BEE 469/470  
Fall 2017/Winter 2018  
BEE 469 Ecological Engineering Design I

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Credit Hours: Four  
Pre-Requisites: BEE 322, ENGR 391  
Lecture Hours: 5.00-5.50 pm MWTR Gilmore 234  
Office Hours: By appointment

Catalog Description: BEE 469 Ecological Engineering Design I (4 hr) Engineering design processes for ecological engineering applications, including specifications, performance criteria, timelines, and project logistics, principles and practices of working in engineering teams. PREREQ: BEE 322. Unenforced Prerequisites are ENGR391 and Senior Standing or Consent of Instructor. BEE 469 and BEE 470 are taught as a unit each year.

Required Text: None

Recommended Reading and References: Materials will be made available based on the design project.

Instructional Objectives
The primary objective of the design sequence is to provide students with hands-on experience in solving the kind of complex open-ended design problems they are likely to encounter in ecological engineering practice, including satisfying physical, legal, economic, social and environmental constraints. Other objectives include providing the students with experience in the real-world application of mathematics, science, engineering economics, ethics and other disciplines related to engineering analysis and design, and a clearer perspective on the value of research in addressing contemporary problems in engineering design. Attainment of oral and written communication to achieve a level commensurate with professional engineering practice will be a fundamental objective.

The primary focus of the design sequence will be an open-ended design project that promotes critical thinking. The project will have four major components:

1. Develop a feasible engineering solution to a design problem.
2. Perform quantitative evaluation of an engineering project considering ecological, social and economic impacts of the project.
3. Assess project sustainability, economic viability and compliance to applicable laws.
4. Present the results in oral and written form at a level commensurate with professional practice.

Organization of the Course
The design sequence will involve solving an open ended problem. Finding a solution to open ended problems involves a lot of peer-peer discussions and evaluation of technical results using multiple approaches considering technical, economic, legal, regulatory and social factors. A significant part of the course will consist of in-class discussion in an informal setting. Each team will be present an overview of their findings and technical calculations to the class as often as weekly. The student teams will lead the design process, discussions in/outside the class and communication with the clients. Instructors will only facilitate and not lead these aspects of the project. Instructors will respond to all student requests, help in locating technical
resources, oversee the design process, provide timely feedback on all reports and other written/oral communications and help in any conflict resolutions. A background of some important technical aspects, engineering design process, example case studies will be presented through a series of lectures. Additional lectures on professional development, emphasizing written and oral communication, will also be presented.

**Evaluation of Student Performance**

Ecological design always involves a team effort. As a result, student participation as part of the design team, as evidenced through meetings, presentations, written reports and a project log, will be a major determinant in the final grade achieved. Gaining an “A” in the class requires demonstration of consistently effective team performance. Apart from some basic lectures at the outset of the sequence, **students will be in charge of their projects**, with the faculty serving as advisors, who will respond to requests for assistances. Communication skills, as well as technical soundness, will be evaluated. Every two weeks students will present progress oral reports and written memos outlining ongoing progress, technical problems encountered and strategies for problem resolution, and will also summarize their work in a longer presentation at the end of each term. A project log will be an integral part of this process. Interim design report consisting of detailed discussion of current state of the art, detailed discussion of technical alternatives, rational for choosing the proposed solution. A final design report will be required at the end of the second term. Final design report will consist of all the elements of revised Interim report in addition to the final design calculations and recommendations. A cover letter to the potential customer and executive summary are integral elements of both reports. Revising reports in response to peer and instructor evaluations/comments are part of the course learning objectives. The approximate grading breakdown for BEE 469/470 will be as follows:

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<tr>
<th><strong>Table 1. Grading breakdown for BEE 469.</strong></th>
<th><strong>BEE 470</strong></th>
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<tbody>
<tr>
<td>• Project log – 10% (approximately 3000 words)</td>
<td>• Project log – 10% (~ 3000 words)</td>
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<td>• Memos-20% (~1000 words for memos)</td>
<td>• Memos – 20% (~ 2000 words)</td>
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<td>• Site visit Reports- 5%</td>
<td>• Oral Presentations – 20%</td>
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<tr>
<td>• Individual technical report – 15% (~ 2000 words)</td>
<td>• Final design report – 40% (~7000 words, based on the Interim project report)</td>
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| • Oral Presentations – 20% | • Professionalism/team participation -5%
| • Interim design report – 20% (~5000 words) | • Peer review of technical calculations: – 5% |
| • Professionalism/team participation – 5% | |
| • Peer review of technical calculations: – 5% | |

**BEE 469/470 Learning Outcomes:**

The primary objective of the design sequence is to provide students with hands-on experience in solving large-scale open-ended design problems in ecological engineering, while satisfying legal, economic, social and environmental constraints. Other objectives include providing the students with experience in the real-world application of mathematics, science, engineering economics, ethics and other disciplines related to engineering analysis and design, and a clearer perspective on the value of research in dealing with problems in engineering design.
Students should be able to accomplish the following upon completion of the course:

**BEE 469 Learning Outcomes:**
1. Develop the design of an engineering project considering ecological, social and economic impacts of the project.
2. Understand the design concerns with respect to project sustainability, long term economic viability and compliance to local, state and federal laws.

**BEE 470 Learning Outcomes:**
3. Perform quantitative evaluation of an engineering project considering ecological, social and economic impacts of the project.
4. Assess project sustainability, long term economic viability and compliance to local, state and federal laws.

**BEE 469/470 WIC Learning Objectives:**
BEE 469 is also a Writing Intensive Course (WIC) and together with BEE 470 can be used to satisfy the WIC requirements for the BEE undergraduate program. At least 25% of the course will involve individual writing (memos and individual technical report) while the project log, site visit reports, Interim design report and the oral presentations will be group effort. Therefore in addition to the regular course outcomes, the students should be able to accomplish the following upon completion of the course:
1. Develop and articulate content knowledge and critical thinking in the discipline through frequent practice of informal and formal writing.
2. Demonstrate knowledge/understanding of audience expectations, genres, and conventions appropriate to communicating in the discipline.
3. Demonstrate the ability to compose a document of at least 2000 words through multiple aspects of writing, including brainstorming, drafting, using sources appropriately, and revising comprehensively after receiving feedback on a draft.

**ABET Bioengineering Program Learning Outcomes met by BEE 469/470:**
c. Ability to design a system, component, or process to meet desired needs;
d. Ability to function on a multidisciplinary team;
f. Understanding of professional and ethical responsibility;
h. Broad education necessary to understand impact of engineering solutions in global, economic, environmental and societal context;
i. An ability to apply knowledge in a specialized area related to ecological engineering;
j. Ability to model and design ecological systems;
o. An awareness of the forces that impact design and decision making, such as resource limitations, system constraints, and the identified goals for improvement;
p. Recognition of the need for and ability to engage in life-long learning;

**Statement Regarding Students with Disabilities**
"Accommodations for students with disabilities are determined and approved by Disability Access Services (DAS). If you, as a student, believe you are eligible for accommodations but have not obtained approval please contact DAS immediately at 541-737-4098 or at http://ds.oregonstate.edu. DAS notifies students and faculty members of approved academic accommodations and coordinates implementation of those accommodations. While not required,
students and faculty members are encouraged to discuss details of the implementation of individual accommodations."

**Link to Statement of Expectations for Student Conduct:**
ANY act of dishonesty will result in consequences up to and including immediate failure of this course. Examples of dishonesty include copying during an exam, writing a paper for another student, submitting the writing or calculations of others without proper attribution. For additional information see the Office of Student Conduct and Community web-site at http://studentlife.oregonstate.edu/sites/studentlife.oregonstate.edu/files/code_of_student_conduct.pdf. When in doubt, talk to either instructor – this class sees the improvement of understanding of ethical work habits as a key objective in your experience.
Design Problem 1

Nitrates in agricultural runoff are a serious cause of non-point source pollution in the United States and around the world. A possible solution to this problem is to use woodchip bioreactors to denitrify the nitrates in the effluent water into nitrogen through bacterial action. Slow release of structural carbohydrates from wood acts as a source of carbon and energy for the anaerobic denitrifying bacteria. It has been found that the type of wood chips, hydraulic retention times, wood chip size, geometry of the wood chip bioreactor are all variables that impact the treatment efficiency. Technically there are many challenges in designing woodchip bioreactors, including seasonally variable inflows, fluctuations in the nitrate concentrations, microbial activity during cold months, and maintenance of conditions for optimal growth of the microbes for effective treatment to meet the discharge regulations.

In this project you will design a woodchip bioreactors to treat the effluent from a pasture irrigated with effluents from dairy barn at OSU. The objective is to minimize the concentration of nitrates at the outlet of the bioreactor. The system you are designing should be suitable for Willamette valley and a location where line-power electricity is available but may not have internet/cellular connectivity.

You are to complete a technical design, build a prototype and conduct laboratory experiments and demonstrate its effectiveness to treat simulated agricultural field effluents. It is important that you consider scaling effects in you design, prototype and experiments. Your design must include Arduino based monitoring and data storage. Your design should balance cost (initial and operations), environmental sustainability, robustness, and feasibility. Your prototype will be tested under real-world conditions as would be found in the Willamette Valley, Oregon in January-March.

Some of the challenges are:

1. Highly variable influent streams with variable nitrate concentrations.
2. Robust operation under highly variable climatic conditions.
3. Cause minimal disruption to existing farming activities.
4. Multiple stakeholders and operators with differing needs and abilities.

The overall goal of this project is to design, develop and evaluate a wood chip bioreactor to reduce the effluent nitrate to <100 mg/L while minimizing the economic costs and environmental impacts of the proposed design. The proposed design must strive to minimize the need to alter existing farming practices.

At a minimum your design must include the following elements:

1. Meet the safety and environmental regulatory requirements.
2. Meet functionality constraints in terms of agricultural runoff generation patterns, nitrate reduction goals, hydraulic retention times and existing practices.
3. Consider climatic factors in your design.
4. Economic considerations in all designs (Capital versus operating costs, comparison to the current state of affairs).
5. Scalability to accommodate different funding scenarios.

Completion of this project will include the provision of a complete, buildable design with supporting calculations demonstrating feasibility, evaluation of the net present value of the design, and testing of the device at a the dairy farm pasture on OSU farm in Corvallis.
Design Problem 2

Designing water filters to remove fluoride or arsenic is a concept that has received worldwide attention. The goal of this project is to make a water filter for household use in developing countries to remove fluoride or arsenic. In each case you should design the device for a specific region, addressing the availability of materials needed, and the suitability to the culture of people who would use your device. In the case of fluoride, we recommend considering the population of Northern Cameroon, where we have a collaborating university. For Arsenic, you may consider the Willamette valley or Bangladesh, both of which have areas of arsenic contamination.

You are to complete a technical design, build a prototype and conduct laboratory experiments and demonstrate its effectiveness to treat simulated water samples. It is important that you consider scaling effects in you design, prototype and experiments. Your design must include some element of 3D printing, Arduino based monitoring and data storage. Your design should balance cost (initial and operations), environmental sustainability, robustness, and feasibility. Your prototype will be tested under real-world conditions as would be found in the Willamette Valley, Oregon in January-March.

Some of the challenges are:

1. Highly variable input water quality.
2. Robust operation under highly variable climatic conditions.
3. Multiple stakeholders and operators with differing needs and abilities.
4. Assuring long-term effectiveness when the users may not detect deterioration of filtration.

The overall goal of this project is to design, develop and evaluate a water filter to provide the drinking and cooking needs for a family of four while minimizing the economic costs and environmental impacts of the proposed design. The proposed design must strive to minimize the need to alter existing daily practices of people.

At a minimum your design must include the following elements:
1. Meet the safety and environmental regulatory requirements.
2. Meet functionality constraints in terms of arsenic or fluoride reduction goals.
3. Consider sourcing of materials for your water filter.
4. Economic considerations in all designs (Capital versus operating costs, comparison to the current state of affairs).
5. Scalability to accommodate different funding scenarios.

Completion of this project will include the provision of a complete, buildable design with supporting calculations demonstrating feasibility, evaluation of the net present value of the design, and testing of the device at a BEE Department. There is a possibility that this design will be field tested in Cameroon.

References and Resources:

1. Peer reviewed and other literature sources (A list of key references will be provided).
2. Information from professionals involved in the project.

Design Problem 1

- Prof. Frank Chaplen has kindly agreed to serve as the technical expert for the project.
- Dr. Jim Dooley, CEO of the Forest Concepts LLC has kindly agreed to provide technical support, share previous design case studies and provide a supply of various types of wood chips for experiments.
- Numerous studies in peer reviewed literature, extension documents and federal agency guidelines.

Design Problem 2

- Design reports and several videos on design of low cost filters.
- [https://www.youtube.com/watch?v=yd2tR57sVqY](https://www.youtube.com/watch?v=yd2tR57sVqY)
Funding: You will be provided a $500 budget for hardware and shipping required to build your device. All orders must be sent electronically to a folder on google drive and will be processed within two days for further ordering. Jennifer will order the items once authorized by an instructor. You may make no more than 10 purchases, where a “purchase” is a single list of items to be obtained, or a single submission of receipts to be reimbursed, potentially from multiple vendors (to void excessive burden on Jennifer). For computation of shipping costs, note that the department has Amazon Prime.

Text: Class notes and handouts. No required text.

Data Management

All students/teams are required to maintain up to date documentation of their individual/team project memos, meeting minutes, presentations to their respective group folders.

1. Project memos (one page), oral presentation slides and interim technical report will be considered public documents and posted on the course website.

2. A hard copy (three- ring binder) and soft copy (flash drive) of all documentation in a three ring binder submitted at the end of the course (10th week)

Team Member Roles for Team-Related Activities (rotating roles every 4 weeks)

1. **Project Lead**: Responsible for the project coordination, tracking, verifying benchmarks hit. Project lead ensures that all other team members are performing their tasks in a timely manner. Project lead will be responsible for all communications with the client.

2. **Communications Lead/Facilitator**: Ensure timely communications among members. Communications lead will be responsible for the organization of all the written materials. The communication lead will record the meeting minutes and keep a record of all the memos. Communications lead is also responsible to arrange meeting logistics such as meeting time and location generate (collaboratively) and circulate agenda prior to the meeting. Conduct meetings such that all items on the agenda are fully discussed and brought to closure with clear outcomes understood by all.

While we have identified the two different roles, it is important to note that they are only leads and can distribute the work to other members. Therefore, while the project lead will be responsible for the overall project, contribution from individual members is expected.

The team members will rotate the roles of the project lead and communication lead among the members such that each member serves in these roles at least once during the design sequence BEE 469/470.

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<th>Start Date</th>
<th>End Date</th>
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<tr>
<td>21st Sept. 2017</td>
<td>3rd Nov. 2017</td>
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<td>3rd Nov. 2017</td>
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<td>12th Jan., 2018</td>
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<td>16th Feb., 2018</td>
<td>24th Mar., 2018</td>
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Lectures
Lectures will be delivered to cover various aspects of the project design and development during the BEE 469/470 course sequence. The following list of lectures is tentative and lectures will be introduced/changed based on the needs of the class teams.

BEE 469 (Tentative list):
1. Guest lectures by technical experts (two to three lectures).
2. Written Communication: Memo, report and citation formats.
3. Open engineering: estimating energy of aeration and air pump selection
4. Engineering Design/Economics In class discussion
5. Conversations on engineering design: Multiple lines of reasoning to check answers and find elephants (one lecture).
6. Decision matrix discussion
7. General Team Updates
8. Oral Communication: How to design and prepare for 3, 12, and 40 minute talks.
9. Student presentations of the decision matrix
10. Pipes and fasteners, mechanical construction and material selection: FE materials
11. Primer on 3-D printing
12. Discussion Interim Report Feedback /expectations for final report
13. Conversations on engineering design: Economic analysis and introduction to Enterprise budgets.
14. Environmental impact assessment
15. Conversations on engineering design: Scaling up and down: Use of similitude principles for designing prototypes. What to consider, what to ignore and how to tame the elephants.
16. Conversations on engineering design: Identifying design constraints and feasibility analysis; evolution versus revolution.
17. Conversations on engineering design: Accuracy and Precision: assessing model errors and propagating errors in calculations.

BEE 470:
1. Case study of an engineering design problem (one lecture).
2. How to develop a research/project proposals (two lectures).
3. Writing an Effective Resume and/or Cover letter; Job and/or internship search strategies (one lecture).

Site visit
A tour of sites relevant to this project and broadly to Ecological Engineering will be conducted from 8.30AM, 29th September to 30th September. This will be in the in the Washington-Oregon area, food and travel arrangements will be provided. This is a required class activity, so participation is mandatory except in authorized cases. Places to be visited include (tentative):

- Orenco, Sutherlin, OR
- Wetland-Prairie-Restoration, Eugene, OR
- Woodburn waste water treatment plant, Woodburn, OR
- OSU Tillamook Dairy Extension Center
Tentative schedule for the design sequence BEE 469/470

469 Broad Goals: Investigate alternatives and submit individual reports, select an alternative, complete detailed technical design and economic calculations and submit interim technical report (including a bill of materials for construction of prototypes).

470 Broad Goals: Prototype development, collect performance measurement data and revise economic calculations and perform life cycle assessment. Design full scale system and submit final technical report, posters and presentation.

NOTE: These are for provided here as a guideline for planning and are tentative. The deadlines for reports/any assignments in CANVAS are final and binding.

BEE 469 (Fall, 2017)
1. Lectures: Lectures covering strategies for engineering design, example case studies, project site visit, strategies for effective professional communication, and how to bid an engineering project (see details above)
2. Design problem, and formation of teams: 1st week
3. Project schedule:
5. Project updates: 5:00 pm Thursday of every week.
6. Review of progress in one page project memos: 2, 4, 6, 8 and 10th week.
7. Meeting minutes: Every meeting of the group (at least bi-weekly).
9. Presentation of decision matrix: 30th Oct, 2017
10. Team presentation of technical alternative selection: 1-3rd Nov, 2017
11. DRAFT Interim Technical Report (ITR): This comprehensive group report must include: review of literature, technical alternatives discussed in the group, final design layout and technical/regulatory considerations used for preparation of the final design layout. 10th Nov, 2017 (~5000 words).
12. Submission of design calculations and economic calculations for peer review: 17th Nov, 2017
14. Interim Technical Report (ITR): This comprehensive group report must include: review of literature, technical alternatives discussed in the group, final design layout and technical/economic/regulatory considerations used for preparation of the final design layout. 7th Dec, 2017 (~5000 words).

BEE 470 (Winter, 2018)
15. Review of progress in BEE 469: 1st week.
16. Review of the ITR: Instructor feedback must be considered and any issues pointed out in the ITR must be fully addressed. 1st week.
17. Review of progress and project memos: 2, 4, 6, 8 and 10th week.
18. Meeting Minutes: Every meeting of the group (at least bi-weekly).
19. Model building and testing: 2-5th week. (weekly updates from each team)
20. Team presentation (oral) of revised economic calculations: 6th week.
21. Team presentation (oral) of completed design: 7th week.
22. Respond to critique and feedback: 8th week.
23. Preparation of Final Report (FR): This report must include the detailed design calculations, reviewed ITR, covering letter. 7-9th week.
24. Team presentation of final design: 10th week.
25. Final Report submission: Finals week (~7000 words); 10th week.
26. Evaluation by external panel, instructor and peer review of the FR: 10th week.
Report Guidelines

General Guidelines for All Communications

1. All communications must be in grammatically correct English.
2. Use SI units in all your calculations. You may report your final numbers in non-SI units.
3. Pay attention to the significant digits in all your calculations.
4. All communications must be in clear and concise form.
5. All assignments must follow BEE departmental guidelines for all assignments. The guidelines in this document are in addition to these guidelines.
6. For the purposes of this course, one page is defined as about 40 lines of text consisting of about 450-500 words. Similarly one half page will be 20 lines of text with about 200-250 words.

Project Log Guidelines

The purpose of the project log is to document the project and provide a complete detailed overview to your team, clients and other engineers who may refer to your work at a later date. A hard copy (three- ring binder) and soft copy (flash drive) of all documentation in a three ring binder submitted at the end of the course. All students/teams are required to maintain up to date documentation of their individual/team project memos, meeting minutes, presentations to their respective group folders. Project memos, oral presentation slides and interim technical report will be considered public documents and posted on the course website. All project reports must consist of following sections.

1. Project outline and objectives.
2. Gantt charts.
3. Team member and their responsibilities.
4. Project meeting minutes.
5. Project memos to the clients.
6. Individual, interim and final technical reports.
7. Slides of all oral presentations.
8. Details of all technical calculations including assumptions and data sources.
9. List of references. Consistently follow the format of any scientific journal format to cite the references.
10. Appendices: Appendices can consist of important resources such as copies of important papers, reports, product brochures and communications with experts etc.

Project Technical Alternatives Report

The primary objective of a project Technical alternatives report is to briefly describe various solutions that can solve the engineering design problem. The report is typically a brief document that can have figures to convey key ideas. It must also include a bulleted list of advantages/benefits, disadvantages/concerns and ideas that need to be further explored.

Project Memo Format

The primary objective of a project memo is to communicate the status of the project any important developments and any unexpected situations/issues to the client in a timely manner. While the styles of memos vary, all your memos must contain the following elements:
1. A one page (or less) cover letter addressing the client summarizing the big picture for the project.
2. A brief one/two page memo containing three sections: project accomplishments, plans for next two weeks and data needs from the client as a brief bulleted list.
3. Any important data, calculations, documents or references can be attached as appendices.

**Site Visit Reports**

The purpose of a site visit report is to accurately document your observations during the visit to a project site. Site visits are a team effort and must represent the summary of observations made by all team members. Please include separate sections for each site that was visited. Site reports must be limited to 1500 words not including the appendices.

**Individual Report (IR) Guidelines**

The primary objective of the IR is to document and assess the individual team member contribution to the research into different aspects of the design alternatives. As well, the report provides the student an opportunity to practice writing, and demonstrate their ability to communicate formally in well-crafted written English. The report must be comprehensive in scope and synthesize the individual research topic components into a logical narrative. It must not consist of poorly connected paragraphs. The overarching structure and flow of the document will be a central aspect of the evaluation of merit. You are encouraged to adopt a similar report format as other team members.

**Specific Guidelines**

1. The IR will be approximately 2000 words, and may include any number of figures or appendices.
2. The IR must include following mandatory sections:
   a. Comprehensive survey of technology field and alternative technologies.
   b. Technical considerations.
   c. Economic considerations.
   d. Environmental and social impact considerations.
3. The report (15% of the grade) will be evaluated on
   a. content (60%: 45% for technical content; 5% for addressing economic concerns; 5% for environmental and sustainability aspects; 5% for social impacts),
   b. clarity (15%): The ability to communicate clearly with the audience without too much technical jargon.
   c. coherence (15%) and : An organized development of the key concepts, data and references to present the unified solution to the design problem.
   d. language (10%): Ability to write in grammatically correct and simple language.

**Interim Technical Report (ITR) Guidelines**

The primary objective of the ITR is to document the final design and the alternative designs considered. This comprehensive group report must include: review of literature, technical alternatives discussed in the group, final design layout and technical/economic/regulatory considerations used for preparation of the final design layout. Although detailed calculations regarding the technical design are not required at this stage, it is expected that simple economic
or design calculations will be performed to select one option from the list of alternatives considered. The report should specifically address appropriate engineering standards applied in your design and analysis, and should identify and discuss multiple realistic constraints observed and addressed in the design process. The report must be comprehensive in scope and demonstrate integration of technical knowledge, knowledge about the local, state and federal laws, socio-economic factors used to arrive at the design solution.

The ITR will be returned to the team with instructor feedback during the first week of the class in winter term and it is expected that the comments will be fully addressed by 2nd week of winter term.

Specific Guidelines

1. The ITR will be approximately 5000 words and may include any number of figures or appendices.
2. The ITR must include following mandatory sections:
   a. Comprehensive survey of technology field and alternative technologies.
   b. Technical constraints that guided the choice of a particular design alternative.
   c. Economic considerations.
   d. Environmental and social impact considerations.
   e. Compliance with relevant federal, state and local laws.
3. Elements of IR can be used in ITR, however at least 30% of the ITR (>1500 words) must consist of material specific to ITR.
4. The report (20% of the final grade) will be evaluated on
   a. content (60%: 30% for technical content; 10% for addressing economic concerns; 10% for environmental and sustainability aspects; 5% for social impacts; 5% for compliance with relevant federal, state and local regulations),
   b. clarity (15%): The ability to communicate clearly with the audience without too much technical jargon.
   c. coherence (15%) and : An organized development of the key concepts, data and references to present the unified solution to the design problem.
   d. language (10%): Ability to write in grammatically correct and simple language.

Final Technical Report Guidelines

The primary objective of the technical report is to document the final design and the alternative designs considered. Detailed calculations used in the technical design must be reported. The report should specifically address appropriate engineering standards applied in your design and analysis, and should identify and discuss multiple realistic constraints observed and addressed in the design process. The report must be comprehensive in scope and demonstrate integration of technical knowledge, knowledge about the local, state and federal laws, socio-economic factors used to arrive at the design solution.

The FR will be returned to the team with instructor and external panel feedback and it is expected that the comments will be fully addressed and corrected FR returned to instructors within a week.

Specific Guidelines
1. The final design report will be approximately 7000 words, and may include any number of figures or appendices.

2. The FR must include following mandatory sections:
   a. Comprehensive survey of technology field and alternative technologies.
   b. Technical constraints that guided the choice of a particular design alternative.
   c. Economic considerations.
   d. Environmental and social impact considerations.
   e. Compliance with relevant federal, state and local laws.
   f. Engineering calculations, sustainability assessments for the design case. Include a discussion of methods, standards used for design and sample calculations (detailed calculations can be presented in appendix).

3. Elements of ITR can be used in FR, however at least 30% of the FR (>1500 words) must consist of material specific to FR.

4. The report (40% of the final grade) will be evaluated on
   a. content (60%; 30% for technical content; 10% for addressing economic concerns; 10% for environmental and sustainability aspects; 5% for social impacts; 5% for compliance with relevant federal, state and local regulations),
   b. clarity (15%): The ability to communicate clearly with the audience without too much technical jargon.
   c. coherence (15%) and : An organized development of the key concepts, data and references to present the unified solution to the design problem.
   d. language (10%): Ability to write in grammatically correct and simple language.

5. Final reports are due by 10th Week of class.