Teaching Notes

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Abstract
This case study explores the options for using wastewater to produce renewable energy in the context of a public wastewater treatment plant. It provides an opportunity for students to synthesize knowledge from resource economics, engineering, environmental science, agriculture, and public policy to develop a trans-disciplinary approach to a socio-environmental issue. The case is designed for upper division undergraduate courses in resource economics or environmental engineering, but several modifications are provided graduate course applications. Students assume the role of a newly hired analyst at a consulting firm in Washington, D.C. that specializes in renewable energy solutions. They are charged with proposing a system that uses wastewater to produce energy, while accounting for multiple constraints across disciplines. Students are provided with economic, political, environmental, and engineering data on four different solid waste disposal options and work in small groups to develop a proposed solution that balances these factors. They present and justify their suggested solutions in small-group presentations, and the case concludes with an instructor-led discussion of the relevant considerations.

Topical areas/courses: Renewable energy, wastewater, environmental engineering, resource economics, and sustainability
Education level: Undergraduate upper division, Graduate
Type/method: Small group, Student presentations

SES Learning Goals
This case study will address the following Socio-Environmental Synthesis learning goals:

1. Ability to describe a socio-environmental system, including the environmental and social components and their interactions.
   Related Activities: Through the background reading and data, students will explicitly see the socio-environmental components in a wastewater-to-energy system and be able to describe the linkages in the system.
2. Ability to identify disciplines and approaches relevant to the problem.
   Related Activities: In designing a solution, students will incorporate concepts from economics, agriculture, engineering, environmental science, and public policy.
3. Ability to find, analyze, and synthesize existing data (for Modification 2).
   Related Activities: Students will use U.S. state population data and engineering estimates to

forecast the potential energy production capacity from wastewater using simulation and an optimization model.

4. Understand the different kinds of data and research methods used by relevant disciplines in the natural and social sciences (for Modification 1).
   Related Activities: Students will use engineering estimates, cost-benefit analyses, and qualitative data to build a basic economic optimization model.
5. Understand that ecological and social processes often vary across differing contexts, including space, time, and conditions (for Modification 3).
   Related Activities: Students will investigate how regulatory differences across states would affect their proposed solution and offer potential revisions.

Learning Objectives

Through this case study, students will:

1. Understand and recognize waste and resource management in a specific local application.
2. Understand how the political and regulatory environment can affect scientific decisions.
3. Recognize interactions between economic and scientific factors in an environmental issue (wastewater management and energy recovery) and the associated tradeoffs.
4. Develop and compare ways to synthesize different sources and types of data (political, agricultural, environmental, economic, engineering).
5. Learn how to justify and defend a proposal that involves tradeoffs across several disciplines, when a single optimal solution does not exist.

Introduction/Background

Increasing levels of waste (solid waste and wastewater) is a national problem for every country around the world. One important factor that contributes to this problem is population growth. The U.S. population[14] in 2012 was about 314 million people, and the projection for 2030 is 360 million people, roughly a 14% increase.

The U.S. capital city of Washington, D.C., faces a problem of increasing wastewater and requires a good management plan to address this issue. Based on its population (632,323 people in 2012) and wastewater production rate[15] (100 gal/person/day), the approximate wastewater produced by the Washington, D.C., is 63 million gallons per day (MGD).

Wastewater is collected and flows to wastewater treatment facilities. Generally speaking, physical, chemical and/or biological treatment processes are used to separate soluble and insoluble solids contained in used water. The end products from wastewater treatment plants (WWTPs) are

[14] http://www.census.gov/popest/data/national/totals/2012/index.html
[15] Great Lakes-Upper Mississippi Board of State and Provincial Public Health and Environmental Managers, "Recommended Standards for Wastewater Facilities (Ten-State Standards)," 2004.

normally clean water and solids. Clean water flows back to a natural water source such as a river or ocean, but the solid end product is always a significant problem for WWTPs.

Four possible methods are introduced for a WWTP to handle solid end product including land application, high-end fertilizer, anaerobic digestion, and incineration. Solid end product must be stabilized or transformed to different products. It can be converted to Class B biosolids by lime stabilization and delivered to a land application field (farm, mine, or forest). It can be transformed to Class A biosolids through a composting process and sold as organic fertilizer. Biogas can be produced through an anaerobic digestion process and used as natural gas, further processed to produce compressed natural gas (CNG), and/or used to generate biogas-based electricity. Lastly, incineration is another option to dispose of solids and produce energy from heat. However, which option should be used to dispose of solid end product from WWTPs if environmental impacts and economic benefits are considered?

In this case, students assume the role a recently graduated, newly hired analyst named Janine at a renewable energy consulting firm in Washington, D.C. Her first assignment is to develop a proposal that they can pitch to the D.C. Water and Sewer Authority for a system to use wastewater to produce energy, which requires accounting for and synthesizing a multitude of economic and environmental considerations.

This case is designed for upper division undergraduate courses in environmental science/engineering or resource economics. It can also be modified for graduate courses as described in the **Suggested modifications for upper-level courses** section. The unmodified case study requires 3-3.5 hours to complete, with more time required for modifications. For 50-minute class sessions, the authors suggest using four class sessions to allow ample time for discussion.

Classroom management & blocks of analysis

Summary

- Several days before class, students are assigned readings that provide background information for the case study.
- At the beginning of class, the instructor introduces important information from the assigned readings for the case study that will be relevant for designing a solution (10 min).
- The instructor reviews the case study, and students read the student handout describing their assignment to prioritize the four types of solid management processes (10-15 min).
- Instructor describes the types of data required to perform this assignment (5-10 min).
- Students are divided into teams (4 people per team) and given two types of information, one at a time: economic considerations and environmental considerations (10 min).
- Students read and examine each type of data individually and develop a proposed solution based only on those considerations, which includes recommending a specific solid management process for the WWTP. Each team writes a summary of their recommendation for each factor

(economic or environmental) and presents it to the class (1 hr).

- Instructor reviews the recommendations, and the class discusses why/how this is a socio-environmental issue and requires synthesis (5-10 min).
- Teams consider the two factors in combination and develop final proposed solutions. Each team writes a short report summarizing their proposed solution. This should involve a discussion of which factors are most critical and how inclusion of multiple types of information changed their recommendation (30 min).
- Each team presents their final proposed solution (5 min per team).
- Class discusses and compares each team's recommendation. The instructor reviews the main conclusions of the case (10-15 min).

Estimated time: **3-3.5 hours**

Teaching the case

- Pre-class reading
  - U.S. EPA, *Biogas Recovery Systems*. http://www.epa.gov/agstar/anaerobic/ad101/index.html
  - U.S. EPA. (2012). Case Study Primer for Participant Discussion: Biodigesters and Biogas. Technology Market Summit.
  - U.S. EPA. (2011). Opportunities for Combined Heat and Power at Wastewater Treatment Facilities: Market Analysis and Lessons from the Field.
  - U.S. EPA. (2002). Land Application of Biosolids: http://www.epa.gov/oig/reports/2002/BIOSOLIDS_FINAL_REPORT.pdf
  - Heal, G. (2009). Reflections--The Economics of Renewable Energy in the United States. *Review of Environmental Economics and Policy*, *4*(1), 139–154.
  - Chittum, A., & Kaufman, N. (2011). Challenges facing combined heat and power today: A state-by-state assessment. http://www.uschpa.org/files/public/ie111.pdf.

- Pre-discussion
  Before beginning the case, the instructor should review the assigned readings and highlight the information that will be important for designing a solution in this case. The instructor should begin by discussing Heal (2009), which provides a high-level overview of the state of renewable energy in the U.S. and the challenges that such a system must meet in order to displace conventional energy sources (e.g. coal-fired power plants). The concepts of intermittency and capacity factors should be covered in detail. Next, the instructor should address some of the key questions surrounding anaerobic digesters and CHP systems:
  - What are some of the political, regulatory, and environmental concerns with solid waste

management?
- What is an anaerobic digester and what are the byproducts of anaerobic digestion?
- Why would a WWTP consider anaerobic digestion as a solid waste management option?
- How can a WWTP use biogas recovered from anaerobic digestion?
- What types of CHP systems are available, and what are the key differences?

- <u>The case study</u>

  Next, the instructor presents the case study scenario and the different solid waste management options available to the WWTP for consideration. The scenario, procedure, and solid end product management options of the student handout are distributed for the students to read on their own. After everyone has read the handout, the instructor formally presents the options. These options reflect the actual choices WWTPs make in the real world, and they represent a set of solutions with significant trade offs:
    - *Land application:* a relatively low-cost solution with well-documented political/environmental ramifications that must be considered.
    - *High-end fertilizer:* an improvement on land application from the standpoint of political/environmental concerns, but more costly.
    - *Anaerobic digestion:* a capital-intensive, expensive solution that requires complex oversight and long-term planning, but it has revenue potential and favorable environmental outcomes.
    - *Incineration:* historically, a widely-used and low-cost option in solid waste management, but now it has become a controversial political issue with potentially negative health effects for local communities.

  Then the instructor briefly discusses the types of data that might be relevant for a WWTP deciding on solid end product management. After the students discuss what information they'd *like* to have, the instructor introduces the factors they will examine in the form of fact sheets:
    - Economic considerations: investment costs, operation and maintenance costs, potential revenue, carbon credits and/or renewable energy credits (RECs), and political/regulatory concerns.
    - Environmental considerations: net carbon dioxide equivalent emissions, nutrients provided, energy consumption / energy result, odor problems

  The instructor divides the class up into groups of 4 students, and each group is given the *economic considerations* fact sheet to consider first. In the first 30 minutes, the students discuss this factor as a team and develop a recommendation for the WWTP that addresses the