Geothermal Pre-Screening Tool

Waterfront Studies

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Forward

As per New York City Local Law 6 of 2016, a study reviewing the “technical and regulatory feasibility of implementing a geothermal system for waterfront properties within the city by suspending closed loop coils or other heat exchange devices in the marine surface waters around the city” must be completed. Under the guidance of the Mayor’s Office of Sustainability (MOS) and Department of Design and Construction (DDC), Goldman Copeland, along with PW Grosser, developed this report based on actual experience, case studies, and interviews with key parties involved in the design, review, and maintenance of operational river water systems.

Table of Contents

Executive Summary

Through Local Law 6 of 2016, the New York City government established several goals to promote the use of various geothermal systems to reduce the carbon footprint of buildings in the city. While not the primary focus of the law, one type of geothermal system selected for review was the use of river water as a heat sink for heating and cooling systems. Installation of heat exchange devices in marine surface waters near waterfront properties enables the use of river water to supplant the need for cooling towers in the summer and boilers in the winter to condition condenser water for use with water source heat pumps.

This report evaluates two river water based geothermal system types: open and closed loop systems. Open loop systems, which directly intake river water into building systems for use as condenser water, have been in use in the NYC area for some time, with installations serving a number of large commercial buildings in the city. These systems reduce energy consumption somewhat, but the benefits are largely offset by high maintenance costs. Closed loop systems, coupled with water source heat pumps, require the placement of heat exchangers directly in the river, and can off-set both heating and cooling requirements. These systems can generate significant savings, but increased system complexity and maintenance requirements again largely offset the benefits. Both systems have reporting requirements, detailed below, that greatly increase up-front costs. While river water may be the best option for heat rejection in some cases, conventional systems will typically be a lower cost, lower complexity solution.

System Review

A. <u>Overview</u>

A geothermal or ground source heat pump is a central heating and/or cooling system which utilizes the earth as a heat source (in the heating season) and a heat sink (in the cooling season). By taking advantage of this natural resource, the energy impact of these systems is reduced. While the most common form of geothermal system utilizes the earth or ground water for heat exchange, water bodies can be used as an alternative. For New York City in particular, waterfront properties can use nearby rivers for this purpose. Heat exchange with river water can be achieved through either open or closed loop systems, both of which have significant operational challenges.

Open loop systems, which typically require the direct intake of water through sluice gates, have the ability to use cool river water in the shoulder (spring and fall) seasons to provide “free-cooling,” which provides cooling without requiring the use of a compressor. Also, when well-maintained, the heat transfer performance of these systems is superior to that of closed loop systems. Many of these systems were installed in New York City in the 1960s and 1970s, with mixed results (described below). However, in 2011, the New York State Department of Environmental Conservation (NYSDEC) issued Policy CP-#52, which discourages the use of open water loops in favor of embedded heat exchanger systems to reduce environmental impact.

Closed loop systems have been more common in recent installations, many using ‘keel coolers,’ a technology used on large marine vessels as the mode of heat exchange. On marine vessels, keel coolers are pipe systems which are mounted under the hull of the vessel that are used as heat exchangers to cool the engine and other components. By placing these heat exchange devices in the river, systems can still utilize river water as a heat source/heat sink while eliminating the intake of corrosive water and containments. Although system filtration issues are reduced, marine growth and bio-fouling (plants/algae) are a much larger issue in these static installations than when attached to marine vessels. Without regular monitoring and maintenance, heat transfer capacity can be greatly reduced.

Both open and closed loops systems require regular maintenance which can be both difficult and costly. In addition, federal, state and city regulations provide further hurdles to the installation of river water systems. Required permits beyond those of a typical project can include approval from the NYSDEC in several categories, the United States Army Corp of Engineers (USACE), and the NYC Planning Waterfront Revitalization Program, although in most cases the DEC permit is sufficient. Documentation for these applications can be time consuming and costly to complete, and does not guarantee acceptance. These requirements are discussed further below.

While installation of river water systems may reduce the carbon footprint and annual energy consumption costs of some waterfront properties in New York City, the initial installation cost, filing requirements, and ongoing maintenance costs will most likely outweigh these benefits in many cases. The systems are, however, often feasible, and should still be considered where conventional systems are not feasible or ancillary benefits justify the additional costs.

As part of this study, Goldman Copeland reviewed several case studies. Documents on studies and designs were obtained by Goldman Copeland through a request issued to NYSDEC under the Freedom of Information Law (FOIL) for the Intrepid Museum, and through DDC under written approval from the original consultant for Battery Park Pier A. These projects utilize or anticipated use of embedded river water heat exchangers. The Battery Park project evaluated both open and closed loop options.

B. Open Loop Systems

Several open loop river water heat rejection systems have been installed in New York City, including the World Trade Center, 866 UN Plaza, 1 New York Plaza, the UN building, and Con Edison's 14th Street co-generation plant. This technology is not currently in common use and, as noted above, recent regulations have limited their use due to concerns with causing harm to aquatic life through entrainment or impingement. Entrainment is the unwanted passage of fish through the water intake and impingement is physical contact of a fish with the screen/filter due to excessively high intake velocities. Specifically, water systems such as these that use more than 20 million gallons per day (MGD) are prohibited due to their adverse effect on fish and shellfish mortality as per the July 2011, New York State Department of Environmental Conservation (NYSDEC) Policy CP-#52. While it is unlikely that any geothermal installations would approach this flow, smaller systems are discourage in the same policy.

Typical open loop systems intake water through sluice gates, which are fitted with strainers to minimize entrance of particulates into the system. Sluice gates regulate the water intake which is then pumped through a primary condenser water loop. This primary loop can be used either directly for heat rejection if the construction materials are sufficiently robust, or through a secondary heat exchanger with further screens and strainers to provide a barrier between the river water and expensive equipment. Ongoing maintenance of the underwater sluice gates, reservoir, and trash screens at typical installations includes occasional repair and cleaning by divers. The high salinity and particulate content can increase wear and tear on pumps and heat exchangers serving the system. Depending on design, added energy usage of the primary river water pumping loop may exceed the equivalent energy usage of a similarly sized conventional cooling tower based heat rejection system. The primary advantage of river water in most of these installations is the avoidance of loss of space for cooling towers. Use of titanium tubes or heat exchangers mitigates some of these issues.

As noted, filing requirements for the installation of a river water heat rejection system include an Essential Fish Habitat Assessment to prove that the proposed system will not harm fish populations, particularly those of endangered species. Because of the risk to endangered species, the NYCDEC favors the installation of closed loop systems although the open loop systems can still be considered. This study is required for closed loop systems as well.

C. <u>Closed Loop Systems</u>

Closed loop river water systems perform the same function as open loop systems by employing passive, submerged heat exchangers. By circulating a single condenser water loop through this heat exchange device, issues with entrainment of aquatic life and particulate matter is eliminated. However, care must be taken to avoid corrosion of any contact metals. In addition, the system may increase energy and maintenance costs, which is contrary to the goal of reducing carbon emissions.

Closed loop systems mostly use “keel cooler” heat exchangers, a technology commonly used in marine environments for heat rejection from vessels. The keel cooler is typically attached to the hull of the vessel and used to cool the engine and other components as necessary. The moving ship through the water improves heat transfer. The coolers are combined into arrays and can be secured to any piling structure currently in place. In an existing Manhattan installation, these coolers are attached to existing pier structures, with multiple arrays placed vertically on top of each other and horizontally along the pier. By utilizing multiple arrays, it is possible to achieve significant levels of heat rejection through these systems while relying on the river flow and tidal action to destratify thermal discharge.

While geothermal systems can be used with a number of different heating and cooling systems, they are most effective, and provide the most energy savings, when used in conjunction with water source heat pumps. The river water system can be operated through much of the year, providing a heat sink in the summer and a heat source in the winter to the heat pumps. While the energy savings from these systems can be significant, it is offset by a few factors. First, some analyses completed in the New York City area suggest that, at especially low river water temperatures, river water will not achieve high enough temperatures to meet heat pump requirements, and a supplemental boiler plant may be necessary. Also, these systems are typically installed with glycol mixtures instead of pure water, which results in reduced heat transfer efficiency and increased pumping requirements. Before implementation, a detailed study should be completed for the specific location to compare the river water system to a more conventional option.

For the preservation of marine organisms, closed loop systems are preferred to the open loop systems because they do not directly interact with marine life. However, they still present a number of maintenance complications. Although river water is not introduced directly into the piping and main systems, maintaining the keel coolers is a labor-intensive process. Although most of these heat exchangers are constructed of admiralty metals (alloy metal made of a minimum 70% copper), marine growth and biofouling can quickly accumulate on the tube assemblies, requiring routine inspections and cleaning by divers. Reports from existing facilities suggest that cleaning could be required on a monthly to quarterly basis with an increase cleaning during the warmer months. Therefore, if maintenance is not regularly performed, heat transfer could be significantly impacted.

Although keel coolers are designed to eliminate concerns of impingement or entrainment of marine life, they do result in an increase in downstream river temperature which must be measured as per NYSDEC requirements. Previous thermal impact studies suggest that these systems can meet the regulatory requirements. As per Section 10 of the Rivers and Harbors Appropriation Act, the creation of obstructions to navigable waters requires a permit by the USACE. In New York City, these permits are only issued when obstructions are avoided through the utilization of existing piers.

Regulatory Requirements

In addition to the typical Department of Buildings (DOB) filing requirements for new construction projects, utilization of river water for heat rejection purposes triggers a number of regulatory requirements. Therefore, the following documentation must be completed:

- Environmental Assessment for an NYSDEC permit, with the following key concerns:
  - Impact to Natural Resources

        - A thermal impact analysis must be conducted to confirm compliance with NYSDEC thermal criteria.
        - The site location must by reviewed to confirm that there is sufficient depth to sediment to be exempt from consideration as a wetland; most sites along the Manhattan shoreline were found to meet this requirement. Wetland sites would not be conducive to a river water heat rejection system, so it should not be a major concern.
        - An Essential Fish Habitat (EFH) Assessment must be completed to evaluate the impact of the project on local aquatic life, particularly threatened and endangered species.
    - Other components of the environmental assessment must be reviewed, but do not typically create major concerns.
- USACE - Section 10 – Rivers and Harbors Act
    - All projects must prove that no obstructions to navigable waterways are created through the development of the project
- New York City and State Waterfront Revitalization Programs
    - All projects must prove compliance with the goals of these programs

Case Studies

A. <u>Battery Park City, Pier A – Closed Loop River Water System</u>

Pier A in Battery Park City is a 33,000 square foot historic structure located at the southernmost point of Battery Park City. The building was renovated with the goal of implementing many energy savings measures to obtain a LEED Silver certification. Amongst the measures put into place was the use of river water in conjunction with a water source heat pump system with river water used as a heat sink in the summer and a heat source in the winter. The system was sized to provide up to 250 tons of heat rejection, and consists of keel coolers, as described in the technical review section above. A supplementary heating system is installed to operate when river water freezes and to serve a number of supplementary heating systems in the space.

Several analyses were completed during the design phases of this project. Building energy models were compared with a river characteristics evaluation to confirm both that sufficient cooling could be achieved, and that the impact on the river conditions would meet NYSDEC requirements. Similar installations in other locations were reviewed to estimate maintenance requirements. The early engineering recommendations were to use an open loop as opposed to a closed loop since it saved energy costs. However, final implementation was with the closed loop keel cooler system. Shortly after installation and commissioning, the anodes failed along with certain metallic fittings leading to discharge of the propylene glycol into the Hudson and circulation of river water thereby compromising the heat pump units. The system is complex and costly to maintain requiring both wet and dry areas of service. River water heat exchanger repair and maintenance require costly diving services. A full maintenance RFP was released last year by Battery Park City. It appears that maintenance will require expenditures of between $160,000 to $200,000 for a 3 year contract depending on additional replacement parts. This does not include maintenance of the HVAC system.

B. Intrepid Museum – Closed Loop River Water System

The Intrepid Sea, Air, & Space Museum proposed the implementation of a river water cooling system at Pier 86. The system design consisted of 40 keel cooler units combined in a set of eight arrays. The arrays were divided between four locations, each of which stacks two arrays on top of each other. The arrays were stacked such that the lowest is located four feet above the mudline, and there is a four foot space between the two arrays. All arrays were designed to be located along Pier 86 and connected to the pier for support.

The closed loop system provided heat rejection in the summer sufficient to serve two 200 ton gas driven chillers and two 155 ton absorption chillers. The absorption chillers handled the building's base load, and were powered by hot water generated by the facility's Combined Heating, Cooling, and Power (CHCP) system. The gas driven chillers provided supplemental cooling upon demand. As the CHCP system generated heat as a by-product, the river water system was not used as a heat source in the winter. It still operated at low flow, however, to provide cooling to some interior spaces in the Intrepid. According to a former supervising operations manager, these areas of the Hudson are prone to silting up with the nearby luxury boat piers, requiring costly dredging each year. The silt is now required to be deposited approximately 200 miles out at sea.

As part of the design and permitting process, a full environmental assessment of the system was completed. Thermal analysis found that the impact on river water was well within the guidelines set forth by the NYSDEC. The EFH Assessment found that the location of the system is only a transitory location for endangered species such as the Atlantic Sturgeon and Shortnose Sturgeon, and that no risk of entrainment was present. The location of the system was also found to be of sufficient depth to avoid consideration as a wetland. It is likely that the bulk of these findings would be true for many sites within New York City along both the Hudson and East Rivers.

C. 866 UN Plaza – Open Loop River Water System

866 UN Plaza is a mixed use building consisting of two 32 floor residential towers rising above a 6 story commercial office space, constructed in 1965. The building is located between 1st Avenue and FDR Drive, 48th and 49th Streets, and is cooled by two 1,250-ton steam absorption chillers, and one 700 ton electric centrifugal chiller. During initial construction of the building, thermal discharge was designed to utilize East River water rather than a cooling tower largely for aesthetic and land use issues. Three 125 HP river water pumps are used to provide condenser water to three heat exchangers. Two of these heat exchangers serve the absorption chillers, with the third providing water-side free cooling during shoulder season operation. The electric chiller's tubes were constructed from high durability titanium enabling this chiller to directly utilize the river water, although building staff report some corrosion on the water box, which necessitates replacement approximately every four years. Due to high solar gain, cooling is often required in the off-season which can be accomplished with free-cooling when the water temperature is appropriate.

Several maintenance issues are associated with river water use. Although the heat exchangers are constructed of titanium, making them highly resistant to salt water, they collect particulate matter and require cleaning several times a year. Additional challenges associated with using local waterways include the collection of various particulates that settle on heat exchange surfaces as well as the corrosive saline component of the water, which adversely affects many metals. Use of river water requires occasional repair of the underwater sluice gates by divers, ongoing maintenance of reservoir and trash screens and eventual replacement of pumps and piping in contact with the river water. Start-up of the river water pumps is also problematic during low-tide when back pressure is low. Currently, building staff must prime the pumps with a shop-vac to ensure proper operation.

Goldman Copeland has performed current conditions assessments and energy studies for the building over the years, all of which have found that replacement of this system with a conventional cooling tower would reduce energy consumption and maintenance costs, even with increased cooling tower maintenance requirements because of legionella concerns. However, due to issues with available space, there is no future plan to discontinue use of river water at the site.

D. Bear Mountain Inn – Closed Loop Lake Water System

Along with incentives from NYSERDA, a closed loop system was installed with a heat exchanger submerged under nearby Hessian lake for the Bear Mountain Inn HVAC system. Shortly after installation, the heat exchanger silted up and failed. Several attempts were made to clean it, but it was eventually decommissioned and the system converted to conventional boilers and air-cooled HVAC units.

Conclusions

Review of current technology for waterfront geothermal systems suggests that, while these systems may be feasible on waterfront properties throughout the New York City area, regulatory and maintenance issues will make the systems uneconomical in most cases. The closed loop system, which is the preferred option by the NYSDEC, will generate some energy savings. However, in terms of costs, this will be largely offset by the ongoing maintenance costs associated with keeping the heat exchangers free of marine growth and biofouling. As far as initial installation costs are concerned, the increased regulatory requirements will significantly increase up-front soft costs associated with projects, and likely lengthen the installation schedule. Moreover, in all likelihood, most installations will also require boilers to supplement heating, preferably high efficiency non-condensing units. Additionally, the labor intensity of installing the system under water will increase construction costs far beyond the relatively economical installation of cooling towers. We recommend that the use of such systems be considered on a case by case basis, but expect installation to move forward only in cases where a cooling tower is impractical for a site-specific reason.

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