Life Cycle Assessment of a Willow Agriculture and Biomass Energy Conversion System: Methodology and Preliminary Results

Martin C. Heller*[a], Gregory A. Keoleian[a], Timothy A. Volk[b], Margaret K. Mann[c]
[a]Center for Sustainable Systems, University of Michigan,
430 E. University St., Ann Arbor, MI 48109-1115; Fax: 734-647-5841; mcheller@umich.edu
[b]SUNY College of Environmental Science and Forestry, Syracuse, NY
[c]National Renewable Energy Laboratory, Golden, CO

Short rotation woody crops are emerging as a renewable energy option with potential to reduce greenhouse gas and other environmental emissions while providing stable economic markets for rural America. In New York, the Salix Consortium is facilitating the commercialization of willow biomass crops as a renewable feedstock for electricity generation. Overall sustainability of this bioenergy system, however, is dependent on its environmental performance, in addition to economic and social aspects. Evaluation of complete systems must be conducted to assure that developments do move towards sustainability and environmental soundness. Life Cycle Assessment provides a valuable tool for carrying out this type of holistic evaluation.

Life Cycle Assessment (LCA) is a methodology for evaluating the resource consumption and environmental burdens associated with a product, process, or activity. This evaluation takes into account the entire life cycle of the product or function: extraction and processing of resources; manufacture, transport, and distribution; use, reuse, and maintenance; recycling; and final disposal. LCA is composed of three main analytical stages. The energy and raw materials used, as well as the emissions and wastes released, are identified and quantified. The potential environmental and human health impacts of these inventoried flows of energy and materials are then assessed. Finally, the opportunities available to bring about improvements in the environmental impacts are considered.

Objectives

A thorough LCA of the willow to electricity system will be conducted. Such an evaluation of the Salix Consortium demonstration project is important at this early state in order to compare performance with other biomass demonstrations, promote the project, and assess areas of necessary research and development within the project. The specific objectives of the LCA study include: providing system performance indicators such as overall system energy efficiency and net energy generation per hectare of agricultural production; quantifying CO_2 mass balance closure of the entire willow to electricity system; quantifying other environmental emissions (air, water, and soil) from agricultural, transportation, and electricity generation portions of the system; modeling and evaluating system alternatives such as agricultural management decisions and energy conversion alternatives; and benchmarking the environmental performance of the willow to electricity system through comparison with other LCA studies of biomass systems and other sources of electricity production.

Methodology

The system under consideration in this study includes both the agricultural production of willow biomass and the conversion of that biomass to electricity. Figure 1 shows a general schematic of the system boundary. In LCA methodology, inputs and outputs are quantified in reference to a functional unit. In addition to the obvious functional unit of *one kWh of generated electricity*, the LCA will also be conducted using a functional unit of *one hectare of agricultural produce during one year*. The second functional unit will allow for easy comparisons of land area demand between different bioenergy systems as well as with alternative uses of the land Energy and material requirements, atmospheric emissions, waterborne emissions, and solid wastes will be accounted for throughout the stages of raw material acquisition, manufacturing of ancillary materials and equipment, agricultural production of biomass,

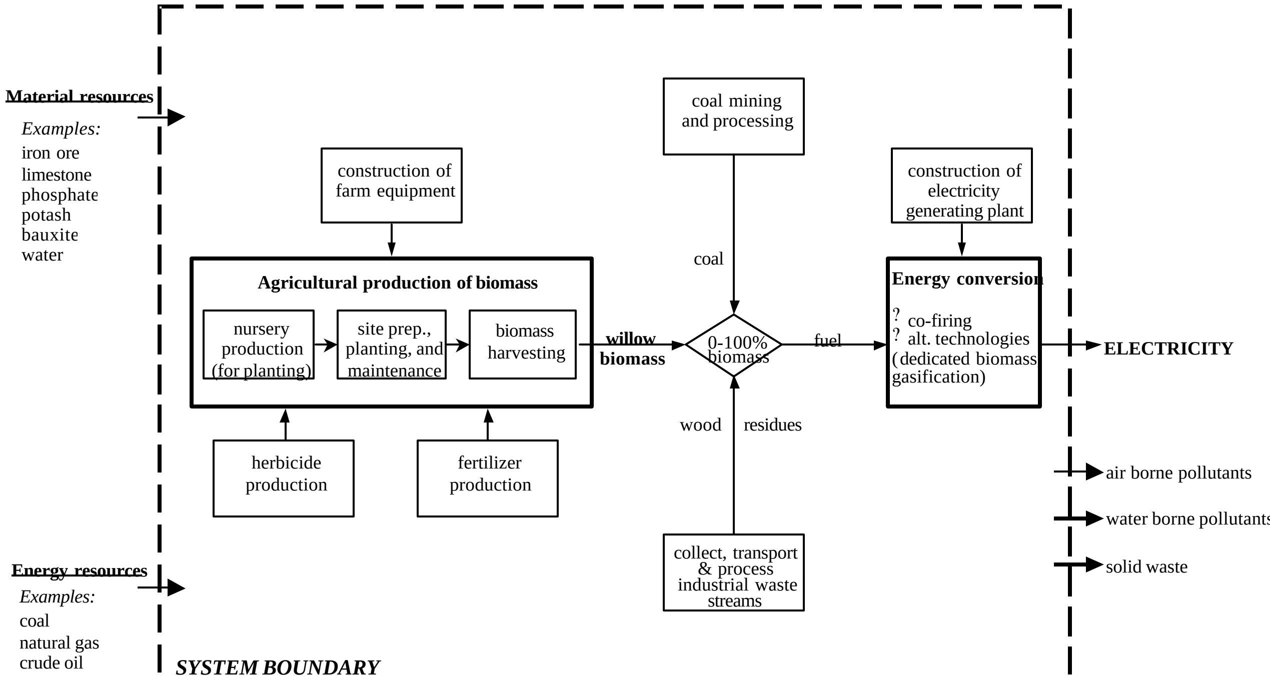

Figure 1 Willow biomass to electricity system boundary schematic

transportation, energy conversion, and disposal of wastes. Data on willow cuttings production, field site preparation, willow planting, and biomass harvesting will come directly from production-scale activities of the Salix Consortium. These data will be complemented with existing databases for process modules such as raw material extraction and transportation fuel combustion. Modeling efforts will be assisted by the use of life cycle software developed by Ecobalance, Inc. A wood/coal co-firing life cycle model developed by researchers at NREL will be used in the energy conversion stage, with supplementary data from test co-firing at the Dunkirk plant in New York.

The life cycle model will first be built around a base case scenario which best replicates the current and planned practices of the Salix Consortium project (limited herbicide and fertilizer use, average transportation distances, 10% by energy co-firing of biomass). A number of alternative scenarios will then be considered. These include varying the biomass co-firing ratio, alternative energy conversion methods such as dedicated a biomass boiler and a gasification system, and various agricultural management choices.

Preliminary results of the life cycle assessment will be presented, using field site preparation data from the previous three years combined with representative data for the co-firing of wood and coal.