ABSTRACT
The James Madison University in Harrisonburg, Virginia utilizes the energy produced from the combustion of Municipal Solid Waste (garbage) to provide steam for the heating and cooling needs of the campus. This facility also has a small turbine that can be brought on line to produce electricity for sale to the local utility. CHP facilities which use a locally generated fuel (MSW) are a good fit to provide heat and power to a campus or district energy system.

Key Words
Campus, Steam, CHP, Energy, Garbage
University campuses, institutions and municipalities have long relied upon fuel in the form of natural gas, coal and fuel oils to power their institutional and industrial boiler systems. These fuels have historically been readily available and relatively cheap. Regrettably, the prices for some of these fuels, most notably natural gas, have been rising and many institutions, municipalities and industries are now looking for alternative means of generating energy. One of those alternative means that utilizes a locally produced, plentiful, sustainable source of fuel is the Waste-to-Energy (WTE) process. The purpose of this paper is to highlight the use of this fuel to provide energy to the James Madison University steam plant. This WTE facility, originally built in 1982 but upgraded in 2004, is owned and operated by the City of Harrisonburg, Virginia and is located adjacent to the University. This facility utilizes municipal solid waste (garbage) as fuel to produce approximately 57,000 lbs per hour of saturated steam for export to the James Madison University central heating & cooling system.

This facility uses a mass-burn style waste combustion system to accomplish this. The combustion of municipal solid waste is a highly regulated process that requires specialized waste combustion and air pollution control equipment. The Harrisonburg Waste-to-Energy facility was originally built as a 100 ton per day (TPD) facility utilizing an older combustion system. This system was adequate at the time but to meet the requirements of the Clean Air Act the facility needed to upgrade its air pollution control and combustion equipment. In 2002 the City of Harrisonburg made the decision to contract with Barlow Projects, Inc. to perform this retrofit and expand the capacity of the facility from 100 to 200 TPD, doubling its steam production and supply to the campus.

From the point of export from the WTE facility to the heating & cooling plant the system works much like any other industrial or institutional boiler system. However, a WTE facility is very different from most other boiler facilities from both an economic and operational standpoint. Where natural gas, coal and fuel oil fired facilities are required to purchase their fuel, a waste to energy facility is actually paid to take its fuel. The reason for this is that the primary purpose for a WTE facility is the diversion of municipal solid waste from landfills. We now know that the decay of municipal solid waste in landfills is the largest contributor of methane to our atmosphere. Even landfills with landfill gas recovery systems only capture a portion of this methane with the balance contributing to global warming. WTE facilities not only prevent this
emission of methane, but use the fuel (garbage) to displace other fossil fuels which makes them a net reducer of greenhouse gas emissions.

The process used at the Harrisonburg Resource Recovery Facility is referred to as a mass-burn process. This type of combustor requires no preparation of the garbage before it is fed into the combustor. The garbage is brought to the facility by the same packer trucks that would pick it up at your curb and dumped into a pit located in an enclosed receiving hall. See photo below:

The garbage is then removed from the pit of the facility by a crane and grabble mechanism and deposited in one of two feed hoppers which feed the fuel to the combustors. The system has two independent process lines (or trains) to provide additional capacity and higher availability. Each process line includes a feed chute, feed ram, combustion chamber, boiler, economizer, scrubber, baghouse and ash removal system.

Unlike coal or biomass fuels like wood, garbage is an extremely non-homogeneous fuel and very difficult to handle and burn. Specialized equipment is necessary to deal with the constantly
changing size, heating value and moisture content of the garbage and still achieve high combustion efficiencies. The Barlow Aireal\textsuperscript{TM} Combustion System (ACS) is the premier system available today to safely and economically combust municipal solid waste. This is the technology that was selected and installed at the Harrisonburg facility.

The Aireal system consists of an inclined grate with no-moving parts. Garbage is moved through the 5 zones of the combustion chamber using a pulse air system which assists the combustion process by adding air or re-circulated flue gas in specified zones while simultaneously creating voids in the bed which allows for the migration of the fuel down the grate (as depicted below).

This system was designed specifically for the combustion of municipal solid waste but is also capable of burning other biomass fuels. The combustion chamber is generally pre-heated using natural gas or fuel oil to a temperature of 1800° before garbage is introduced. This process typically takes less than 4 hours. Once garbage is introduced into the combustion chamber and ignited, the process is self sustaining. No supplemental fuel is required to continue combustion. Garbage is continuously fed into the chamber using a feed table and feed ram which can be adjusted for varying conditions.
Fuel bed depth and bed temperature are critical to preventing slagging and insuring continuous movement of the garbage down the grate. These parameters along with zone temperatures, oxygen levels, CO levels and various other parameters are constantly monitored to insure optimal performance of the system. Cameras are also installed in each of the combustors so that operators can continuously watch the process and make manual adjustments as necessary. This process continues 24 hours a day, 7 days a week with availability levels around 90%. The combustors must be taken off line occasionally to perform routine maintenance generally consisting of refractory replacement, grate plate replacement and to drill out clogged pulse holes.

The Harrisonburg facility uses refractory lined combustion chambers and duct work feeding into waste heat boilers. The two waste heat boilers at the Harrisonburg facility are capable of producing approximately 28,500 lbs/Hr of steam each. As with most solid-fuel burning power plants, on-line cleaning is performed using steam soot blowers. Off-line, mechanical cleaning is generally performed at least once a quarter to insure higher efficiencies. The drawing to the right is a depiction of one process train of the Harrisonburg WTE facility:

After leaving the boiler, spent gas is ducted to the Air Pollution Control (APC) equipment. APC systems typically consist of a dry sorbent injection system with a fabric filter (DSI/FF). The Harrisonburg facility uses the Procedair all dry scrubbing process to scrub out acid gases like HCL and SO2. Dry sorbent is injected into the cooler combustion gases leaving the boiler economizer. The sorbent, typically dry lime, provides for the removal of a large portion of the acid gases (SO2 and HCl). Powdered activated carbon (PAC) is also injected at this point to remove heavy metals and dioxins/furans. In larger facilities
an SNCR system injects an additional reagent (typically urea) in the furnace to control the emissions of Nitrogen Oxides (NOx). The gases then pass through a fabric filter, which removes in excess of 99.99% of all particulates. The clean gas exiting the fabric filter is discharged to the stack, where the gases are then emitted at an elevated point in the atmosphere. Fly ash collected in the boiler and fabric filter hoppers is transported by conveyor to the main ash discharge conveyor. To insure that emissions from waste-to-energy plants meet regulatory requirements, sophisticated monitoring systems which continuously sample and analyze flue gas emissions Continuous Emissions Monitoring, or CEM for short, are installed at the Harrisonburg facility and all U.S. WTE facilities.

**Economics:**
The steam from the boilers leaves the Harrisonburg WTE facility at 215 psig and 395° F and is sold to the James Madison University central heating & cooling system located in a smaller building adjacent to the WTE facility. Along with the tipping fee for receiving the garbage, this is a major source of revenue for the WTE facility. The university also benefits from this relationship because it pays less for the steam it receives than it would pay if it were creating its own steam using natural gas, coal or fuel oil. We will add a graph here comparing the cost of steam production to that using gas.

A portion of the steam can also be routed to a small Turbine Generator located in the Harrisonburg WTE facility. This generator is owned by the local utility and can be brought on line as needed generating approximately ___ MWs of electricity. This CHP capability is an option for any WTE facility as long as the economics of making and selling electricity make sense. The local price the facility would be paid for the electricity created must justify the capital cost of installing the super-heaters, cooling towers, condensers and auxiliary equipment needed to make that electricity.

**Environmental concerns**
Modern resource recovery facilities differ significantly from the old fashioned municipal incinerators. Waste-to-energy facilities that use municipal solid waste to generate steam and electricity are subject to strict EPA emissions standards. Those standards ensure that waste-to-energy is one of the cleanest sources of power in the world. Contrary to popular belief, WTE does not compete with recycling either. Recyclables are recovered from the household garbage
before energy is recovered from the residual waste through the waste-to-energy process. This allows for maximum diversion of material from landfills.

The only residual from the WTE process is ash, which is about 10 percent by volume of the pre-treated MSW. This ash would be transported to an ash monofill or landfill. This ash leaves the WTE facility as a wet, cement-like material that eventually solidifies and is often used as daily landfill cover. Ash from modern WTE facilities consistently passes the EPA’s Toxic Characteristic Leaching Procedure test and is considered safe for landfilling. Ash has also been tested as road base material, cinder blocks and artificial reefs, and applications continue to be researched by the University Ash Consortium.

**Conclusions**
Utilizing a locally available, plentiful, sustainable fuel to generate steam and electricity for a university campus, institution or municipality makes good sense. The fuel (garbage) is generated locally, reducing hauling costs, and the WTE facility is paid to take it. Garbage as a fuel has a heating value of between 4500 – 6500 BTU/lb depending on the region and the amount of recycling done on the front end. This fuel is currently being buried in landfills at a rate of approximately 130 million tons a year. The WTE facility in Harrisonburg, Virginia, providing steam to the James Madison University heating & cooling plant, is an excellent example of how this system can work. It is reliable, efficient, and cost effective compared with fossil fuels and a good neighbor to the campus and community. Campuses and institutions world wide currently using fossil fuel fired boiler systems should consider retrofitting their existing systems to take advantage of this fuel.