Optimum biomass power plant size in western Canada

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Using biomass as a power plant fuel displaces fossil fuel and hence contributes to a reduction in net GHG emissions to the atmosphere. Net CO_2 emissions are reduced because the energy source is renewable and the fuel is CO_2 neutral. In addition, when compared to the alternative of coal or natural gas, methane releases to atmosphere are reduced. Biomass usage is a major component of a strategy of dealing with global warming.

One key problem with biomass usage is the sparseness of reliable cost data that limits an evaluation of its affordability and cost effectiveness. Researchers around the world are looking at specific opportunities to use biomass as a fuel, and are quantifying the overall cost of such projects and the cost per unit of net carbon reduction.

This paper identifies two potential sources of biomass fuel in Western Canada as candidates for evaluation, based on their abundance: the boreal forest and agricultural residues.

Biomass power fuel sources usually have a significantly lower energy density (MJ/ha) than coal based plants. For power generation plants located at the fuel source (e.g. a “mine mouth” coal fired power plant or a wood based biomass power plant located in the forest), transportation costs are significantly higher for biomass-based projects because of the longer haul distance. The “footprint”, i.e. the area of land required to sustain a given size of power generation project, is far higher for biomass plants. These values are documented for boreal forest and agricultural residue material in Western Canada compared to coal reserves that are surface mined to support mine mouth power generation plants.

For biomass power projects there is an inherent economic tradeoff that sets optimum plant size. Increased size of power plant leads to a reduction in the net capital investment per MW, i.e. there is an economy of scale that reduces the per unit capital cost as size increases. However, there is an offsetting increase in the delivered cost of fuel, since larger size means longer transportation distances for the biomass fuel, which is often of low physical and energy density. Note that these factors do not arise for many fossil fuel plants. In Western Canada, for instance, coal energy densities are so high that transportation cost of fuel is not a significant element of overall cost, and optimum plant size is set by technological, environmental or social limitations.

This paper identifies the optimum plant size for several cases that involve the usage of boreal forests and agricultural residues in Western Canada in direct combustion steam boilers for power generation. Two cases are evaluated for the boreal forest. The first is the use of forest residues (branches and tops from harvesting operations that are feeding tree trunks to pulp and lumber operations), plus brush and litter that would be simultaneously recovered. In current operations, whole trees are typically cut and skidded to a roadside where they are delimbed and cut to economic length. Branches and tops are usually burnt at the roadside. The first case would be to chip this material plus recovered brush and litter as a fuel source. The second case for boreal forest biomass uses all of the biomass from a stand, i.e. the whole forest would be harvested for fuel.

For each of the boreal forest cases, fuel delivery is based on field chipping and truck transport; alternate transportation schemes including pipeline delivery will be evaluated in the future. Cost estimates include harvesting, fuel preparation and transportation, power generation and transmission to market, ash disposal, and replanting and nutrient balance. Replanting alternatives include natural replanting of native species and human replanting of hybrid species selected to support future power generation.

Two cases are also evaluated for agricultural residues: grain straw (wheat, oat, barley) and corn stalks and hulls. Fuel economics are based on single pass collection (retrieving the stalk material at the same time that the grain is harvested) and storage along the roadside of a field. The biomass is truck hauled to the plant site (again, pipelining of fuel will be evaluated in the future). Cost estimates include harvesting, fuel transportation, fuel preparation (at plant site), power generation and transmission, ash disposal, and nutrient balance.

The optimum size of power generation plant is determined from minimum delivered power cost over the life cycle of the plant. The cost effectiveness of GHG abatement is estimated by comparison with a coal based surface mining plant.

The paper concludes with an assessment of those factors which have a high impact on the determination of economic size, and an assessment of risk and uncertainty in using these fuels.