

Mechanical Engineering

Converting Washington Lignocellulosic Rich Urban Waste to Ethanol: Part 2, Process modeling and life cycle assessment.

Elliott Schmitt, Joyce Cooper, Rick Gustafson, Azra Vajzovic, and Renata Bura

Goal

To use LCA to evaluate the environmental burdens associated with the conversion of three lignocellulosic rich waste streams (Municipal Solid Waste (MSW), Mixed Waste Paper (MWP), and Yard Waste) to ethanol fuel as a waste management option for the State, including all major unit processes within the life cycle.

Approach

Life Cycle Assessment (LCA) is a protocol standardized within ISO 14040 that is used to,

- quantify environmental, social, and economic impacts of emerging technology within the life cycle of a defined system,
- it extends from material and energy acquisition and processing, through system manufacturing/construction, use/maintenance, and ultimate retirement.

LCA has four main phases:

- Goal & Scope Definition**, outlines the objectives of the study, the intended audience, the systems and subsystems boundaries, a data collection and quality plan, and critical review
- Inventory Analysis**, a system model is built according to the previous phase and includes: the construction of a flow model, data collection, and calculations of resource use and pollutant emissions
- Impact Assessment**, is used to indicate the impacts of the environmental loads quantified in the inventory analysis
- Interpretation**, the interpretation phase assesses the overall context of the LCA and is used to provide recommendations

Table 1: Select inventory emissions and impact categories

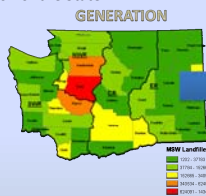
photochemical smog	emissions of CH ₄ , NO _x , CO, & NMVOCs (as NO _x equiv)
PM emissions	Sum of particulate matter emissions (as tons PM)

photochemical smog	emissions of CH ₄ , NO _x , CO, & NMVOCs (as NO _x equiv)
PM emissions	Sum of particulate matter emissions (as tons PM)

photochemical smog	emissions of CH ₄ , NO _x , CO, & NMVOCs (as NO _x equiv)
PM emissions	Sum of particulate matter emissions (as tons PM)

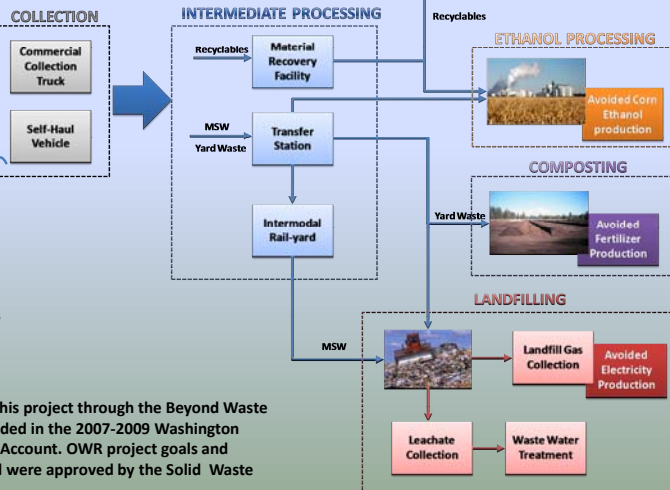
System Flow Diagram

1. The largest amount of waste generation occurs in the Western portion of the State.



2. LCI model for collection includes both commercial collection vehicles and self-haul to intermediate processing facility.

3. Intermediate processing includes LCI data for MRF, Transfer Stations, and Intermodal rail-yards.



4. LCI module for recycling mixed waste paper includes: option for recycled pulp type (ONP, OCC, Tissue,...etc), option for virgin pulp avoidance (TMP, Chemical, or NSSC), forestry operations, fuel and electricity production.

5. The biorefinery model was based off ASPEN Plus model. LCI data includes the production of sulfuric acid, lime, enzymes, ammonia phosphate, corn steep liquor, fuel, and electricity.

6. The LCI model for composting is based on LCI data for a windrow composting facility with a 110,000 MT per year capacity.

7. Landfill LCI model includes equipment operations, landfill gas collection and emissions, leachate collection, waste water treatment and fuel production.

Table 2: Comparative scenarios and functional unit

Scenario	Functional Unit	Percent of Waste Sent to Process			
		Landfill	Recycle	Compost	Ethanol
Scenario 1, base case	5,763,904 MT	84%	6%	11%	0%
Scenario 2; All waste to ethanol	5,763,904 MT	0%	0%	0%	100%
Scenario 3; All MSW to ethanol	5,763,904 MT	0%	6%	11%	84%
Scenario 4; All MWP to ethanol	5,763,904 MT	84%	0%	11%	6%
Scenario 5; All YW to ethanol	5,763,904 MT	84%	6%	0%	11%
Scenario 6; All waste to landfill	5,763,904 MT	100%	0%	0%	0%

Results

Figure 1: Normalized impact results for the six scenarios

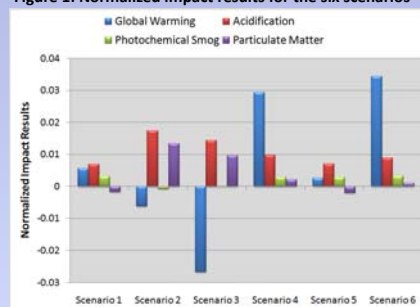


Table 3: Percent change in impacts from baseline

	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Energy Consumption	-644%	-763%	237%	-118%	305%
Global Warming	-210%	-574%	420%	-56%	509%
Acidification	153%	109%	42%	2%	30%
Photochemical Smog	-121%	-100%	-10%	-12%	2%
Particulate Matter	860%	650%	224%	-13%	153%

Discussion

Converting MSW to ethanol has significant benefits in terms of reducing energy consumption, climate change, and photochemical smog. It may not offer benefits in terms of acidification and particulate matter formation.

Acknowledgments

The Washington State Department of Ecology provided funding for this project through the Beyond Waste Organics to Resources (OWR) project. These funds were provided in the 2007-2009 Washington State budget from the Waste Reduction Recycling and Litter Control Account. OWR project goals and objectives were developed by the Beyond Waste Organics team, and were approved by the Solid Waste and Financial Assistance Program.