Ashley, G.C. 1978. Heating greenhouses in northern climates with power plant reject heat. *HortScience* 14: 155-160.

Arch roofed, gutter connected greenhouses, with air-inflated double poly roofs, each unit 17×96 ft, enclosing 22,848 sq.ft. were heated by condenser cooling water from a coal-fired power plant, 45 miles northwest of Minneapolis. Winter design, minimum cooling water condenser outlet temperature was 85°F at full load electrical output. Design criteria for the greenhouse heating systems were based on a -30 F outside temperature and 50 F inside, with a calculated heat loss of 2 million BTU per hr. Both air heating and soil heating was employed, although the air heating system was designed to handle the full load. Air was distributed down each bay from the heat exchanger with a 30-inch poly tube.

The heating systems performed wholly satisfactorily during 1975-76 and 1976-77. In the last season, performance was less than optimal due to fouling of the fan coil heat exchangers. The lowest temperature recorded was -42.9 F, with an inside temperature of 58 F, and warm water available at 91 F. Crop production included roses, tomatoes and peppers, with improved production of tomatoes in the second season as experience was gained with the system and CO_2 injection was installed. Crops included freezias, snapdragons, cineraria and geraniums.

In 1977, a one acre commercial floral greenhouse, of similar construction, was built, with bay widths of 17.5 ft., and a length of 144 feet.

Warm water service became available in 1977, operating with an over-all availability of 96.4%, unavailability primarily due to pipeline failures. Water was not always warm enough to maintain temperatures desired by commercial operators, due primarily to reduction in electrical load at the power station. Condenser water temperature could vary over a 20 F range due to load. Despite this, waste heat was available at the condenser outlet for 73% of the time above 85 F. A backup system is provided, using propane, and the 1 acre floral range consumed 8,000 gallons of propane, with about 2,000 gallons for CO_2. It is expected that as operating availability improves, standby heat requirements will decrease.

Because of the relatively low temperature differences, a significant amount of electrical energy is required for pumping. In the one acre commercial operation, the heating system requires 85 hp, with 10 hp for liquid pumping, or about 70 kw electrical load at full operation. The total consumption during the first heating season was 237,000 kw, with about 85% directly attributable to the heating system. Presently, the cost of electric energy to operate a warm water system for an acre is $7,000 per year, while the cost to deliver warm water is about $8,000 per year.

Economic feasibility to utilize condenser heat is dependent upon many variables. The most important are: 1) distance from waste heat source to greenhouse, 2) climatic conditions, 3) electric rates, 4) land cost, and 5) distance to market. At least at this particular site, conditions are such that the concept appears feasible. The most recent cost estimates to install pipeline services for 14 acres within one-half mile of the waste heat source is $35-40,000 per acre of greenhouse served. In addition to the capital cost of the pipelines, there is the cost associated with pumping and with maintenance of the pipeline. The power company estimates that the total variable operating cost will run roughly 1¢ per 1,000 gallons delivered to the user. At this rate, one acre in Minnesota will have an operating cost of $1,500 per year. The approximate total cost at the site is now $8,000 per acre-year, with the power company providing waste heat on a cost-of-service basis with a return on investment equivalent to the rate of return for other utility investments.

There is also a significant investment in heating equipment, and for Minnesota conditions, including controls, electrical work and back-up, is about $85,000 per acre.

The big advantage of waste heat systems is more apparent in the future as fuel costs escalate. The overall waste heat costs would not increase as fast as other costs due to the fact that a large part of waste heat cost results from the fixed pipeline investment.

The actual operating costs for the one acre commercial range totaled 36¢ per sq.ft. for the period of November to May. This compared to 63¢ per sq.ft. for a glass house owned by the same company. At least 8¢ per sq.ft. was saved as the result of using waste heat. The actual experience in the first year showed the waste heat system falling considerably short of the projected annual savings of $8,000. But, the outlook for achieving projected savings is optimistic.

The increased transportation costs must be considered by the greenhouse owner if he locates far from the metropolitan centers, as most power stations may be close to fuel sources or removed because of pollution requirements. A second consideration is cost of the land. At Sherco, MN, the power company owns the land, and is leased to the operators at a nominal fee. Leased land may be welcomed where land costs are high. Generally speaking, the value of a power station is so great that local property tax rates tend to be low.

	1978 costs		1998 costs	
	Waste heat	Conventional	Waste heat	Conventional
Standby propane	2,000	- -	6,000	- -
#2 fuel oil		25,000		80,000
Electricity	8,000	1,000	26,000	4,000
Waste heat cost	8,000	- -	10,000	- -
Total per acre per year	18,000	26,000	42,000	84,000

Fuel oil at 45¢/gal; propane at 43¢/gal; electricity at 3.5¢/kw; future fuel and utilities escalate at 6% per year.

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