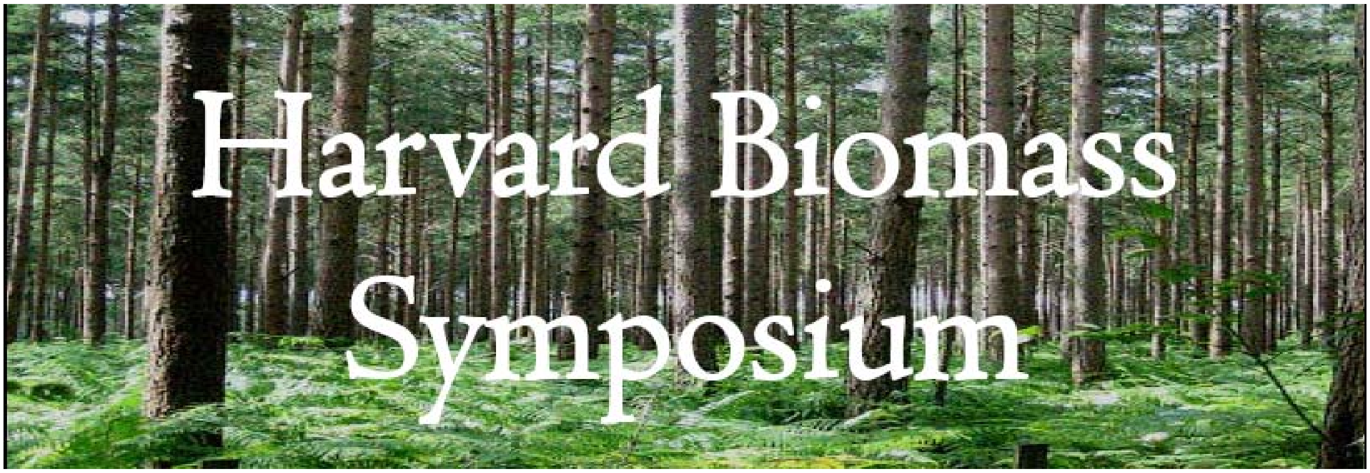

October 5, 2007

Hosted by the Harvard Green Campus Initiative

Leith Sharp, Director, Harvard Green Campus Initiative

Leith began by framing concerns about GHG reductions and the importance of conservation and renewable energy on campus. She talked about the importance of large renewables on campus, especially as Harvard's Allston campus comes online.

Leith suggested that wood is to the northeast as oil is to the Middle East. Biomass can grow quickly here, and it's important to look at biomass as a tool to drive down GHG emissions in our region since it's a local resource.

Ben Urquhart, Biomass Specialist, MA Department of Conservation & Recreation (DCR)

Ben provides biomass technical assistance to building owners and managers in Massachusetts. The DCR is interested in biomass energy because it can improve forest health and can create a local industry for low value wood.

Biomass is defined as any biological material that can be burned to produce energy, including wood, animal waste, etc. It's the most common renewable energy in the world — 77% of all renewable energy is biomass. In the U.S., utilization of solid biomass has increased 1.8% per year, while liquid biofuel use has increased 84% annually.

Wood is a good fuel option for social, environmental, and economic reasons. It is low in sulfur, which causes acid rain; it is generally considered to have negligible greenhouse gas emissions; and, if trees are regrown, it is considered carbon neutral over its life cycle.

Wood smoke can be a major contributor to air pollution in MA — especially NOx and particulates — but modern stoves and boilers can be very efficient and low emitting if combined with proper control measures.

Social and economic benefits of biomass include energy independence, direct local economic benefit, long term price stability, and cheaper prices per MMBtu. Natural gas is price competitive with biomass, but wood has been cheaper per MMBtu since 1970. Historically, electricity is the most expensive fuel, followed by oil, then natural gas, then biomass. Currently, wood chips are the cheapest fuel per MMBtu available.

Can biomass work at Harvard? Successful implementation of biomass will require careful analysis of cost, emissions regulations, and supply options. Some factors to consider include size (MMBtu demand), current systems retrofit, fuel type and supply (cord wood, bio bricks, pellets, etc.), method of combustion, and other possibilities (direct feed, volatilized, fluidized bed, gasification, pyrolysis, or cofiring).

Where is the supply of biomass? Sources include forest management, municipal residues, primary wood producers (mill residues), secondary wood products (dry sawdust), pellets, construction and demolition waste, waste wood (pallets), or paper cubes.

MA has 3 million acres of forest that are more stocked than they have been for years. Experts estimate that 2-4.5 million tons of wood can be used annually (less than 0.5 million tons of this figure come from the forest; the rest is other sources like mill residues). No one exactly knows how much supply exists. Currently, most of Massachusetts' wood goes to Canada.

Capital cost for a biomass system is definitely higher than conventional options. The typical simple payback is around 10 years, but some systems can have shorter paybacks. Grants and low interest loans can help reduce those payback periods. However, no state assistance is likely to be available except for biomass cogenerations.

The Cooley Dickinson Hospital in Northampton has had a biomass system for over 20 years; wood fuel is stored in the hospital basement. They save $1,000 per day and recently added a second 80 kW combined heat and power (CHP) system.

Ben currently works with the MA Sustainable Forests Bioenergy Initiative, which is funded by the Department of Energy and the Massachusetts Technology Collaborative to improve biomass options in the state. The Initiative researches forest health implications, infrastructure questions, and economic development and works to improve the MA energy mix and fulfill RPS and climate protection commitments. Grants websites: www.rurdev.usda.gov and http://www.mtpc.org/
More info: www.biomasscenter.org, www.nrbp.org, www.mass.gov/doer, Ben.Urquhart@state.ma.us.

Questions:

1. Where is the DEP in terms of biomass regulations? What are the emissions issues and where does the DEP fit in? MA is still figuring out what to think of wood energy. It is so new that no one knows what to put on the books.

2. Cambridge is in a non-attainment area for NOx, so what are our options for using biomass? Ben is trying to get all of the state agencies at one table to figure this out. Within 1 to 2 years we should have an answer. (A representative from DOER added that any biomass plant in MA needs a permit from the DEP, and the DOER is working with them to set specific emission levels to be met. These are limits on DOER's website.)

3. How far do you draw your circle around what is considered carbon neutral? If you are producing a wood product from a forest in a way that does not exceed forest growth, then it is considered neutral. Regarding upstream impacts such as transportation — some people consider these to be negligible. A recent report from the NREL lab on the life cycle of electricity generation found that the GHG benefits of biomass offset the fossil fuel costs.

4. What kind of technologies exist for emissions reductions? Multi cyclones, large bag houses, catalytic converters for NOx and particulates. Efficiencies are much higher than in 70s and 80s, for example, emission reduction efficiencies were 35% in 70s but 70% today.

5. Are there long term issues of forest soil depletion? Minnesota has draft recommendations of techniques for biomass harvesting that do not deplete the soil. Biomass harvesting removes a small percentage of total nutrients of the system. Ben is looking for an answer to how much of the forest can be removed without damaging it. Accumulated leafy debris would make a significant contribution to soil nutrient and carbon levels.

6. What does the estimate of 2-4.5 million tons of available wood in MA per year include? This includes waste wood, sawmill waste, and secondary residues. Forest waste alone would be less that 0.5 million tons per year on a sustainable basis, and even this figure depends on land attitudes, parcel size, wildlife habitat, etc. Remember that wood is a regional resource, and our wood usually goes to Canada. There's a lot of waste wood in MA, and there are questions of what should be legal to burn and what shouldn't.

7. Can we use gasification in an urban setting by processing the biomass elsewhere and bringing the gas in? A UMass recently professor found a microbe that converts cellulose to ethanol, which might make this possible. Existing technologies include gasification or pyrolysis (making liquid or gaseous fuel for burning in a more traditional system), and fermentation to make ethanol. Pyrolysis is close to being commercial, but it's not there yet. Only a few gasification facilities exist, and it would be great for Harvard to do a demonstration project for either technology.

8. What is the minimum scale of those technologies? The smallest one he knows of is in Fitchburg, MA and they use 6-7 tons of wood per week and make a bio-oil. He doesn't think there is a minimum size.

Rob Rizzo, Director of Facilities Administration, Mount Wachusett Community College (MWCC)

Regarding the sustainable harvesting of forests discussed earlier: Finland has over 25 years of extensive research on nutrient cycling, and they have found that needles on the ground leave enough nutrients to maintain even fragile soils.

Harvard already uses biomass; the Harvard Forest's main campus is heated with wood (4 foot logs are carried into basement and put into converted coal boiler), but it is not an efficient system.

MWCC is a community college, and renewable energy is one of the tools that they use to keep costs down for students (energy costs are partially paid for by students' tuition). They have many types of renewable energy on campus including wind, solar, and biomass. Students can take classes in renewable energy and use the college as a case study.

Wind: MWCC is committed to having wind on campus. The College received a $10,000 grant and used it to purchase an anemometer from Second Wind in Somerville, MA. The anemometer has been up for a year and a half, and MWCC just hired a consultant to begin the feasibility analysis. The school has a good location — 1,200 feet in elevation and has open wind. They are looking to install a 1 MW system.

Solar: Their installation has been working for 20 years and is still working well — output hasn't decreased much. In March 2006, they conducted a roof survey to see where they can put more solar PV. They want to install 100 kW. In MA, five state colleges and five jails will be installing PV. MWCC will finance their solar system with a clean renewable energy bond (CREB) from the IRS (15 year, 0% interest) and MTC grants. The budget is $870,000, the MTC grant is $560,000, and the CREB is $310,000. Loan repayment will be $20,667 per year for 15 years, and avoided electrical costs & REC savings is $24,069 per year.

Heating plant: MWCC converted an all electric resistance heating system (built in the 1970s) to a closed loop hydronic system using biomass feedstock. It saves the College $300,000 per year in heating costs.

Research: They looked at many alternatives – including #2 fuel oil, #6 fuel oil, and biomass.
They also looked at the biomass supply issue, especially price volatility. They found that biomass's prices have remained stable over time.

Partners on the biomass project include: MA Division of Capital Asset Management; NORESCO; National Grid; MA DEP; DOE; CONEG, etc.

The system started up in December 2002 and consists of a closed loop, two pipe hydronic system — one pipe supplies hot water (190 degrees F), one returns it (170 degrees F) to 3 buildings. The central plant is an 8 MMBtu combustion unit made by Messersmith Inc. (from Michigan) and a Hurst fire tube boiler (heat exchanger). The plant has 85-100 tons of chip storage. 85 tons is approximately four days worth of supply, and this takes up 10,000 cubic ft. (For reference, a tractor trailer truck can hold 25 tons). MWCC uses 1,200 tons of wood chips annually. The feedstock is green hardwood sawmill residue chips, which is typical of northeast biomass supply. MWCC has a baghouse for emission control. Before using the baghouse, the college used a multicyclone machine where heavy emissions drop out of the air currents, but it didn't work well. MWCC's air permit does not allow visible smoke.

They had to retrofit the entire campus (450,000 sq ft) to be able to receive hot water heating and had to build a new power plant, biomass storage facility, conveyance, and combustion system. Simplicity when conveying wood chips is very important. MWCC also uses a high efficiency Cleaver Brooks #2 oil boiler (325 bhp) for shoulder months. The turn down ratio of wood is 10 to 1, but these systems like to run full throttle. So they use 10,000 gallons of #2 oil per year in the early fall and late spring. They also use process controls because it was important to convince decision makers that the system wouldn't require a lot of staffing. They also integrated the system with the existing digitally controlled Johnsons Controls energy management system.

For distribution, super insulated pipe is buried underground to maintain the 190 temperatures; they don't see snow melt over it, so the insulation must be working. It is possible to send hot water up to 10 km away (as in Finland) with virtually no heat loss. Montpelier, VT has biomass district heating, and downtown St Paul, MN has biomass cogen and district heating.

Prices for biomass are $3/mmbtu for chips. In the first year, MWCC paid $264,000 for chips and saved $275,000. MWCC used a performance contractor, NORESCO, to get the capital to build the plant. During the contract, NORESCO assumes the risk and MWCC only pays only utility bills (i.e., MWCC does not make payments towards the capital cost of the system). After the contract, MWCC will get all the savings from the project. MWCC hired NORESCO for a ten year contract and have a guaranteed energy price. When they started the contract electricity cost 4 cents per kWh — Rob doesn't know what the College would have done if the electric resistance heating system had still been in place now that electricity costs 14 cents per kWh.

MWCC also hosts a biomass cogeneration research project that studies downdraft gasification with a BioMax 50 cogen system made by Community Power Corp. Partners on this project include USDOE, NREL, and the USDA Forest Products Lab. This project cost $1.2 million.

Downdraft gasification is the thermal decomposition of organic matter in an oxygen deficient atmosphere, which produces combustible gases, tars, water, and charcoal. To do this, you take biomass and a little air, feed a chamber from the top, superheat the chamber to 1100 C (with only 1/3 of air needed for combustion). This produces char, ash, and a producer gas (50% N_2; the rest is H_2, CO, and CO_2) which can be burned to make power. They hope to run the system 24/6 with no additional staffing. Electricity from this unit is fed into the campus grid, so that if it goes down, no one building loses power. The efficiency of the system is still unknown.

To test the cogen unit, MWCC uses CA air emission standards. NOx is 8% below CA standard, CO is 99% below, and THC is 97% below. In another six months, this research project will be done. MWCC will then allow any other researchers to use the machinery to test it.

Mike Moser, Assistant Director, Middlebury College Office of Facilities Services

Middlebury College has a 1912 vintage central heating plant that had to be updated. It did not have good reliability and would soon be unable to meet peak demand. They broke ground in early October, 2007 on a biomass steam plant, which will come online in 2008. The project was started because of a student led GHG reduction initiative that showed that #6 fuel oil was the worst GHG offender on Middlebury's campus.

The Middlebury Student Initiative defined a carbon reduction goal; conducted a fuel availability study; assessed the environmental impacts of transporting wood to campus; explored which technology to use, and looked at cost, CHP options, location of storage, and operating cost.

Mike's Initiative studied steam plant peak capacity, thought about location and appearance of the new plant, and conducted an equipment reliability assessment.

The Middlebury Board of Trustees endorsed a carbon reduction initiative, which set a GHG reduction goal of 8% below 1990 levels by 2012. This is equivalent to a 12,250 MTCDE reduction per year.

Supply questions that Middlebury explored were: is there enough wood available locally, where will it come from, who will supply it, what are the harvesting impacts, what are the combustion impacts, will Middlebury's use affect the Wood For Schools program?

Finding a "green" (carbon neutral) chip was very important to Middlebury. They looked for a wood chip that was sustainably grown, harvested, processed, and delivered to the plant. It took 6 months to find and assess the real impact of the switch to wood, and Middlebury worked with the Vermont Family Forest, FSC, SFI (wood for schools), and Biomass Energy Resource Center.

Middlebury decided to try to grow their own wood source and planted a 9 acre test plot of willow plants with a SUNY professor's help (see www.esf.edu/willow or *Willow Biomass Producer's Handbook* for more information). Willow's yield is 28-30 tons/acre on a 3 year rotation. The willow plots are experimental, so Middlebury also secured a 3 year contract with a wood chip supplier, and are working with a local green feed distributor to make corn pellets. Wood pellets were deemed too expensive. Middlebury addressed the concern of reliability by locking into a 3 year contract and by creating a plant that can burn a variety of wood chip types.

The Middlebury plant will use a ChipTec B series gasifier and Johnson fire tube boiler. This system can control temperature, airflow, and oxygen in the gasification chamber. The wood chip pile gasifies and then goes straight to a fire tube to make 250 lbs of steam. For emissions controls, they use a cyclone separator and baghouse. Particulate emissions on their air permit are less than the emission permitted from the new oil boiler. NOx wasn't a consideration at all for them. CO is 150 ppm.

Middlebury also had to consider where to locate the new biomass plant, since the original heating plant is in the middle of the campus. They looked at many options, none of which were ideal, and decided to keep the biomass plant close to the original plant because of the steam distribution system that was already in place. The biomass plant will run 350 days/year (the down time is used for cleaning and maintenance). The plant is permitted to consume 24,500 tons by permit, but they do not expect to use this much wood. Because the biomass system coordinates with all existing plant facilities, they did not need to increase man power. The existing steam plant uses steam to cogenerate 25% of current campus electric consumption (1.5 MW) by backpressure turbines; the biomass system will not alter this figure.

The Middlebury biomass plant is rated at 30 MMBtu; this system requires 150 tons of storage capacity, (15,000 cubic feet of storage, which goes 20 feet underground). The plant will use 60-70 tons per day, so only two days of fuel can be stored onsite. Three trucks deliver chips per day. Because only 2 days of fuel can be stored, biomass was not a realistic option for Middlebury's peak capacity.

Middlebury spent 18 months researching their options; they created a matrix to pick the location, technology, fuel supply, staffing, etc. They decided that 1) biomass is not feasible for peak demand and 2) relocating the plant is not feasible. Their ultimate recommendation was to replace an existing oil boiler with a new 50 million Btu #6 fuel oil/B20 biodiesel boiler to meet peak demands. The biomass plant will be connected to the existing heating plant and will supply approximately half of campus demand. This will reduce Middlebury's #6 oil consumption from 2 million gallons to only 1 million gallons. Chip consumption will be 20,000 tons annually.

Kamalesh Dosi, Project Director, Biomass Energy Resource Center (BERC)

Biomass feedstock can be put in four groups: forest residue, agricultural residue, energy crops, and biomass feedstocks (waste). Biomass is mostly carbon neutral, and is considered 85-95% carbon neutral when biomass is sourced within 50 miles (any farther and too much oil is used for transport).

Biomass is one of the few fuels that can be a problem if it is NOT used; forest fires can occur from biomass building up, and animal waste can create methane issues. Any school in Vermont can get funding for biomass boilers — 75% of biomass capital cost is paid for by the state. About 70 towns in Vermont use biomass in their schools, and heat distribution can be of any form: hot air, steam, or hot water.

Wood pellets contain 7,750 btu/lb. Pellets are no more than 6% moisture (as opposed to wood which is 45-50% moisture). Pellets can be used for buildings that are 10,000-50,000 square feet. Pellets are generally not price competitive with natural gas. Fuel cost equivalencies are $200 / ton of wood = $1.67 per gallon of oil = $1.18 per gallon of propane = $12.50 per 1,000 cubic feet of natural gas. Currently, pellets cost 27% less than oil.

A life cycle cost analysis of biomass looks at the total cost over 30 years in present dollars. Wood pellet systems have a high first cost investment, but are cheaper over time. Life cycle cost analysis includes all costs, such as equipment, construction, professional fees & permits, and annual fuel costs. BERC has a life cycle calculator that they use.

Cost competitiveness chart:

Biomass tons	Cost per gallon of oil
5,000	$1.95 or higher
10,000	$1.80 or higher
15,000	$1.75 or higher

1 ton of pellets = 120 gallons of heating oil = 170 gallons of propane = 16,000 cubic feet of natural gas = 4,775 kWh of electricity.

A wood pellet heating guidebook is available online at www.mass.gov/doer/home.htm. A book on woodchip heating system for building-scale and district-scale systems is also available on the DOER website.

Gasification of biomass involves: 1) heating and drying the biomass 2) pyrolysis by heating dry biomass with little oxygen, which liberates chemicals 3) combustion with air releases heat 4) reduction makes CO and hydrogen, creating syngas. Syngas is used commonly by the chemical industry. The MTC funded a project that demonstrates gasification, and a gasifier is also being tested at EERC in North Dakota.

Question: *Is there any research on the GHG emission conversion factors for wood pellets versus woodchips?* Answer: It depends on the supply chain of the particular wood pellet source. It is hard to get GHG data on wood pellets, but there is energy used to make pellets that needs to be taken into consideration. The DOER has done detailed studies looking at biomass as a whole, including examination of different efficiencies for various biofuel uses. DOER's ranking for biofuel uses was 1st heating, 2nd combined heat and power, 3rd liquid fuel gas.

Question and Answer Period

1. Has anyone done a detailed analysis of the GHG costs of transporting biomass fuel to a power plant?
Mike: Our oil comes from Venezuela versus our wood which comes from New York, so we assumed that the GHG costs of transporting biomass are better than those of oil.
Rob: We are diverting woodchips from going 200 miles to Canada, where they used to be shipped.

2. I am interested in creating gasification for the steel industry, is that possible?
Rob: The process of gasification is difficult as it is, so nobody is really thinking about making it available for commercial purposes yet.

3. Could you talk about your wood supply contracts?

Rob: We have an annual contract. When we first started to buy chips we sent our RFPs to 50 sawmills in New England. Last year we considered a multi-year contract, but it was a higher price because they could not predict how much supply would be available in the future. We currently pay $44 per ton.

4. Could you talk more about Middlebury's supply?
Mike: We are not using willow trees – we are using a willow plant that is similar to corn. The thing that pushed us in that direction was the need to engage with the local economy and cultivate it as a real business. The willow is preserving farm land and can be planted on bad soil.

5. What are the biomass applications for residential houses?
All: Pellets are the way to go because pellet boilers have up to 90% efficiency. Boilers are in short supply – it's a Scandinavian technology, but more are trying to enter the US market. There are hybrid products the combine biomass boilers with solar panels to generate hot water. Biobricks are another product on the market that can be used.

6. One of the more interesting things that came about with conversations with gasifier manufacturers was using the same technology of gasification for household trash. This is being tested now in Tennessee- they are monitoring emissions and the chemistry of combustion. If everyone in New England burned trees, then we wouldn't have any trees left. There are many other sources of biomass. BERC has developed a mathematical model for working out fuel supply — infrastructure, land productivity, etc.— they know which school is getting woodchips from which supplier.

7. Have there been price increases with the increase in demand from so many schools using woodchips?
Kamalesh: Yes. The schools started converting about 15 years ago. At that time, all woodchips were coming from saw mills as a waste product. But in the last three years they have reached almost the total peak supply from sawmills. The first question to ask is what is the source? If it is a waste product, then it does not affect forests. In their mathematical model, BERC determined that if woodchips reach $80/ ton then it would be economical to cut forests.
Mike: Middlebury has a steam absorption chiller for cooling with allows for a steady demand of chips. The steadiness allows them to get cheaper prices.

8. Is there any danger of self-combustion for wood chips?
Yes, but the Forest Service has information on safety — such as to keep the pile under 40 feet high, keep piles moving, etc.

9. Please speak more about emerging technologies for electricity generation from biomass.
Mike: The gas has to be clean. We can clean it, but we're still getting the data from our research.
Ben: There is a company in Italy that is cleaning the gas, but it's very expensive.

10. Is electricity more valuable than heat?
Ben: He generally feels that electricity production from biomass is not beneficial. Biomass in a lot of ways is a thermal product. Kamalesh: The economic model says that biomass electricity cannot compete with the grid.

11. How is the McNeil plant doing? Is it economic?
It is producing electricity. Mike: I don't know their financial model.
The Schiller power plant in New Hampshire has recently converted its old coal plant to biomass. They could make the conversion possible because of the credit they got from selling RECs. That made them economically viable. Without RECs they would not have opened the plant.