each process, cost analysis, benefit and shortcoming of each system.Capstone Design Project Summary

28. Smart grid design integrated with renewable energy technology for remote communities.

Students: Tejas Kamath, Faeeza Jamil, Amad Khan
Supervisors: Zhongwei Chen Jason Grove

The vision behind the project is enabling remote communities, reliant on non-renewable energy sources, to utilize renewable energy alternatives by implementing smart grid technology. Smart grids are advanced versions of electrical grids that can efficiently manage the electrical power distribution between multiple energy sources.

The main goal, our team is aiming to accomplish by means of this project, is to reduce the utility of non-renewable energy sources in order to reduce greenhouse gas emissions as well as reduce the cost of electricity, and create sustainable communities that rely entirely on clean energy. In addition we also want to create jobs and a healthier environment for the communities through this project.

Currently our team is working on a feasibility study on the remote community of Poplar Hill, Ontario. Our team is performing a comprehensive cost analysis, and is also measuring the reduction in greenhouse gas emissions following the implementation of

the project. The logic behind the smart grid is being simulated with MATLAB/Simulink.

29. Feasibility Study of Using SOFC to Improve Power Generation

Students: Daniel Cho**,** Zehra Hameed, Sujeet Gubbala**,** Mohammad Suria, and Zohaib Narejo

Our group has provided a proposal to design a Solid Oxide Fuel Cell (SOFC) as a source of power generation for a typical hospital located in Toronto. The objective of this proposal is to observe the feasibility for SOFC by comparing both based and projected scenarios for energy efficiency, economy and environmental sustainability. Energy scenarios such as pressurized SOFC system, and pressurized SOFC with heating generation would be compared to determine an alternative energy source.

Further, utilizing battery for SOFC system would be used to control the hospital's utility consumption on a daily basis. Economic conditions would also be compared by assessing both the manufacturing cost and the operating cost of SOFC. The purpose of conducting economic analysis would be to observe the economic feasibility of SOFC technology. Comparing environmental scenarios would be used to support the part of the objective for SOFC design based on practicing environmental conservation. Comparing legislations for commercial areas would be used to support the viability of SOFC technology. Aspen software is used to model the electrical load and the corresponding gas input required for the SOFC to perform at the specific load. Those values would be used to model economic data and present a case that signifies the technology as a viable alternative in the modern energy industry. The secondary gains from using the technology such as cooling and heating would be analyzed and brought into scope and energy saved in terms of those gains would be calculated for a final projection.Integration of Renewable energy into Oil sand Extraction Processes in Alberta

Students: Ashkan Jannati Masoum Hussain Arwani, Mohammad Reza Zoolfagharian
Supervisor: Dr.Ali Elkamel

Oil sand extraction is an energy intensive process and provision of this energy input has been a point of concern in terms of sustainable development and socio-environmental impacts. Our project analyzes the feasibility of integrating renewable sources of energy for energy input into oil sand extraction process. A typical In-Situ process requires 95% steam and 5% electricity. Through research we determined that it is not feasible to generate steam using

renewable energies. This is simply because steam is required to be at 300^{O}C and 1,000 bars for the extraction process. It is possible to achieve that through renewable energy if we overcome many restrictions, which would make the process very costly. Therefore, the focus of our project would mainly focus on the 5% electricity that is required in the process.

To assess the eligibility of different renewable sources of energy for provision of this 5% electricity requirement , we have set the conventional Gas Turbine that is industry standard as the bench mark for our comparisons. There are two scenarios associated with this bench mark; the initial cost of purchasing the turbine and the long term expenses and maintenance costs.

The three elected renewable source of energy that could possess the potentials to support the energy need for our process are:

- Wind Energy
- Geothermal Energy
- Biomass

We will be focusing more intensely on Wind Energy as our recent research indicates its higher viability among the other candidates.

30. A Feasibility Study on Process Alternatives for Benzene Reduction in Gasoline Feedstock

Students: Yustus Cyizere Llewellyn Human, Zahra Elahipour, Micky Agrawal
Supervisors: Jason Grove, Ariel Chan

The overall objective of our fourth year design project is to study the feasibility of reducing the benzene content in gasoline feedstock while maintaining current market octane ratings and minimizing additional process costs. The need for benzene reduction in gasoline arises from new lower acceptable limits of benzene content in gasoline as stated in EPA's Mobile Air Source Toxic (MSAT) phase II regulations.

Two process alternatives are being evaluated upstream and downstream of the reformer unit in order to reduce benzene content in the final gasoline product. The upstream alternative removes benzene precursors to the reformer whereas the downstream design directly removes benzene with potential market value.

These alternatives (along with a base case for comparison) are being simulated using Aspen Plus process simulation software. It is expected that the successful completion of this project could lead to a significant reduction of benzene emissions. Outcomes of this project include Aspen simulations for the base case and two process alternatives, an economic analysis of process alternatives, preliminary equipment sizing and design, and a HAZOP analysis of the processes.

31. NanoServe Brewing

Students: Michael Rolfe, Gabriel Leduc, Ian Droog, Troy Stevenson
Supervisors: Jason Grove and Marc Aucoin

NanoServe Brewing is designing a full technical and business plan for the launch of its first product, a 15L intelligent home scale brewing unit for the purpose of allowing the casual beer drinker an engaging, creative and fun way to brew the beer of their choice. The end user will be able to use an accompanying mobile application to view brewing recipes, be instructed how to load the unit, and be given real-time data on the process of their brew such as temperature and time for the particular recipe.

The objective is to have a comprehensive technical design and scale of the unit and the materials needed for construction in order to determine an accurate cost of production, a complete business plan for a launch to market, as well as a mobile software prototype for the control and monitoring of the unit by the end user. The end goal will not just be the design of the unit, control methods, and accompanying user interface but a strategy to launch the company and product to the market to as a prospective entrepreneurial business.

32. Ocean Thermal Energy Conversion

Students: Eric Bernard and Riley Dahmer
Supervisor: W.A. Anderson

This project examines the idea of producing electricity using the natural thermal gradient found in the ocean, a concept called ocean thermal energy conversion (OTEC). It is proposed to be an alternative source of energy production for tropical islands which require imported resources, such as oil, to produce their electricity. OTEC uses seawater, a free resource, and can potentially produce no greenhouse gas emissions, making it an attractive source of renewable energy. In spite of these advantages, OTEC requires large flow rates of water to operate which requires a large capital cost investment and could lead to a potentially high cost of electricity produced.

The purpose of this project is to design a 10 MW net OTEC power plant for use on an island in the Caribbean region and to perform an economic feasibility study of the design. The economic feasibility study will determine under which conditions this design will be favourable to implement over current conventional sources of electricity. A capital cost estimate will be generated as part of this study and provide insight into the level of investment required to implement the OTEC design.

To date, background research has been conducted and the different design configurations and constraints for an OTEC system identified and evaluated. An onshore, closed-cycle configuration was selected as the best alternative for the design and preliminary simulation work was performed to model this design. Preliminary heat and mass balances have been performed in Aspen HYSYS and have yielded the required electricity output of 10 MW. Equipment sizing and cost estimates will be performed with the finalized simulation from HYSYS.