Invasives to Energy

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We live in a fossil fuel based economy. This means that most of the things that we do, including traveling, heating our homes, turning on our lights, producing and shipping food, and using a computer relies on energy that comes from fuels like coal, oil, and natural gas. The energy in fossil fuels really does come from fossils—mostly from partially-decomposed plants that lived during the Carboniferous period 300 million years ago. Back then, the earth was warmer and moister, and there were vast swamps filled with plants that were the ancestors of today’s horsetails and ferns. The plants grew quickly and fell into the water when they died. Because they were submerged, they did not decompose very quickly, accumulating thick layers of dead vegetation over thousands of years. These layers were buried in sediment and over time, pressure and heat changed them into the hydrocarbon-rich fossils that we use today. All of the energy contained in coal and oil originally came from the sun and was captured by plants through photosynthesis.

Over the past few decades, agronomists we have been developing biofuel crops such as miscanthus and switchgrass that can be grown on marginal cropland and used as an energy source. However, many of these crops are dependent on inputs such as fertilizer, and they often do not provide as good of wildlife habitat as the old-fields they are replacing.

Some invasive plant species share many of the traits that characterize biofuel crops: they are fast-growing, and tend to grow in monoculture, often on a large scale. Because invasive plants do not need fertilizers or other inputs, they may have the potential to be used as a biofuel feedstock source. Our lab at Loyola University Chicago has been investigating a suite of invasive plant species from the Chicago region to see whether they have the potential to be used as biofuel feedstock.

There are many ways to convert biomass to a usable energy source. We have been focusing on two energy conversion strategies:

**Direct combustion**

The plant tissue is dried, compressed into a density that can be more effectively shipped and handled, and it is burned in a small stove or furnace to heat a building, or it can be burned in a retrofitted coal-fired power plant to create steam that spins a turbine and makes electricity. Many invasive species can be used for direct combustion. Woody plants have the most potential to be used in this way because they can be easily dried after harvest, which is a pre-requisite for direct combustion. Woody plants also have lower ash content, which is important for use in some types of furnaces. We found that cattail and phragmites made good pellets when they were dried beforehand, but to produce pellets on a commercially viable scale a significant amount of drying would be required.
Figure 1. (Clockwise from top left) 1) The Softrak harvester cuts phragmites in Mentor Marsh to be used in Quasar’s methane producing anaerobic digester. 2) Phragmites australis are an abundant wetland invasive plant in the Great Lakes region and represent a potential source of biomass for energy production. 3) Research associate Brendan Carson and field tech Logan Palowski prepare the hammer mill and pelletizer for Typha pellet production in Cheboygan. 4) Hybrid cattail (Typha × glauca), is another fast growing and abundant wetland invasive that could represent a substantial energy source.
Anaerobic digestion

When carbon is broken down by microbes in the absence of oxygen, methane has is produced. This methane is the same kind of natural gas that is used for home heating and cooking today, and it can be burned in a generator to produce electricity. Many invasive plants, especially non-woody species such as grasses, cattails, and forbs, are well suited for anaerobic digestion. The plant material does not need to be dried out prior to digestion, which can save on processing time and effort. However, there are not a lot of anaerobic digesters set up that can readily accept plants that are not finely ground, and at this point, most digestion facilities are run as a waste disposal service. This means that they are paid to accept organic waste rather than paying for a fuel source. This will likely continue to be the case until energy pricing reflects the true costs of fossil fuels.

At this point, the cost of transporting biomass appears to be the largest barrier to using invasive plant biomass as an economically viable energy source. Because sites that are a priority for restoration are often located far from facilities that can use them for energy production, we have found that shipping harvested invasive plant materials on an energetically meaningful scale is often cost-prohibitive. However, if invasive plant biomass can be condensed or fully processed at the site of harvesting using a mobile production unit, the economics and energetics would become more favorable.
Figure 3. Total energy production potential in Mega Joules ($10^6$ joules) of *Phalaris arundinacea*, *Typha × glauca*, and *Phragmites australis* from combustion and methane production. Black bars show potential energy using combustion and gray bars show potential energy gain using methane production.

The following is an excerpt from a report on our work at Horicon Marsh, Wisconsin, which was funded by the Wisconsin Department of Natural Resources. The report evaluates the energetics and economics of harvesting cattails at Horicon and shipping them to UW Oshkosh’s anaerobic digestion facility:

We are still awaiting a report from the anaerobic digestion facility at UW Oshkosh that will include their assessment of the cattail biomass’ usefulness as a feedstock for anaerobic digestion. We over four days, we removed 36.7 tons of wet biomass. Using data we have from laboratory testing, this 36.7 tons wet mass would equate to about 74,037,000 KJ of energy once it is converted to methane. The real amount realized from the UW Oshkosh digester is probably less than that, because the digestion efficiency in their facility is unlikely to achieve laboratory optimum.

To harvest the material, the Softrak used 30 gallons of diesel, which is the equivalent of 4,099,000 KJ of energy. Transporting the material to UW Oshkosh’s facility took 160 gallons of diesel, the equivalent of 21,861,000 KJ of energy. So the energy used in harvesting the biomass and getting it to the facility in Oshkosh totaled to ~25,500,000 KJ. This is the equivalent to 35% of the energy that was gained, or a 285% gain.

The net energy gained was 48,000,000 KJ, or 13,355 kilowatt-hours. The average cost of energy in Wisconsin in 2011 was reported as 13 cents per kilowatt-hour. Thus, the monetary value of the energy produced was $1,736. The base monetary costs of this operation included operator salaries ($1,500), harvester maintenance costs, the cost of shipping material to Oshkosh ($4,000), and the tipping fee required by the digester ($2,000), totaling to $7,500.
Thus while the energy efficiency of harvesting biomass at Horicon Marsh and transporting it to Oshkosh for anaerobic digestion is substantially positive, the economic incentives to do so are not favorable on the scale at which we were operating. However, the large net energy potential means that there could be opportunities in the future. If the material could be compressed prior to shipping, or if a more effective shipping method were devised, it would substantially lower the cost and increase the relative energy gain. Alternatively, if a digester were built closer to Horicon Marsh, it would substantially improve the potential for economic viability. Finally, if there was not a tipping fee associated with the use of cattail biomass it would improve the viability of harvesting for energy production.