US Army Corps of Engineers

Welcome to the U.S. Army Corps of Engineers, Savannah District

Hartwell Dam & Lake

Did You Know?

The generator rotors, which are turned by the turbines, are 30 feet in diameter and weigh 300 tons each. They are the heaviest part of a generator unit.

Find out more interesting facts about Hartwell Lake **here!**

October 24, 2010

Hydropower at Hartwell

Introduction

Hartwell Dam and Lake was the U.S. Army Corps of Engineers second multipurpose “project” in the Savannah River Basin. Authorized by Congress under the Flood Control Act of 1950, the Hartwell Project was built between 1955 – 1962 for the purposes of hydropower, flood control, and downstream navigation. Additional purposes of the project now include water supply, water quality, recreation, and fish and wildlife management. Filling of the lake began in February 1961 and was completed in March 1962. The powerplant first went on-line in April 1962.

The powerplant originally consisted of four generators with provisions made for a 5th generator based on the foresight that additional power demands would be likely. The 5th generator was installed in 1983. The powerplant at the Hartwell Project has the distinction of being the only hydroelectric plant to be totally designed and constructed by the Corps with the generators located outdoors.

Hartwell Dam is a concrete-gravity structure flanked on both sides by embankments of compacted earth. The concrete section is 1,900 feet long and rises 204 feet above the riverbed at its highest point. The earthen embankments on each side of the dam lengthen it to over 3 miles. The dam creates a 55,900-acre lake that stretches 49 miles up the Tugaloo River and 45 miles up the Seneca River. These two rivers – the Tugaloo and Seneca – come together to create the Savannah River, 7.1 miles above the Hartwell Dam.

The dam is located approximately 300 river miles above the mouth of the Savannah River where it empties into the Atlantic Ocean (in Savannah, Georgia) and 90 miles above Augusta, Georgia. Two other Corps projects – J. Strom Thurmond (formerly Clarks Hill) located near Augusta (completed in

Hydropower Links

1954), and Richard B. Russell, located between Hartwell and Thurmond Projects near Elberton, Georgia (completed in 1985) – join Hartwell to form a chain of lakes 120 miles long.

The Corps of Engineers is the nation’s leading producer of hydroelectric energy and Hartwell Dam and Powerplant is part of the Corps’ national commitment to this energy. Hydroelectric power generation continues to be the only pollution-free means of producing commercial energy.

Hydropower Generation

Hartwell Powerplant is referred to as a “peaking” plant – which means the powerplant is designed to supply dependable power during hours of “peak” daily demand. In addition to being a very clean energy source, another major advantage of hydropower is the availability to come “on-line” (begin producing power) within a few minutes. Other types of powerplants such as nuclear and fossil fuels often take several hours, at which point the peak demand has often passed. This ability to virtually produce power on demand during peak periods helps to reduce energy shortages (especially during the summer months) and makes hydropower, and the Hartwell Powerplant, an exceptional resource.

The original four generators were designed with a nameplate rating of 66,000 kW. In other words, under controlled conditions, each unit could produce up to 66,000 kW of electricity per hour (the latter installed 5th unit has a nameplate rating of 80,000 kW). However, the nameplate rating of the first four generators recently increased due to a “rehabilitation” or overhaul (click here for more on rehab). The rehab increased the overall plant capacity from 344,000 kW to 422,000 kW, a 22.7% increase; this is equivalent to adding a 6th generator.

On average, the Hartwell Powerplant produces over 468 million-kilowatt hours per year. Revenues during 2001 totaled over $14 million and have exceeded $330 million since 1962.

How Hydropower Works

Hydroelectric power is produced when water from Hartwell Lake flows through the intake section of the dam by large pipes called “penstocks”. The penstocks are located approximately 100 ft. below the surface of the reservoir. Water flows through these 24 ft. in diameter penstocks at a rate of 2 – 3 million gallons per minute when generating. The force of the water rotates the “turbines” which resemble large water wheels or fan blades.

The rotating turbine causes the 41-inch diameter generator shaft to spin, which then causes the rotor to turn (the rotor is a series of magnets where the magnetic field is created). The rotor turns inside the “stator” – a stationary part of the generator made of copper coils of wire called “windings”. Electricity is produced as the rotor spins past (inside of) these windings.

The generators create electricity in the form of volts. By means of transformers, the electric current produced is “stepped up” or increased in voltage from 13,800 volts to 230,000 volts for transmission to power companies or decreased in voltage for use in powerplant operations. Water used in generating the power is discharged into the river below the dam, where it can be “reused” for additional purposes such as water supply and water quality needs of the Savannah River Basin.

Where Does the Power Go?

Power produced at Hartwell and all other Corps operated powerplants in the southeast, is marketed by the Department of Energy’s Southeastern Power Administration (SEPA). Power is sold through SEPA to private power companies and public cooperatives in the Southeastern U.S. and from there to customers of those companies. Although electricity is not sold directly to the consumer, the underlying goal of all Corps hydroelectric projects is to provide power to consumers at the lowest possible rates. Rates are set by the marketing agency and approved by the Federal Energy Regulatory Commission. Revenue from Corps powerplants is returned to the U.S. Treasury.

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Hartwell Powerplant Rehabilitation("Rehab") Phase I

The life span of the Hartwell Powerplant's four original generators was expected to be approximately 30 years. So, after 37 years of service, the four original generators underwent a "rehabilitation" (rehab), or overhaul. Each of the four generators had over 60,000 hours of operating time; this is equivalent to an automobile having over 2,700,000 miles on it (if an automobile averaged 45 mph).

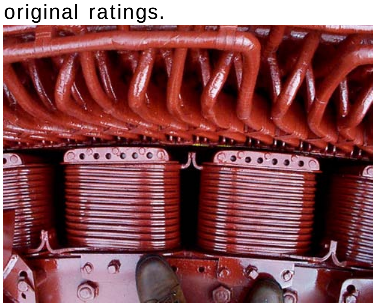
Phase I of the rehab work got underway in 1997. There were three major components of the rehab work - generator rewinding/turbine refurbishment, replacing and upgrading circuit breakers, and replacing and upgrading the transformers (this included installation of an oil/water separator). Phase II includes more equipment such as replacing all of the switchyard breakers and buswork and updating the powerhouse and Clemson Pumping Station.

Preparations

The Gantry crane seen here is a permanent part of the dam and is used to move generator parts from the outside deck into a workspace within the powerplant. Before the rehab began, a stress test was performed on the crane because it would be needed to lift and move the rotors that weigh approximately 300 tons (the rotor is the heaviest part of each generator). To do this, water was placed in large balloons to a weight of 375 tons.

Generator Rewind & Turbine Refurbishment

The generator rewind involved stator coil replacements. Coils are the wound wire components in a generator that produce electricity when a magnetic field is passed across them (this is what the rotor spins inside of). Due to technological advancements, the new coils can be rated at a higher power output and the generators were upgraded to 129% of their original ratings.



Turbine refurbishment consisted of repairing turbine blades. Over the years, water to blade contact results in very small nicks and general wear to the turbine blades (referred to as "cavitation"). Old paint was sandblasted and blades were welded, sanded, and repainted.

In addition to the refurbishment, "hub-baffles" were added to the turbines. Hub baffles are devices designed to pull air into the water flowing through the turbines – this increases dissolved oxygen downstream water and improves water quality conditions for fish.

Replacing and Upgrading Circuit Breakers

The circuit breaker upgrade involved replacing existing air circuit breakers with gas breakers. Gas breakers are more efficient and have a longer life span. Air breakers required bi-annual maintenance, while the new gas breakers only require maintenance every 10 years. Repair work is easier and less expensive. Additionally, the new circuit breakers have a higher current rating to handle the higher output of the generators.

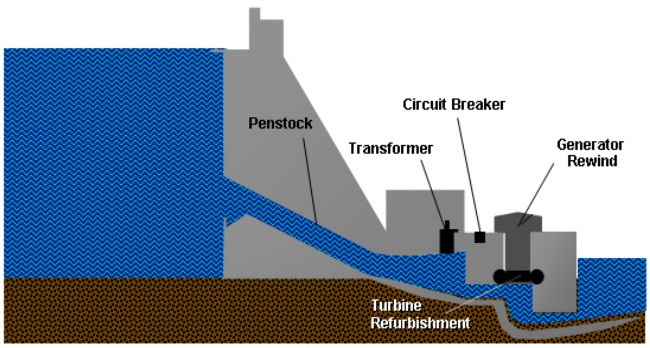
Replacing and Upgrading the Transformers

Transformers have been replaced to handle the additional increase in power being generated. Instead of two banks of three, single-phase transformers, there are now two three-phase transformers (one transformer for units 1 & 2 and one transformer for units 3 & 4; unit 5 has its own transformer). Each new transformer, weighing in at over 242,000 lb. (or over 121 tons) and 32.5 ft. long by 21' wide, was transported (on separate occasions) by train from St. Louis to the Airline community of Hart County, where it was then placed on a specially designed flatbed trailer and brought to the powerplant.

Each transformer requires between 6,000 to 10,000 gallons of insulating oil. As part of the transformer work, an oil/water separator was installed. An oil/ water separator is a secondary containment feature that will prevent oil from entering into the river should a spill occur in relation to the transformer. It is basically an underground holding area, should a spill occur, oil would enter into the holding area where it could then be pumped and properly disposed of.

Conclusion

This diagram gives you a good idea of the location of the major rehab components in relation to one another.



The rehab has resulted in a 29.5% capacity increase each for units 1 - 4, or a 22.7% increase in plant capacity. (Capacity is the amount of electricity a generator plant can produce). In other words, due to the increased nameplate rating, we can produce 22.7% more power than before the rehab. The rehab has increased the nameplate rating of 66,000 kW to 85,500 kW. This is equivalent to adding a 6th generator. The rehab is also expected to extend the life of the generators by 35 years.

The Corps continues to provide clean energy as the nation's power demands continue to grow.

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Downstream Safety

The production of hydropower at the powerplant is accompanied by a rise in the level of the river below the dam, as water used to drive the generators is discharged into the river. Air horns located on the top of the dam will sound for one minute before water is released into the river. The horns are to alert fishermen and other visitors who might be on the rocks in the riverbed that the river will soon rise and that they must immediately move to the riverbank. For safety's sake, fishermen are encouraged to fish from the riverbank or from the fishing piers that have been provided.

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Flood Control

Normally, water released from the reservoir passes through the dam and into the river below by way of the powerplant. However, there are times when it is necessary to pass substantial quantities of water downstream quickly for flood control purposes. The spillway, located on top of the dam, contains 12 large gates, each 40 ft. by 35.5 ft., for the quick release of water from the lake. Water can be released at the rate of 5.8 million gallons* per minute with all floodgates open one foot (gates can be opened to five feet or more).

The concrete bucket at the toe of the spillway deflects the flow upward to dissipate its destructive energy and prevent erosion of the foundation. The training walls of the concrete structure at each end of the spillway direct the flow into the river channel below the dam. Water released through the floodgates cannot be used to generate electricity.

The floodgates at Hartwell Dam have been opened three times for flood control purposes – in 1964, 1965, and 1994. The three Corps managed dams and lakes on the Savannah River have prevented over $40 million in flood damages since 1954.

**Figure based on lake elevation of 660 ft. msl.*

Clemson Diversion Dams

In addition to the main dam, two diversion dams were constructed from 1960 - 1961 to divert the flow of the Seneca River around Clemson University, preventing inundation of a large portion of Clemson property that was developed before the lake was created.

The construction of the diversion dams created an interior drainage area of 1,659 acres with 125 acres being the Clemson bottoms or levied area. This required the construction of a pumping station to remove the water from this area and to control the elevation between 610' and 614'. Water flowing into the basin comes from several sources:

- Hunnicut Creek - a free flowing natural stream.
- Old Seneca River Channel - several springs supply water to this channel.
- Upper and Lower Diversion Dams - these have a continuous flow of seepage from the reservoir into the pumping station basin.
- Storm water - from local rains.

The pumping station is equipped with two 40 HP vertical turbine electric pumps, with a pumping capacity of 2,000 gallons per minute (each). Under normal weather conditions with little or no rainfall, these two electric pumps will maintain the specified water level elevations of 610’ to 614’. The two emergency pumps are 30 ft. in diameter vertical turbine type pumps, with a capacity of 23,500 gallons per minute each. They are powered by D-398 caterpillar engines rated at 660 HP each.

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Historical Photos Library

Link to: **Historical Photos**

Facts and Figures

- When the reservoir is at full summer pool (elevation 660 ft. msl), it covers nearly 56,000 acres. Approximately 24,000 acres of public land surrounds the lake. The lake has 962 miles of shoreline.
- The generator rotors, which are turned by the turbines, are 30 feet in diameter and weigh 300 tons each. They are the heaviest part of a generator unit.
- The penstocks are 214 ft. long, made of boilerplate steel, and are 24 ft. in diameter. Water flows through the penstocks at a rate of 2 – 3 million gallons per minute.
- It takes 138,000 gallons of insulating and lubricating oil to operate the generators. The oil is continuously recycled inside the powerplant, saving millions of dollars each year.
- Hartwell Dam is built of more than 880,000 cubic yards of concrete and more than 3 million pounds of reinforcing steel.
- The depth of the lake behind the dam is approximately 180 feet.
- The top of the dam is 204 feet above the Savannah River Bed.

LOCATION:

89 miles above Augusta
67 miles above Thurmond Dam
7.1 miles below confluence of Seneca and Tugaloo Rivers

DRAINAGE BASIN AREAS:

above mouth of Savannah River 10,579 sq mi
above Augusta, GA 7,508 sq mi
above Hartwell Dam 2,088 sq mi

RESERVOIR:
Top of Power Pool 660 ft-msl 2,549,600 Ac-Ft 55,950 Acres
Top of Flood Control Pool 665 ft-msl 2,842,700 Ac-Ft
Top of Dam 679 ft-msl
Conservation Pool 1,415,500 Ac-Ft 461,170 Million Gal (461,170,000,000)
Flood Control Pool 293,100 Ac-Ft 95,492 Million Gal (95,492,000,000)
Water Supply Available (50000 Ac-Ft/1,415,000)*3117 cfs = 110.14 cfs = 71.18 MGD

DAM LENGTHS:
Concrete Section 1,900 ft

Earth Embankments & Saddle Dike 17,852 ft

SPILLWAY:
Type: Concrete Gravity
Gross Length 568.00 ft
Clear Opening Length 480.00 ft
Tainter Gates 12, 40' X 35.5'
Type of Bucket Flip
Radius of Bucket 30.00 ft
Powerhouse Length 340.00 ft

QUANTITIES:
Concrete 975,100 cu-yd
Compacted Fill 4,342,300 cu-yd
Excavation Borrow 5,251,600 cu-yd
Excavation Common 93,900 cu-yd
Excavation Rock 244,200 cu-yd
Rock Toe 33,100 cu-yd
Riprap and Filter 168,400 cu-yd

HYDROPOWER:
Number 5
Diameter 24.0 ft
Spacing 68.0 ft
Max Velocity 15.25 ft/sec

GENERATORS:
Installed Capacity 4 Units at 85 MW 1 Unit at 80 MW
Gross Static Head 192 ft
Average Head 171 ft
Minimum Head 142 ft
Generator Bay Floor Elev. 516.0 ft-msl
Turbine Axis 484.0 ft-msl

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Abbreviations & Glossary

Acre-foot (AF)	The volume of water require to over one acre to a depth of one foot. 1 acre-foot= 43,560 cubic feet or 326,000 gallons.
Capacity	The load for which a generator, turbine, transformer, transmission circuit, apparatus, station or system is rated. Capacity is also used synonymously with capacity.
Circuit Breaker	Any switching device that is capable of closing or interrupting an electrical circuit.
Confluence	The combining of two streams.
Conservation Pool	Usable storage in reservoir for hydropower, recreation, water quality, fish and wildlife management, navigation, and water supply purposes, designed to be filled during normal and high flow periods for use during low flow periods.
Cubic Feet per Second (cfs)	1cfs=450 gallons per minute (gpm)
Demand	The rate of water flow through, over, or around water control facilities. The rate of flow is measured by stream gage or calculated from predetermined rating tables. The term may be applied to the rate of flow from each individual source (such as a particular turbine) or to be algebraic summation from all individual sources (which would be the total rate of flow). Total discharge is synonymous with outflow.
Discharge	The rate of water flow through, over, or around water control facilities. The rate of flow is measured by stream gage or calculated from predetermined rating tables. The term may be applied to the rate of flow from each individual source (such as a particular turbine) or to be algebraic summation from all individual sources (which

	would be the total rate of flow). Total discharge is synonymous with outflow.
Drawdown	The distance that the water surface elevation of a storage reservoir is lowered from a given or starting elevation as a result of the withdrawal of water to meet some project purpose(s) such as power generation or creating flood control space.
Drought Contingency Plan	Detailed drought management plan that addresses current water conditions in the Savannah River Basin, and serves as a baseline for future
Drought Indicators	Mechanisms which reflect drought conditions and severity. Drought indicators consist of hydrologic indicators such as streamflow, rainfall, reservoir storage levels and groundwater levels, meteorological indicators such as rainfall, and human activity indicators, which include navigation cutbacks and reduction in hydropower generation.
Drought Response	A response network consists of trigger levels and appropriate management action. Triggers are predetermined standards reflecting drought intensity which induce responses.
Effluent	Waste material discharges into the environment.
Flood Control Pool	Storage above the conservation pool elevation designed to store floodwater and reduce flooding downstream.
Flow	The amount of water passing a given point within a given period of time.
Forebay	The impoundment immediately above a dam or hydroelectric plant intake structure. The term is applicable to all types of hydroelectric developments (e.g. storage, run-of-river, and pumped-storage).
Generating Unit	A single power producing unit, comprised of a turbine, generator, and related equipment.
Generation	The act or process of producing electricity from other forms of energy. Also, the amount of electric energy so produced.
Generator	The electrical equipment in power systems that converts mechanical energy to electrical energy.
Governor	The device which measures and regulates turbine speed by controlling wicket gate angle to adjust water flow to the turbine.
Guide Curve	(also Rule Curve or Target Pool Levels). Guides established to regulate and manage optimum pool elevations for yearly operations at impoundments. Rule curves can be designed to regulate storage for flood control, hydropower production, and other operating objectives, as well as a combination of objectives.
Hydroelectric Plant	An electric power plant that uses water to generate power.
Hydropower Power	The energy that is produced from water.
Impoundment	A confined body of water such as a reservoir or lake. Typically created by a dam to store water that is released to meet to maintain authorized purposes
Inflow	The rate of water flow into a reservoir or forebay during a specified period.
Kilowatt (kW)	The electric unit of power, which equals 1,000 watts or 1.341 horsepower.
Kilowatt hour (kWh)	Unit for measuring electric energy consumption or generation over time; it equals one kilowatt of power applied for one hour of time. A typical home uses about 800 kilowatt hours per month.
Load	The amount of electric power consumed/delivered at a given point.
Megawatt(mW)	Unit of electric power, used for measuring

	rate of producing or consuming electric energy. One megawatt = 1,000 kilowatts or 1 million watts. A megawatt is equal to 1,341 horsepower.
Meteorological Conditions	Atmospheric phenomena and weather of a region.
Minimum Discharge	The minimum flow that must be released from a project to meet environmental or other non-power requirements.
Minimum Pool Level	The lowest elevation to which the pool is to be drawn.
Multi-Purpose Reservoir	A reservoir planned to be used for more than one purpose.
Normal Pool Level	The elevation to which the reservoir surface will rise during ordinary conditions.
Outage	The period during which a generating unit, transmission line, or other facility is out of service.
Peak Demand Month	The month or months of highest power demand.
Peaking Plant	A powerplant which is normally operated to provide power during maximum load periods.
Penstock	A conduit carries water from the reservoir to the turbine in a hydroelectric plant.
pH	The condition represented by a number, used to express both acidity and alkalinity on a scale whose values run from 0 to 14 with 7 representing neutrality, numbers less than 7 increasing acidity.
Powerplant	A generating station where prime movers (such as turbines), electric generators, and auxiliary equipment for producing electricity are located.
Pumped Storage	A hydropower facility that has reservoir pumps which also serve as generators, installed in the dam. During the night, when cheap surplus power is available, the pumps are run to pump water from a lower reservoir to an upper reservoir (upstream). During mid-day, when valuable peaking power is needed, the units are reversed and water is released back to the lower reservoir to generate electricity.
Releases	A determined amount of water that is allowed to pass through or discharged from a dam.
Reregulation Structure	Peaking power plants generally release water only a few hours per day. A reregulation structure is a smaller dam located downstream that is capable of storing the intermittent slugs of water and releasing a continuous flow.
Rule Curve	Same as “Guide Curve.”
Streamflow	The rate at which water passes a given point in a stream, usually expressed in cubic feet per second.
Switchyard	An assemblage of electrical equipment for the purpose of tying together two or more electric circuits through switches, selectively arranged in order to permit a circuit to be disconnected or to change the electric connection between the circuits. In a hydroelectric project, the switchyard is the point at which the energy generated at the project is connected to the distribution system.
Tailrace	The area below a dam; the channel that carries water away from a dam.
Thermally Stratify	During the warm months of the year, the sun heats the upper layers of the lake. Since the warm water rises, the surface of the lake continues to warm while the bottom layer stays cold. During the winter months, the upper layers of the lake are cooled. The warmer water on the bottom rises, causing

	destratification, or "turnover", of the lake.
Transformer	An electromagnetic device used to change the electricity from the generator to usable voltage levels.
Transmission Line	The high voltage lines that carry electricity from the hydropower plant to the electric distribution system.
Triggering Mechanism	An indicator that is put in place to indicate the need to initiate or terminate specific action before a crisis occurs. At the action levels, the trigger elevation will initiate a series of actions that will culminate in the reduction of releases from the projects.
Turbine	Large blades that are turned by the force of water pushing against it; is connected to the generator.
Voltage	The force which causes the current to flow through an electrical conductor.
Watt	Basic unit of electrical power that is produced at one time or rate of doing work. The rate of energy transfer equivalent to one ampere flowing under a pressure of one volt at unity power factor. One horsepower is equivalent to approximately 746 watts.
Wheeling	The transfer of power and energy from one utility over the transmission system of a second utility for delivery to a third utility, or to a load of the first utility.
Wicket Gates	Adjustable vanes that control the amount of water that can enter the turbine.

ABBREVIATIONS

AF	acre-feet
cfs	cubic feet per second
cu	cubic
ft	foot, feet
gal	gallons
gph	gallons per hour
gpm	gallons per minute
km	kilometer
kv	kilovolt
kva	kilovolt-amperes
kWh	kilowatts per hour
m	meter
mgd	million gallons per day
mi	mile
MWH	Megawatts per hour
MSA	Metropolitan Statistical Area
NGVD	National Geodetic Vertical Datum
rpm	revolutions per minute
SAD	South Atlantic Division
SEPA	Southeast Power Administration
sq	square
WES	Waterways Experiment Station
/	per

CONVERSION FACTORS

Length
1 mi = 5,280 ft = 1.609 km
1 km = 0.6214 mi = 3,281 ft
Area
1 sq mi = 640 acres = 2.590 sq km
1 acre = 43,560 sq ft = 4,047 sq m
Volume
1 AF = 325,872 gal = 1,233 cu m
1 AF = 43,560 cu ft = 1,613 cu yd
1 cfs-day = 1.983 AF
1 cubic foot = 7.48 gallons = 0.0283 cubic meters
1 cfs-day = 1.983 AF
1 cubic meter = 35.51 cubic feet
Discharge Rate
1 cu m/sec = 15,850 gpm = 70.04 acre-ft/day

1 cfs = 2,228 gpm = 0.646317 mgd = 1.983 AF/day
1 AF/day = 226.3 gpm = 0.5042 cfs
1 gpm = 8.0208 cu ft/hr
1 cubic foot per second
(cfs) = 448.83 gallons per minute
(gpm) = 0.646 million gallons per day
(mgd) = 0.0283 cubic meters per second (cms)

Energy

1 kilowatt –hour (kWh) = 3,413 BTU [i]
1 kilowatt (kW) = 1,000 watts
= 1.341 horsepower
= 56.88 BTU/minute
= 737.56 ft-lbs/second

1 megawatt (MW) = 1,000 kilowatts
= 1 million watts
1 gigawatt (gW) = 1,000 megawatts

Energy Equivalents

1 barrel of oil (42 gallons)
= 470 kWh at 27% efficiency [i]
= 520 kWh at 30 % efficiency
= 660 kWh at 38% efficiency [iii]
1 ton of coal = 2,500 kWh at 37% efficiency [iv]
1,000 cubic feet of natural gas = 59 kWh at 27% efficiency [ii]
= 83 kWh at 38% efficiency [iii]

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[i] 1 BTU (British Thermal Unit) is the amount of energy required to raise the temperature of one pound of water one degree Fahrenheit.

[ii] Typical efficiency for a combustion turbine.

[iii] Typical efficiency for new oil- or gas-fired base load steam plant or combined cycle plant.

[iv] Typical efficiency for a new base load coal-fired steam plant.

Hartwell Dam & Lake
5625 Anderson Hwy
Hartwell, GA 30643-5259

Phone Numbers
706-856-0300
or toll free at
1-888-893-0678

E-mail Us

Interesting Hydropower Links

- National Inventory of Dams
- Southeastern Power Administration
- U.S. Department of Energy Hydropower Program
- U.S. Bureau of Reclamation Power Program
- Federal Energy Regulatory Commission
- Southern Company/Georgia Power Hydroelectricity & Recreation

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