Understanding the Environmental Trade-Offs of Wastewater Treatment Options:

An Introduction to The Life Cycle Assessment Approach

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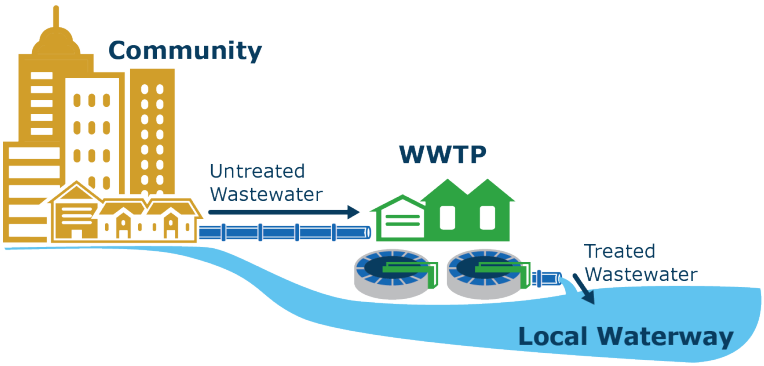
Introduction



When communities use water, they produce wastewater. In larger communities, sewer systems collect wastewater and convey it to wastewater treatment plants, which remove pollutants from the wastewater to protect the quality of local waterways. To keep wastewater treatment plants functioning well, communities must periodically make decisions on how to maintain or upgrade them.

These decisions can affect many aspects of the environment. Some effects are positive (i.e., environmental benefits), such as cleaner water for recreation and aquatic life. Other effects are negative (i.e., environmental impacts), such as increased energy demand for plant upgrades, leading to increased burning of fossil fuels that may harm public health and the environment.

When considering how to operate or upgrade its wastewater treatment plant, a community can use a *life cycle assessment (LCA)* to identify, quantify, and compare the environmental benefits and impacts of different options. An LCA may be especially useful in helping the community understand and evaluate trade-offs between environmental benefits such as water quality protection and environmental impacts such as reduced air quality and increased greenhouse gas emissions.

What Is a Life Cycle Assessment?

An LCA is a standardized method for evaluating the environmental impacts and benefits of a product or process over its full life cycle. An LCA helps people holistically understand the environmental outcomes of different options for manufacturing a product or building and operating a process in terms of their environmental trade-offs. For a product, this might include impacts from the extraction of raw materials and the production, use, and eventual disposal of the

product. An LCA of a process, like that used by a wastewater treatment plant, can be thought of as an LCA of all the smaller products needed to build and operate that process.

The Four Main Steps of an LCA

1. Define the goal and scope
2. Create a life cycle inventory (LCI)
3. Perform a life cycle impact assessment (LCIA)
4. Analyze and interpret the LCA results

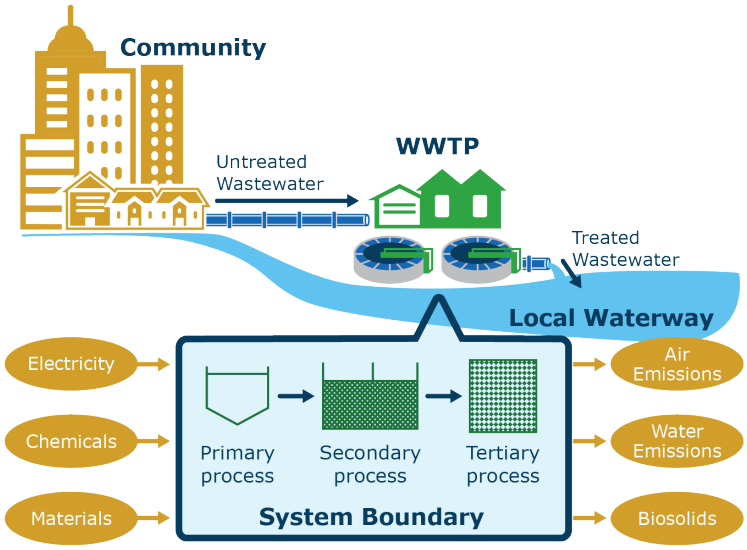
This handout describes each step of the LCA method. To show how each LCA step could be useful for decisions related to a community's wastewater treatment plant, we present a hypothetical example from an imaginary community called Valley City.

Valley City needs to upgrade its wastewater treatment plant. City leaders and residents care about water quality, but they also care about other aspects of the environment, including air quality, water quantity, and greenhouse gas emissions. Valley City leaders have decided to conduct an LCA to help the community examine options and determine which treatment alternative best balances water quality protection with other environmental goals.

Step 1: Define the Goal and Scope

First, we define the goal(s) of the study. Next, we establish a "system boundary"—the portions of the product or process that will be analyzed. This provides a common reference point for measuring inputs to that system (e.g., electricity and materials) and outputs (e.g., greenhouse gases and sludge) across options. Finally, we define a "functional unit"—the quantity of interest that goes through the system. For example, a common functional unit for a wastewater treatment plant is a gallon of treated wastewater. The functional unit serves as the basis for measuring inputs, outputs (e.g., emissions), and the environmental benefits and impacts across options.

The LCA system boundary of the Valley City wastewater treatment plant is around the three main wastewater treatment processes. The LCA will focus on the electricity, chemical, and material inputs and the air, water, and sludge outputs of these processes. The functional unit for the LCA is 1,000 gallons of treated wastewater.



Valley City's treatment plant LCA system boundary with inputs and outputs

Step 2: Create a Life Cycle Inventory

An LCI is a comprehensive list of inputs and outputs to and from the system across the entire life cycle of the product or process. Examples of inputs are raw materials, chemicals, and energy. Examples of outputs are releases of solid waste, air emissions, and water emissions.

For the Valley City wastewater treatment plant, the LCI includes electricity inputs for the existing plant and for each option under consideration, as shown in the example below. Other inputs and outputs are also documented in the LCI.

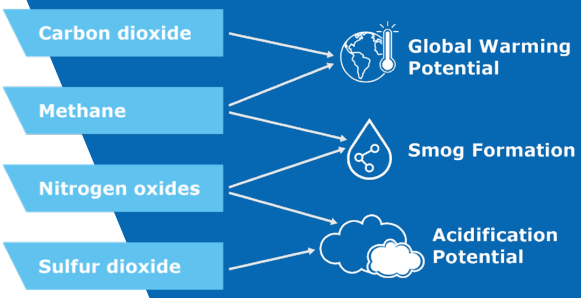
Valley City Plant LCA Options	Energy Use
Existing wastewater treatment plant	1.5 kWh/1,000 gallons
Upgrade Alternative 1	2.2 kWh/1,000 gallons
Upgrade Alternative 2	2.5 kWh/1,000 gallons
Upgrade Alternative 3	3.8 kWh/1,000 gallons

Step 3: Perform a Life Cycle Impact Assessment

To perform the LCIA, we group the inputs and outputs from the LCI (Step 2) and align them with several common LCA metrics, such as those listed to the right. For example, methane and carbon dioxide are two greenhouse gases (outputs) that contribute to the global warming metric. Next, the contribution of each gas is added up and expressed in terms of one single unit for that metric. For the global warming metric, the unit is "carbon dioxide equivalents." This process is repeated for all inputs and outputs for all LCA metrics.

Common LCA Metrics

- Water depletion
- Cumulative energy demand
- Eutrophication
- Global warming
- Fossil fuel depletion
- Acidification
- Smog formation
- Ecotoxicity
- Human health toxicity

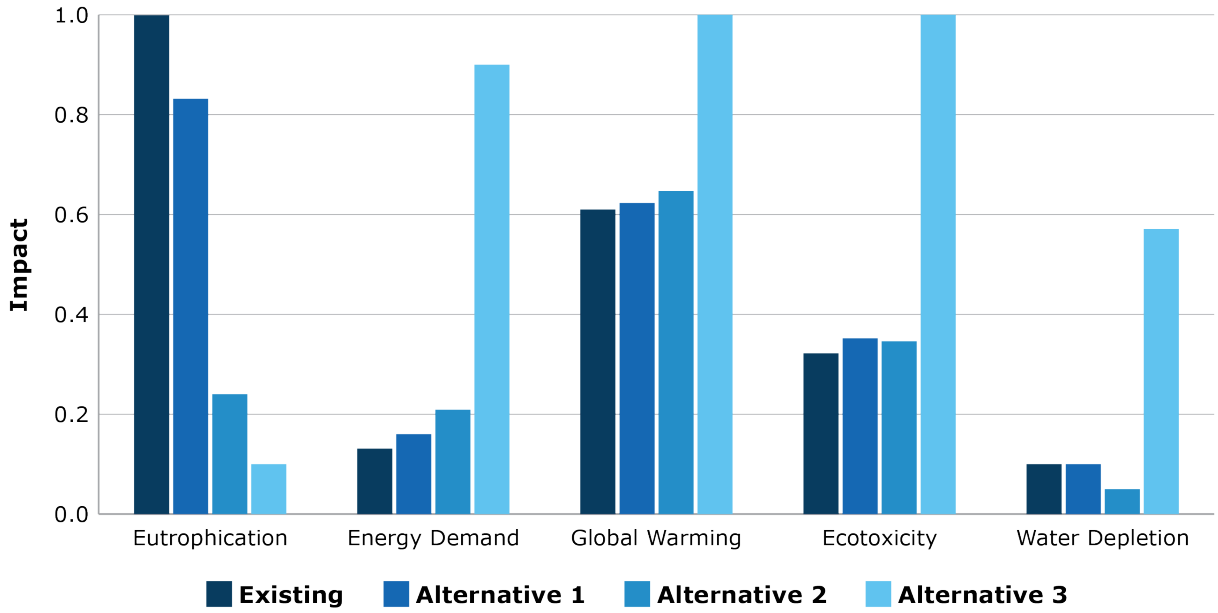


The LCIA for the Valley City wastewater treatment plant includes LCA metrics that focus on water and air quality, climate, and public health. The inputs and outputs are mapped to those metrics and combined. For example, the mapping of some air emissions (outputs) to their associated metrics is illustrated to the left.

Step 4: Analyze and Interpret the LCA Results

The last step is to analyze and interpret the LCA results. The data are shown in figures, graphs, and charts to help visualize the information and compare benefits and impacts of different alternatives in terms of each metric. The data are also examined in terms of limitations, the level of certainty and uncertainty, and their sensitivity to changes in the wastewater treatment plant. The findings on the potential environmental impacts, benefits, and trade-offs are then summarized and evaluated.

One of the charts in the Valley City LCA compares the results from five LCA metrics for the current treatment process and three upgrade options. The community can compare the possible environmental benefits of reducing water pollution (i.e., excessive algal growth) across the options, as well as possible environmental impacts (i.e., energy demand, global warming, ecotoxicity, water depletion) of each option at the same time.



Results of Valley City's LCA in terms of five different environmental metrics.

Using an LCA in Community Decision Making

LCAs are valuable analytical tools that decision-makers can use to understand environmental trade-offs and inform decisions for the good of their community. Community leaders can use LCA results as part of a larger decision-making process that incorporates public values and goals.

For More Information: [insert state or city contact, website, links here]