NON-PEER-REVIEWED PAPER

Green cooling towers

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Abstract

Green Cooling Tower Solutions (GCTS), based in New Orleans, USA, has patented an induced draft, modular cooling tower (Green Cooling Tower – GCT) that uses pressurized water available within the cooling system, and does not use electricity. It eliminates all electrical infrastructure, and saves 100 % cost of electricity, in addition to lower annual maintenance costs, improved reliability and safety (no spark/explosion risk).

GCT harnesses hydraulic energy to drive a specially designed hydro-turbine, which turns a fan shaft and fan blades on the unit. A sufficient amount of airflow is generated by this mechanism to cool the water flow (supplied to the turbine) to the optimal approach to the saturation (wet bulb) temperature of the air.

It has been used at Citgo refinery in Lake Charles, LA since early 2009, where GCT 2-cell tower has replaced an existing 7-cell tower and enabled Citgo to take the old system offline permanently. The tower has performed flawlessly since its installation, maintaining existing production, requiring little maintenance and eliminating electricity costs. Its energy efficiency impact is both large scale and significant – in power plants, for example, it can achieve savings of 0.5 % to 2 % (up to 20 MW in a 1,000 MW plant) of the gross generation capacity.

It is the best-in-class cooling tower technology currently available for refineries, power, chemical and processing plants – it minimizes energy consumption, achieves optimal efficiency in production, and helps with environmental compliance (lower noise, higher safety, low water use and less environmental footprints). GCTS targets large manufacturing and power plants that currently use cooling towers or once-through cooling systems. By embracing this rare advancement in cooling technology that is both green and energy efficient, its user can save energy and O&M expenses, bring additional revenue by sale of saved energy, and potentially generate additional revenue through carbon and green credits.

Introduction

Green Cooling Tower Solutions (GCTS) has patented an induced draft modular cooling tower (Green Cooling Tower – GCT) that uses no electricity to power the fan, instead using the existing water flow inside the facilities to power our fans.

GCT can be used as both base load (for replacement or new installations) and supplemental (designed to take partial load off of existing cooling towers). It can operate in any industrial setting where a cooling tower is needed; however, the largest markets are power plants, petroleum refineries, and chemical plants.

Conventional style cooling towers are typically powered by 100 to 300 HP electric motors running 24 hours/7 days a week, and some plants use up to 100s of these units. At an average electricity cost of $0.07/kWh, this could be over $11,000 per month per motor; however, this number is much higher in places like California and New York, where power tariffs are much higher.

Regulations from the EPA's Clean Water Act, Section 316B, passed in 2012, addresses the serious environmental problems with once through cooling systems. This is a worldwide issue.

The US EPA already suggests cooling towers as the best technology available to address this problem.

Industrial Energy Efficiency is a priority area for the Government. Electric Motor Driven Systems (EMDSs) is the single largest electrical end – use and, therefore, are a critical area for any successful energy efficiency strategy.

GCTS welcomes any assistance from the eceee to disseminate information about this technology to the largest users of cooling towers and once-through cooling in the global context.

Technology – How It Works

Green Cooling Tower harnesses hydraulic energy to drive a specially designed hydro-turbine, which turns a fan shaft and fan blades on the unit. A sufficient amount of airflow is generated by this mechanism to cool the water flow (supplied to the turbine) to the optimal approach to the saturation (wet bulb) temperature of the air. This cooling is done by draining the return water out of the hydro-turbine into a spray nozzle assembly which distributes the water evenly across the section of the film fill. The airflow so generated flows upwards in a counter-flow fashion, exchanging heat with the water across the film fill. The cool water then is returned to the system. The amount of reduction in water temperature achieved is dependent on the baseline performance capability of the existing tower and the number of "Green" Cooling tower units used.

It is **Energy Efficient**, because it uses the pressure already available within the recirculating cooling system to run the fan without any use of electricity or electric motor. It also saves the electricity that would have been required otherwise (in conventional towers) for powering the motor to run the fans.

GCT's tower heights vary: from 20 ft to 30 ft (deck height) and total height from 32 ft to 42 ft, while conventional cooling towers generally have a height of around 60 ft (deck height ~50 ft). Conventional cooling towers have inlets at a height of around 40 ft. In contrast, GCTs have an inlet at a height of 13.5 ft. This difference in height creates a pressure head that is used by GCTs to drive the turbines.

Higher Efficiency and Reliability: The power typically delivered to each fan of GCT is more than the power used on electrically driven motors to run fans in conventional cooling towers. This ensures better airflow, more cooling efficiency and higher reliability in GCT system. The fills in GCT have larger surface areas that aid more evaporation and therefore better cooling. The fans used by our cooling towers are among the most efficient ones in the industry and have efficiencies of up to 87 %.

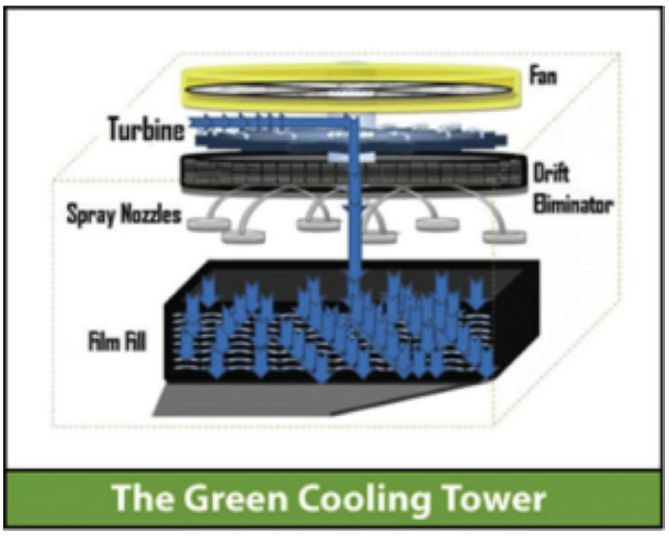

Figure 1. GCT Schematic Model.

GCT's Citgo Demonstration Results:

GCTS's new 2-cell tower at Citgo's PFU unit has performed flawlessly since installation over 2 years ago. Citgo has since taken their existing 7-cell tower offline and has slated them for demolition. Cooling performance of our 2-cell tower is in line with the previous performance of the 7-cell tower. GCT's tower has taken 400 horsepower from existing 7-cell tower offline permanently. Production has been maintained with electricity cost savings of approximately $16,000 per month:

$$400\ horsepower = 298\ kW \times 24\ (hours) \times 30\ (days) \times \$.075/kWh = \$16{,}114.$$

GCT's Superior Technology:

Reduced energy consumption: If GCT replaces cooling towers or if is placed in a new installation, it will function with existing or designed pumping capacity (no additional electricity is required). If GCT is used as a supplement, it can remove up to 80 % of the load off the existing cooling towers it supplements.

Production improvements: GCTS can address inefficiency problems, which several plants currently face, with a truly affordable solution. Additional cold water in most plants usually takes an enormous capital expenditure; so most plants operate at a fraction of their capacity in warmer months. The increased revenue from the optimization of the plants will usually dwarf the energy savings, especially in petroleum refineries that produce different products depending on the temperature of their process water.

Energy independent: It may seem illogical to stress the significance of losing power in a power plant, but as we saw in the disaster at Fukushima with the primary and backup generators down, it is a major undertaking to circulate and cool water. Our GCT technology can address primary or secondary cooling needs without costly additional and sometimes unreliable backup generators. We believe, GCT can be a key component in making nuclear plants safer.

Environmental Compliance: In today's environmentally conscious world, there is both social pressure and regulatory requirements and incentives for plants to retrofit from open (once through cooling) to closed (cooling tower) cooling systems. This will essentially eliminate about 97 % of the current water demand industrial plants take from clean water sources, such as rivers, lakes and oceans.

The GCTS Approach: GCTS addresses the damage to ecology from the hot water (from once-through cooling systems) discharged into these clean water sources with the most economically feasible approach. GCT will eliminate electrical infrastructure like switchgear, motor control centers, etc., and the electrical engineering involved with the equipment. This upfront expense could be in the order of several million dollars.

Figure 2. Current Installation at CITGO.

Table 1. Additional Revenue from Sales of Saved Energy (1,000 MW Plant).

Tariff ($/kWh)	5 MW Add'l Sales ($ Mn)	20 MW Add'l Sales of Saved Energy ($ Mn)
0.07	$2.76 Mn	$11.04 Mn
0.20	$11.04 Mn	$44.15 Mn

The plant also capitalizes on immediate energy savings from GCT, and can project these cost savings out as long as our cooling tower is in their plant. This could be in the hundreds of millions of dollars.

Further, it can get customers compliant with EPA's 316B (or local regulation) with very little capital expenditure. The US is addressing this environmental issue, and many other countries have taken effective steps in this regard. The largest hurdle for industry to become environmentally compliant has always been the cost. GCT is the solution for many such cases, including once-through cooling and conventional, electric motor operated cooling.

Benefits for Power Plants

A typical thermal power plant uses about 0.5 % to 2.0 % of its gross energy generation in cooling. GCT can enable the plant to save and sell this substantial amount of electricity. For example, in a 1,000 MW plant, it can range between 5 MW and 20 MW (0.5 % to 2 %). At a 90 % PLF and at sales tariffs of $0.07/kWh and $0.20/kWh, respectively, the additional revenues (*which goes directly to Profit Before Tax*) can be significant even for a large utility. Moreover, the capital cost of installing a capacity of 5–20 MW can vary from $5 mn to $20 mn for coal fired power plants, which is avoided by use of GCT.

Further, the power plants may also become eligible for Energy Savings Certificates (ESCs) or some of their variants in countries where energy savings have been adopted to encourage energy efficiency. The following table provides a broad comparative cost structure of a 24-cell and a 72-cell cooling tower using conventional, motor-driven cooling and green cooling. As can be noticed, the use of GCT can bring in significant savings over the life of the cooling tower.

The above table compares the cost savings in electricity costs and O&M costs if conventional CT is replaced with GCT either as a new installation or as a retrofit. With a typical payback period ranging between 4–6 years, GCT becomes a *Profit Center* rather than a *Cost Center* (in other CTs), and its lifetime benefits over 20–25 years far outweigh those of any other cooling tower.

GCT Overview

Improved conditions inside plants: Once installed, customers will benefit from the high reliability of our cooling towers.

Safety: GCT involves no electricity; therefore, GCT avoids any spark hazard or explosion risk, eliminates potential for motor, shaft or gearbox failure which can result in catastrophic damage to structure and dangerous work/repair situation. Lock out/Tag out is accomplished by simply closing a water valve.

Maintenance: GCT eliminates the most troublesome components of the cooling tower (motor, shaft, gearbox, wiring, and switches). It has sealed bearings enclosed in an oil bath, so there are no high maintenance grease points. This brings down substantially the annual maintenance cost of cooling towers.

Table 2. Green Cooling Towers vs. Traditional Motor-driven Cooling Towers.

Green Cooling Towers vs. Traditional Motor-driven Cooling towers

IN USD Cost Items	24-Cell Tower			72-Cell Towers		
	Traditional CT (Motor-driven)	Green CT (GCT)	Net Benefit from GCT	Traditional CT (Motor-driven)	Green CT (GCT)	Net Benefit from GCT
Cooling tower	TBD	Comparable	$0	TBD	Comparable	$0
Civil/Structural/Piping	TBD	Comparable	$0	TBD	Comparable	$0
Mechanical	$8,700,000	$8,700,000	$0	$26,100,000	$26,100,000	$0
Electrical Infrastructure	$6,200,000	$0	$6,200,000	$18,600,000	$0	$18,600,000
Total Capital Cost (Front-end)	**$14,900,000**	**$8,700,000**	**$6,200,000**	**$44,700,000**	**$26,100,000**	**$18,600,000**
Electricity Cost (10-yr)	**$27,594,000**	**$0**	**$27,594,000**	**$82,782,000**	**$0**	**$82,782,000**
O&M (10-years)	**$11,000,000**	**$6,000,000**	**$5,000,000**	**$33,000,000**	**$18,000,000**	**$15,000,000**
TOTAL COST (10-YR)	**$53,494,000**	**$14,700,000**	**$38,794,000**	**$160,482,000**	**$44,100,000**	**$116,382,000**

* These numbers are an approximation based on current market conditions, and will vary depending upon the specifics of each cooling tower, its locations, and the cost of power in local markets.

*O&M costs for wet cooling tower system based on average of $4.00/GPM include routine maintenance activities, chemicals and treatment systems to control fouling, labor, and an allowance for spare parts.

Low noise levels: Lower noise levels from elimination of electric motor improve plant's overall noise pollution.

Reduced Operational Cost: GCT eliminates electricity use while producing better efficiency.

The Green Cooling Tower design is a patented technology (Patent No: US 8,104,746 B2) that has been proven in a real industrial complex and its performance has exceeded expectations.

The Global Context

Electric Motor Driven Systems (EMDSs) are the single largest electrical end-use, accounting for about 7,108 TWh (2006), 43 %–46 % of all global electricity consumption, about 6,040 Mt of CO_2 emissions, and end-users' spend of $565 billion per year on electricity used in EDMS. In the US, it represented about 38 % of the total electricity consumption (total electricity use in 2006: 3,722 TWh). (IEA Report). By 2030, without comprehensive and effective energy efficiency policy measures, energy consumption from EDMS is expected to rise to 13,360 TWh per year, CO_2 emissions to 8,570 Mt per year, and end-users annual spend of $900 billion (IEA Statistics). In the US, in 2011, of the total electricity use of 3,841 TWh, about 440 TWh (11.5 %) was used for cooling (commercial and residential). Use of energy in conventional, electric motor driven cooling towers constitutes an important sub-set of EMDS, where substantial energy efficiencies can be harnessed worldwide. Hence, substitution of conventional cooling by green cooling should be a high priority area for energy efficiency programs of the governments.

Technology Dissemination Worldwide

GCTS is convinced that its Green Cooling Tower is a financially attractive and environmentally friendly alternative to once-through cooling and electric motor operated induced draft cooling towers. It has the potential to achieve significant energy efficiency in the global industrial sector within a span of 5–10 years.

After its successful and seamless operation of over 2 years at Citgo refinery in Lake Charles, LA, the GCT technology has commenced rapid commercialization. If each of the top 100 refineries, power plants, steel plants, chemical plants and process plants can implement GCT technology in the next 3 years, it could certainly materialize a considerable amount of energy savings and improve production process, where ever feasible, resulting in significant savings of resources for the world. GCT welcomes any large utilities, potential users and government teams to visit the Lake Charles facility to see the working of the Green Cooling Towers and explore the potential to use in their respective industrial settings.

Abbreviations

CO_2	Carbon Dioxide
CT	Cooling Tower
eceee	European Council for an Energy Efficient Economy
EMDS	Electric Motor Driven System
EPA	Environmental Protection Agency (US)
ESC	Energy Savings Certificate
GCT	Green Cooling Tower
GCTS	Green Cooling Tower Solutions
HP	Horsepower
IEA	International Energy Agency
kWh	Kilowatt Hour
LA	Louisiana (US)
Mt	Metric Ton
MW	Megawatt
O&M	Operation and Maintenance
TWh	Terawatt Hour