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MEMORANDUM

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ARCADIS Project No.:
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Subject:
Assessment of Sewage Heat Recovery Technology and Applicability to the Milwaukee Metropolitan Sewerage District

EXECUTIVE SUMMARY

In the Milwaukee Metropolitan Sewerage District (District) *2035 Vision Report*, the District stated goals of meeting 100 percent of its energy needs with renewable sources and 80 percent of its energy needs with internal renewable sources. Malcolm Pirnie, the Water Division of ARCADIS (Pirnie/ARCADIS) was retained by the District to perform an assessment of sewage heat recovery technologies and their applicability to the District in an effort to support these goals.

Sewage heat recovery is the capture of heat that is inherent in wastewater, and utilizing that energy to offset heating demands. This is an emerging market within the wastewater sector. A significant number of sewer heat recovery projects have been implemented in Europe, and Canada has several facilities installed. There are facilities in the United States that are currently recovering heat from wastewater treatment plants. One such facility is a pilot installation in Philadelphia, PA. There are very few examples of facilities in the United States utilizing untreated wastewater for heat recovery, though there are several projects in the planning phase, including a full-scale facility in Seattle, WA that is planned for completion in 2015.

Pirnie/ARCADIS first developed a broad listing of commercially available heat recovery systems for decentralized deployment within conveyance systems. From the broad listing of heat recovery technologies, five technologies were selected for comprehensive review. These five technologies are described in this memorandum, and are summarized in Table 1. Additional details regarding the selection of these five technologies are available in Appendix A, and additional information from each manufacturer is provided in Appendix B.

Pirnie/ARCADIS developed a triple bottom line (TBL) evaluation tool to review the five technologies. The TBL evaluation tool is based on a pairwise analysis of elements determined to be important to the District. The elements are contained in three categories:

1. Social
2. Technical and Environmental
3. Economic

The largest difference between technologies is the technical and environmental elements, which includes the risk of cross-contamination, operations and maintenance requirements, and upstream and downstream impacts. In this category, the in-sewer integrated heat exchangers have significant advantages over modular systems. Modular systems have advantages over in-sewer integrated heat exchangers when considering constructability and disruptions to the community. The complete TBL evaluation is available in Appendix C.

Each technology was assessed and is discussed in detail in this memorandum. For each technology, economic calculations were performed. The detailed payback calculations are available in Appendix D. A payback was not available for the evaluated technologies, as positive savings are not generated. This results from the relatively low cost of natural gas, and the relatively high cost of electricity. If the cost of natural gas increases, and the cost of electricity decreases, this would improve the economics.

Using GIS data provided by the District, Pirnie/ARCADIS identified areas within the District conveyance system where deployment of the evaluated technologies may be feasible. Two sets of maps were generated that highlight candidate locations for sewer heat recovery. The following maps are available in Appendix E:

- Potential Candidate Sewers for Sewer Heat Recovery
    - These maps show all potential candidate sewers, regardless of land use type.
    - These maps should be consulted during new development or redevelopment to investigate candidate locations.
- Potential Candidate Locations for Sewer Heat Recovery Based on Existing Land Use
    - These maps highlight areas where potential candidate sewers pass near potential candidate land use types.
    - These areas should be investigated as candidate locations for heat recovery projects.

In addition to these static maps, the Sewer Heat Recovery GIS Tool is available online as an interactive method for evaluating potential candidate locations. The GIS tool can be utilized in the following ways:

- As candidate locations are chosen by the District, the online tool can be utilized to facilitate a detailed feasibility analysis.
- As new development or redevelopment is planned, the online tool can be used to identify opportunities to implement sewer heat recovery.

Early coordination between Municipal and District staff will improve the odds of success for a sewer heat recovery project. The limited number of currently operating sewage heat recovery systems, were initiated during planning of new buildings, and were integrated with the design of the HVAC systems. Early identification of potential candidate locations will allow heat recovery technology to be assessed and considered before the building systems are designed. Early coordination will also allow the District to develop partnership agreements with project owners.

Table 1: Sewer Heat Recovery Technologies

Category	Company Name	Product Name	Description	Applicability	Unique Benefits
Modular Heat Exchange	Huber Technology	ThermWin	• Utilizes a wet well. • Filters wastewater using the "ROK 4" screen. • Utilizes the "RoWin" modular heat exchanger.	• Sewage Flows > 150 gpm • Heating Capacity > 200 mBTU/hr	Company has broad experience with large-scale installations.
	International Wastewater Systems	SHARC	• Utilizes a wet well. • Filters wastewater using the "Sewage SHARC". • Utilizes conventional heat exchangers.	• Sewage Flows > 150 gpm • Heating Capacity > 200 mBTU/hr	
In-Sewer Heat Exchange	Huber technology	TubeWin	• In-pipe heat exchange liner. • Ideal for existing sewers.	• Diam. 36" + • Sewage Flows > 150 gpm • Heating Capacity 100 - 500 mBTU/hr • Slope < 5%	Company has broad experience with large-scale installations.
	Rabtherm Energy Systems	Rabtherm Series	• Series E - In-pipe heat exchange liner. • Series I - Heat exchangers integrated into new pipes.	• Pipe Liner (Series E) Diam. 30"+ • New Pipe (Series I) Diam. 18"+ • Sewage Flows > 150 gpm • Heating Capacity 200 - 500 mBTU/hr • Slope < 5%	Options available for new and existing pipes, and configurations available for atypical sewer shapes.
	Frank Der Vorsprung	PKS-Thermpipe	• Heat exchangers integrated into new pipes. • Heat exchange element is arranged in circumfrential loops around the pipe. • Utilizes heat from wastewater as well as soil.	• Diam. 18" - 72" • Sewage Flows > 150 gpm • Heating Capacity 100 - 500 mBTU/hr • Slope < 5%	Pipe is constructed from a durable Polyethylene material.

SEWAGE HEAT RECOVERY TECHNOLOGY ASSESSMENT

Pirnie/ARCADIS initially developed a broad listing of commercially available heat recovery systems for decentralized deployment within conveyance systems. This listing of technologies was submitted to the District for consideration and is available in Appendix A.

From this list, five technologies were selected for comprehensive evaluation. The selected technologies fall into two main categories.

- Wet Well or Modular Heat Exchange
  - These are systems that remove wastewater from the sewer to perform heat exchange.
  - The heat exchange either occurs in a wet well adjacent to the sewer, or in a structure installed near the sewer.
  - This technology could be utilized at an existing wet well location such as a pump station, though the presence of a pump station is not required.
- In-Sewer Heat Exchange
  - These are systems that utilize a heat exchanger within the sewer.
  - These technologies may be further subcategorized into plates, internal tubes and external tube heat exchangers.
  - Wastewater is not removed from the sewer with these technologies.

An assessment of each technology is provided below. Pirnie/ARCADIS worked with manufacturers and sales representatives to determine where each technology would be best applied. The representative of each technology provided information for what they considered to be a small, medium, or large system. The heating capacity for small, medium and large systems therefore varies for each technology.

The estimated capital cost associated with each technology and system size includes equipment and installation. The equipment and installation costs, as well as detailed economic calculations, are available in Appendix D. In general, equipment costs include heat exchangers, pumps and heat pumps. Installation costs account for labor, piping, and some site modifications.

The scope of this study was limited to heat recovery strategies for the District's conveyance system; however, additional opportunities may exist at the District's wastewater treatment facilities. Modular or in-sewer heat exchangers could be incorporated at the influent or effluent of the treatment facilities. Based on data provided by the District, electricity rates are lower at the treatment facilities, and this would improve the economics of heat recovery. In addition, the treatment facilities receive higher and more reliable flows, likely resulting in a more robust heat recovery system. These factors may warrant additional investigation of heat recovery at the District's wastewater treatment facilities.

WET WELL OR MODULAR HEAT EXCHANGE TECHNOLOGIES

The following two heat recovery systems remove wastewater from the sewer to perform heat exchange. The heat exchange either occurs in a wet well adjacent to the sewer, or in a structure installed near the sewer. This technology could be utilized at an existing wet well location such as a pump station. However, an existing wet well is not required. A manhole can be constructed adjacent to a sewer to utilize the wastewater supply. The manhole is typically 8 feet in diameter. The size of the manhole diameter depends on the exact number of screens or pumps installed. The depth of the manhole is set by the depth of the sewer, with the manhole typically 10 feet below the sewer invert.

ThermWin by Huber Technology

The ThermWin system is manufactured by Huber Technology (Huber). ThermWin performs heat exchange in a wet well adjacent to the sewer, or in a structure installed near the sewer, and is best applied to systems with a wastewater flow of greater than 150 gallons per minute (gpm).

In the ThermWin system, a side stream of wastewater is removed from the sewer and screened in a Rok 4 screen as manufactured by Huber. The system vertically lifts the screenings using a screw, which both automatically cleans the screen and washes and compacts the screenings. Screenings are then returned to the sewer for treatment at the wastewater treatment facility. The screens are available in a range of sizes, with a screen basket diameter ranging from 1.0 to 2.25 feet. The largest screen can provide a flow rate of up to 1,900 gpm. The RoK 4 screen is well established. It has been used in a variety of wastewater applications, not only sewer heat recovery. This system does not require separate water for its cleaning cycle.

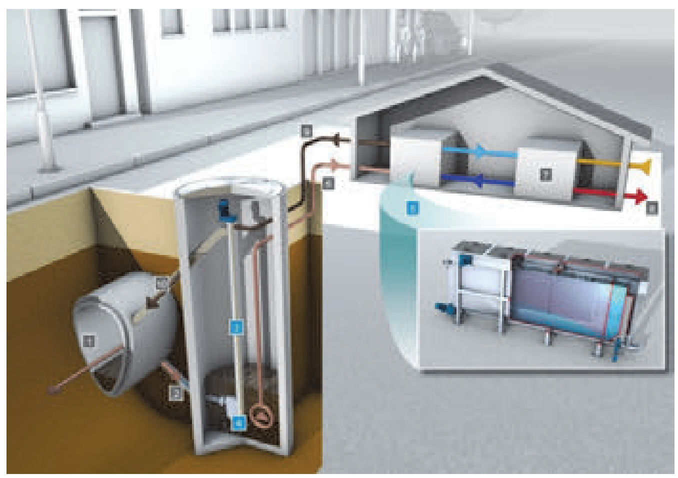

Figure 1: Schematic Drawing of a typical ThermWin System (Provided by Huber)

Screened wastewater is pumped to the RoWin heat exchanger. The heat exchanger consists of a stainless steel tank with several tube loops. Wastewater is piped through the tank, and the heat is exchanged with clean water in the tubes. The clean water, which has been warmed in the heat exchanger, then reaches a heat pump and/or a boiler, where the temperature is further increased for use in a facility. The heat pump adds heat to the building’s heating water connection,

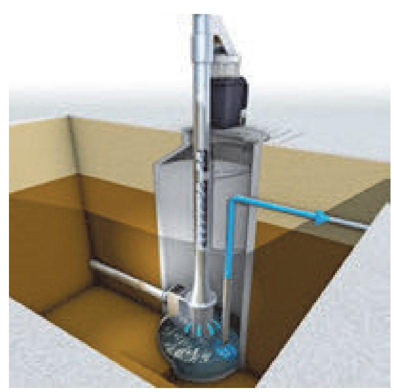

Figure 2: Schematic Drawing of HUBER’s RoK 4 Screen (Provided by Huber)

reducing the heating requirements on the facility's boiler, or other heating equipment. The wastewater removed from the conveyance system is cooled by approximately 3.5 °F, and is returned to the sewer, along with screenings. Cross contamination between wastewater and the building's heating or domestic hot water is possible with a failure of the heat exchanger. The risk of such contamination can become significant in poorly maintained systems, but is not generally a concern for systems with proper maintenance, and frequent inspections and systems that incorporate backflow prevention systems.

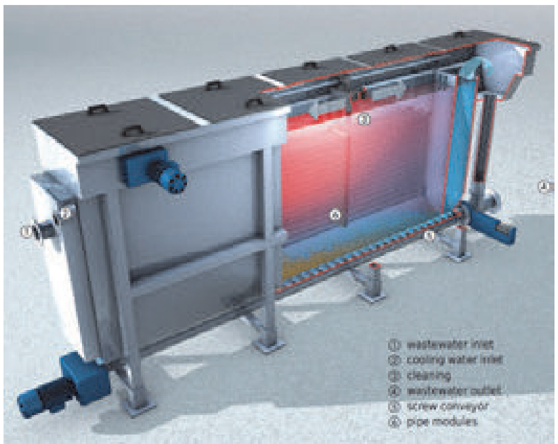

Figure 3: Schematic Drawing of RoWin Heat Exchanger (Provided by Huber)

The heat pump is not included with the ThermWin system, and must be acquired separately. The estimated price of a heat pump has been included in Table 2. Periodic cleaning is required at the heat exchanger to prevent bio-fouling by removing accumulated debris. This is performed automatically by a wiper system built into the heat exchanger. The heat exchange wiper operates on a timer, clearing the heat exchangers approximately once each hour. This automatic cleaning cycle reduces operations and maintenance costs. Occasionally, the system will be cleaned with an acid wash or anti-scaling agent. Wipers are recommended to be changed every 2 to 5 years.

A single RoWin heat exchanger is adequate for delivering approximately 850 mBTU/hr to a heat pump. The heat pump can then provide 1,000 mBTU/hr to the building's heat system. In this situation, the heat pump would draw approximately 120 kW of electricity. This assumes a heat pump efficiency of 80%. A small motor of approximately 1 horsepower (hp) is required to circulate the wastewater to the heat exchanger.

Huber has successfully implemented several large heat recovery projects using the ThermWin system. A recent ThermWin installation in Quebec, Canada has a heating capacity of 1,100 mBTU/hr, and flow rates ranging from 150 to 450 gpm.

Table 2: Summary of the ThermWin System

System Size	Heating Capacity (mBTU/hr)	Minimum Dry Weather Flow (gpm)	Equipment Cost	Installed Cost
Small	400	200	$250,000	$500,000
Medium	800	300	$325,000	$650,000
Large	1,200	400	$400,000	$800,000

*The costs presented in Table 2 do not include any significant modifications to the existing heating system, and do not include a structure to house the equipment.

SHARC System by International Wastewater Systems

The SHARC system is a pre-engineered packaged wastewater heat recovery system manufactured by International Wastewater Systems (IWS) in British Columbia, Canada. It features a self-contained clog-proof filtering system that reduces potential odor issues and fouling of the heat exchanger by reducing the formation of a biofilm. The SHARC system screens wastewater in a wet well adjacent to the sewer, and performs heat exchange in the facility, or in a structure installed near the sewer.

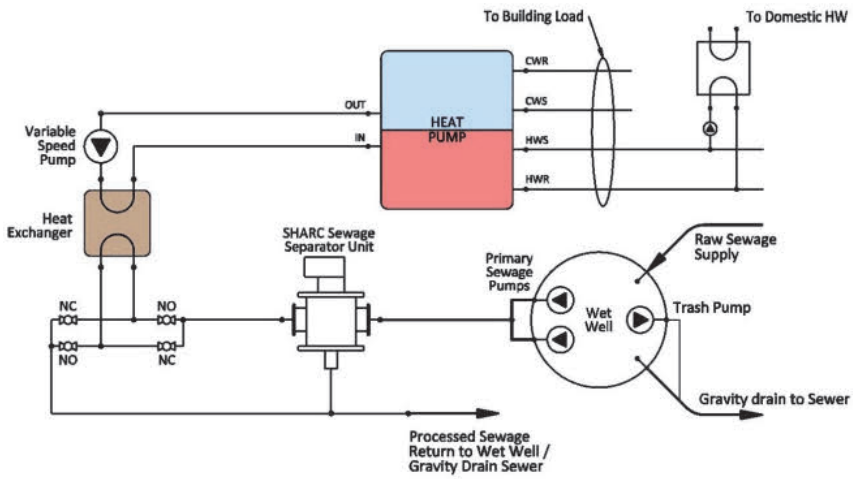

Figure 4: Schematic of the typical SHARC System (Provided by IWS)

The SHARC series sewage heat recovery system is available in diameters ranging from 4 inches (200 gpm) to 8 inches (1,000 gpm). The diameter refers to the influent pipe connection of the SHARC sewage separator unit. Multiple units can be installed to utilize higher flows. The anti-clogging mechanism of the SHARC separator utilizes spinning blades that continuously clean the auger mechanism. This system does not require any separate water for its cleaning cycle.

Figure 5: Sewer SHARC wastewater screen (Provided by IWS)

The SHARC system is available with or without heat pumps. Heat pumps are included in the costs in Table 3. Heat pumps are available in standard or high-temperature versions, with exiting water temperatures that range from 100°F to 160°F.

In addition to the heat pump, the SHARC system includes the following components:

- Sewage SHARC (for screening of wastewater)
- Heat Exchanger
- Pumps (2 source pumps and 1 load pump)
- Control System and Master Electrical Control Panel

SHARC systems have recently been installed in several communities in British Columbia, Canada. The systems at the Seven35 and the Sail communities in British Columbia have capacities of approximately

200 mBTU/hr. The Seven35 system is utilized for domestic hot water. The Sail Community system produces hot water and also contributes to heating the building via radiant floor heating. There is also a $3.5 million SHARC installation in design for Seattle, WA, expected to be complete in 2015.

Table 3: Summary of Costs for the SHARC System

System Size	Heating Capacity (mBTU/hr)	Minimum Dry Weather Flow (gpm)	Equipment Cost	Installed Cost
Small	200	n/a	$160,000	$400,000
Medium	2,200	400	$400,000	$980,000
Large	4,400	800	$650,000	$1,350,000

IN-SEWER HEAT EXCHANGE TECHNOLOGIES

The following three systems utilize a heat exchanger within the sewer pipe. These technologies may be further subcategorized into heat exchange liners for existing sewers, and heat exchangers integrated into new pipes. Wastewater is not removed from the sewer with these technologies.

TubeWin by Huber Technology

The TubeWin system is a heat exchange liner intended for use in existing sewers. A system is comprised of heat exchange modules that are 4.25 feet in length, generally arranged in pairs along the base of a sewer. While the paired configuration is common, the modules can be configured within the sewer as a single row for smaller sewers, or in multiple rows for larger sewers. The TubeWin system is best applied where 70 to 500 mBTU/hr is needed, in a sewer greater than 36 inches. Based on a temperature differential of 2°F, each module will transfer roughly 3,400 BTU/hr.

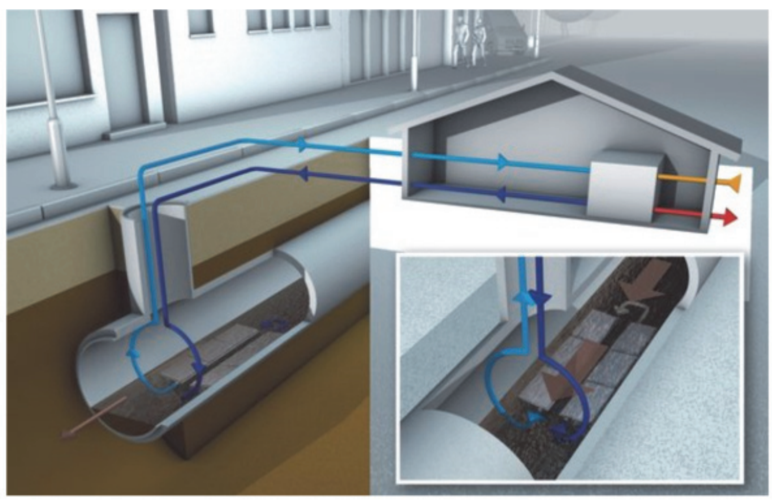

Figure 6: Schematic Drawing of TubeWin System (Provided by Huber)

The practical minimum application of the TubeWin system is 15 pairs of heat exchange modules, which utilizes approximately 70 feet of sewer length. This provides 10.2 mBTU/hr of energy with the assumed energy transfer stated above, representing the heat transferred from the wastewater to the heat exchanger.

The practical maximum application is 75 pairs of heat exchange modules, which utilizes approximately 330 feet of sewer length. This provides 500 mBTU/hr of energy to the heat exchanger.

The TubeWin liners will reduce the cross sectional area in the pipe available for conveying flow. The reduction in area is relatively small when the heat exchangers are installed in a large pipe. The reduction in area is relatively large when the heat exchangers are installed in a small pipe. The cross sectional area of the pipe is reduced between 2% and 15%, which reduces the wet weather capacity of the sewer.

The liners are designed to be streamlined and to minimize accumulation of grit and rags. However, this technology is new enough that the effects of long-term use and service are relatively unknown. For example, the manufacturer does not provide guidance on sewer cleaning methods. It is expected that periodic cleaning of the heat exchange liner will be required.

Table 4: Summary of the TubeWin System

System Size	Heating Capacity (mBTU/hr)	Minimum Dry Weather Flow (gpm)	Equipment Cost	Installed Cost
Small	120	n/a	$115,000	$230,000
Medium	300	n/a	$290,000	$580,000
Large	600	n/a	$510,000	$1,020,000

A small pump is required to circulate the heat exchange water. This pump is typically controlled by the heat pump control system. The heat pump is not included with the TubeWin system, but the estimated cost of a heat pump has been included in Table 4.

Modules are currently priced at $2,400, which includes shipping but not installation. The modules are manufactured in Berching, Germany. Huber Technology also has a facility in Huntersville, NC that provides services for repair and maintenance.

Rabtherm Series by Rabtherm Energy Systems

Rabtherm manufactures a variety of sewer heat recovery products. For broad applicability at the District, the following products were examined in depth.

- Series E - heat exchange liners for existing sewers
- Series I - heat exchangers integrated in new pipes

For installation of a Series E system in an existing sewer, the minimum pipe diameter is 30 inches. For installation of a Series I system in a new sewer, the minimum pipe diameter is 18 inches.

Ideally, the distance from the sewer to the consumer is less than 800 feet. Rabtherm assumes an output water temperature of 158°F. For each square yard of heat exchanger area provided, approximately 5 to

35 mBTU/hr of heat extraction is expected (before the heat pump). The recommended minimum installation size is 200 mBTU/hr.

Based on a review of case studies for ten Rabtherm installations, the minimum flow at the project location ranged from 175 gpm to nearly 5,000 gpm. A common installation length is 100 to 200 feet of heat exchanger, resulting in a heat extraction of approximately 350 mBTU/hr.

All components installed in the sewer are stainless steel. An anti-fouling system is used that consists of thin copper strips spaced every 10 feet.

Figure 7: Rabtherm Series I, Integrated Heat Exchangers (Provided by Rabtherm)

The Series I system, with heat exchangers integrated into new pipe, has no reduction in flow area. All piping and heat exchange plates are contained within the wall of the pipe. The wall of the pipe is therefore thicker than a conventional pipe. The Series E system, with heat exchangers installed within existing sewers, reduces the cross sectional area anywhere from 2% to 18%. As with the TubeWin system, the reduction in area is relatively small when the heat exchangers are installed in a large pipe. The reduction in area is relatively large when the heat exchangers are installed in a small pipe.

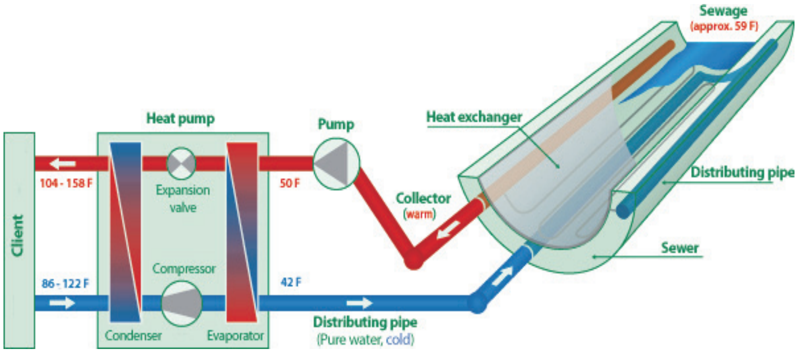

Figure 8: Schematic of Rabtherm Series I (Provided by Rabtherm)

For heat exchangers installed within an existing sewer, the cost of a medium sized system with piping is approximately $780 per linear foot, with an installation cost of approximately $215 per linear foot. Heat exchangers integrated into new sewers are more expensive, by approximately $122 per linear foot. However, installation costs are only slightly higher than installation costs for a standard sewer.

Table 5: Summary of the Rabtherm System (Series E and I)

System	Heating Capacity (mBTU/hr)	Minimum Dry Weather Flow (gpm)	Equipment Cost	Installed Cost
Medium Series E (Liner in Existing Pipe)	400	320	$240,000	$480,000
Medium Series I (Integrated Liner in New Pipe)	400	320	$270,000	$540,000

The Rabtherm system can be paired with a heat pump, and the estimated cost of a heat pump has been included in Table 5. Rabtherm does not manufacture heat pumps. The Rabtherm system can also be used alone to pre-heat water used in a boiler.

PKS-Thermpipe by Frank Der Vorsprung

The Profile Sewer System Thermpipe (PKS-Thermpipe) is manufactured in Germany by Frank Der Vorsprung (FDV). It is a polyethylene pipe surrounded by circumferential loops that transfer heat to a boiler and/or heat pump. The heat pump is a companion technology, and is not included with the PKS-Thermpipe system.

The PKS-Thermpipe is unique due to its polyethylene material, which will likely provide greater durability than concrete pipe alternatives. PKS-Thermpipe also has the unique advantage of drawing heat from both the wastewater and the surrounding soil. The soil around the sewer has an elevated temperature due to the presence of the warm sewer. The PKS-Thermpipe system is therefore less dependent on daily flows. The system is not heavily impacted by irregular wastewater discharges. It acts as a hybrid between a sewer heat recovery system and a geothermal heat recovery system.

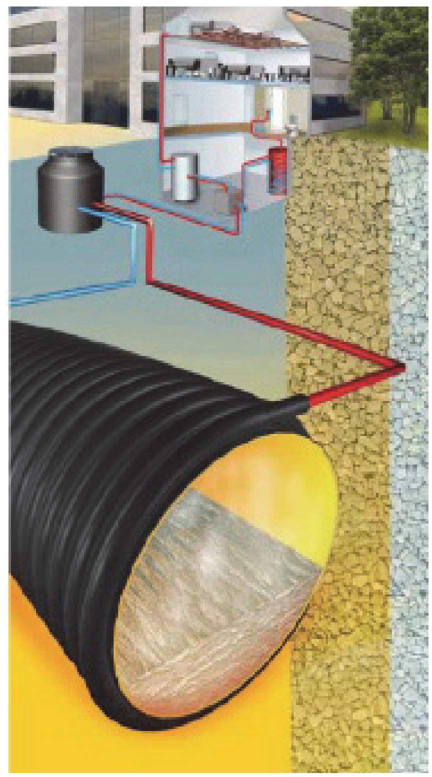

Figure 9: Schematic of PKS-Thermpipe Heat Exchanger

PKS-Thermpipe is currently available in sizes ranging from 12-inch to 72-inch diameter. The expected heat extraction for PKS-Thermpipe ranges from 375 BTU/hr per linear foot for 12-inch pipe, to 1,900 BTU/hr per linear foot for 72-inch pipe. The pipes are manufactured in standard lengths of 20 feet.

The PKS-Thermpipe system is recommended for consumers with a heating system located less than 1,000 feet from the sewer. Ideally, the sewer should carry a minimum dry weather wastewater flow of 240 gpm. However, the PKS-Thermpipe system can operate during lower flows because it draws heat from the soil surrounding the sewer pipe.

There are multiple PKS-Thermpipe heat recovery systems installed in Germany and one installation in France. There are currently no installations in the United States or Canada.

Table 6: Summary of the PKS-Thermpipe System

System Size	Heating Capacity (mBTU/hr)	Minimum Dry Weather Flow (gpm)	Equipment Cost	Installed Cost
Small	95	120	$45,000	$95,000
Medium	1,150	320	$300,000	$600,000
Large	4,900	4,800	$800,000	$1,600,000

SUMMARY OF SEWER HEAT RECOVERY TECHNOLOGIES

All of the five sewage heat recovery technologies are customizable based on the heat recovery objectives of the District. However, each system has definitive individual strengths and weaknesses and no single technology will suit all needs of the District. The modular systems (ThermWin and SHARC) are primarily limited by the wastewater flow, temperature and area available for the footprint of the equipment. Wastewater is removed from the sewer prior to heat exchange. The in-sewer systems (TubeWin, Rabtherm and PKS-Thermpipe) are primarily limited by the condition of the existing sewers, length of straight runs, slope and wastewater flow.

Based on the economic analysis, a payback was not available for the evaluated technologies as positive savings are not generated. This results from the relatively low cost of natural gas and the relatively high cost of electricity. If the cost of natural gas increases and the cost of electricity decreases, this would improve the economics.

This assessment does not take into consideration external cost factors, such as avoided costs for replacing a boiler or existing heating unit near the end of its useful life. In order for the modular systems to be considered for implementation based on economics alone, these external cost factors would need to reduce the simple payback to less than 15 to 20 years (the expected life of the mechanical equipment). A similar assessment applies to the in-sewer heat exchange systems. The technology is relatively new, and lifespans have not been effectively observed. The in-sewer heat exchange liner systems (TubeWin and Rabtherm Series E) should have a payback of 20 years or less in order for the District to consider them for implementation based on economics. Heat exchangers integrated into the sewer (PKS-Thermpipe and Rabtherm Series I) may provide flexibility to increase the payback to less than a 50-year threshold, as both concrete and thermoplastic sewers have 50+ year life spans. For sewers that are scheduled to be replaced due to capacity limitations and deterioration, the cost for replacing the sewer may be factored into the overall cost to improve the economics of an integrated in-sewer heat exchanger.

Pirnie/ARCADIS developed a triple bottom line (TBL) evaluation based on a pairwise analysis of the concepts determined to be important to the District that encompassed social, technical and environmental and economic considerations. Each technology was assessed as an installation that was suited for the technology.

The largest difference between technologies is the technical and environmental consideration, which includes the risk of cross-contamination, operations and maintenance requirements, and upstream and downstream impacts. In this category, the in-sewer integrated heat exchangers have significant advantages over modular systems. Modular systems have advantages over in-sewer integrated heat exchangers when considering constructability and disruptions to the community. Refer to Appendix C for the complete TBL matrix. The District retains a working copy of the TBL matrix spreadsheet, and can modify the tool to evaluate additional technologies as necessary.

The system costs and heating capacities are summarized in Figure 10. The figure illustrates that larger systems (heating capacities from 400 to 5,000 mBTU/hr) provide a greater heating capacity per capital dollar spent. Larger systems provide a better value. Please note that this cost curve is for budgetary purposes only and does not include site-specific information.

The capital cost of some technologies may be offset by “credits,” such as:

- If a sewer requires replacement, this is a potential opportunity to install a heat exchanger integrated in a new sewer. The sewer installation cost would have been incurred regardless of a sewer heat recovery project. The cost of installation for the in-pipe integrated heat exchanger could be offset by the installation cost of a traditional sewer.
- Heat pumps are common in sewer heat recovery technologies. However, the heat pump may replace a traditional heating component such as a boiler.

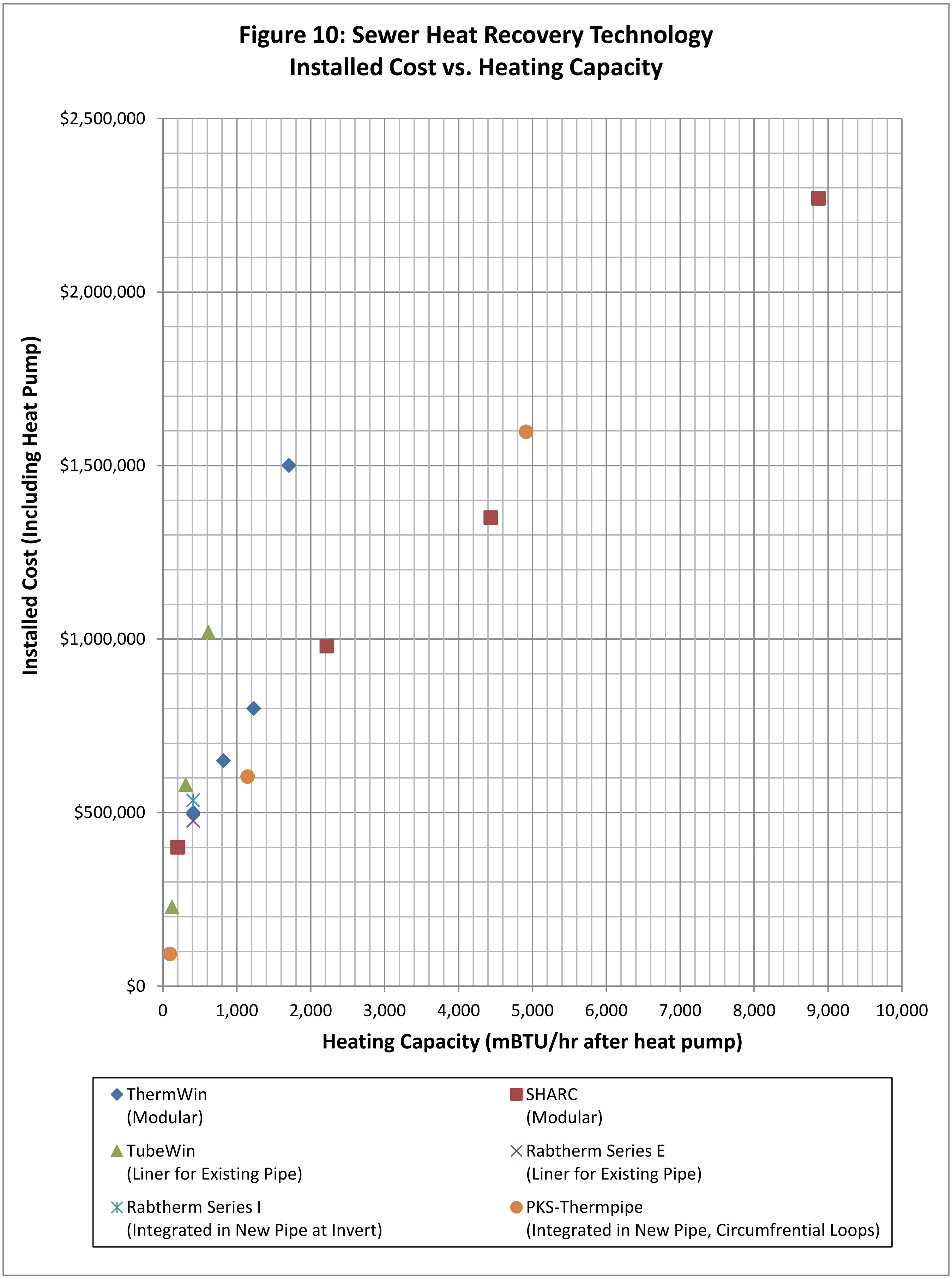
Figure 10: Sewer Heat Recovery Technology
Installed Cost vs. Heating Capacity
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
Installed Cost (Including Heat Pump)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Heating Capacity (mBTU/hr after heat pump)
ThermWin
(Modular)
SHARC
(Modular)
TubeWin
(Liner for Existing Pipe)
Rabtherm Series E
(Liner for Existing Pipe)
Rabtherm Series I
(Integrated in New Pipe at Invert)
PKS-Thermpipe
(Integrated in New Pipe, Circumfrential Loops)

COMPANION TECHNOLOGIES

For the five technologies reviewed, a heat pump is the primary companion technology. A heat pump converts the low-temperature heat recovered from the sewer into high-temperature heat that can be used in building heating or hot water systems. A heat pump is not necessarily incorporated in a heat recovery system, but it is common. If recovered sewer heat is to be used directly for building heat or hot water, a heat pump will increase the recovered heat to a suitable temperature. Recovered heat can also be used to preheat a boiler or a domestic hot water system.

Water reuse technology was also investigated as a companion technology. It does not appear feasible to add water reuse technology unless there is a large industrial facility that can utilize the reused water.

APPLICABILITY TO DISTRICT

The following summary provides an assessment of candidate locations for sewer heat recovery technology within the District's system.

Using GIS data provided by the District, Pirnie/ARCADIS identified areas within the District conveyance system where deployment of the evaluated technologies may be feasible. Two sets of maps were generated that highlight candidate locations for sewer heat recovery. The following maps are available in Appendix D:

- Potential Candidate Sewers for Sewer Heat Recovery
    - These maps show potential candidate sewers that were selected based on size, slope, age and rehabilitation schedule, as outlined below:
        - Sewers with a diameter smaller than 18 inches were not included due to expected low wastewater flow rates.
        - Sewers with slopes greater than 5 percent were not included in the maps due to high velocities and diminished heat exchange efficiency.
        - Sewers used exclusively for wet weather conveyance and storage were not included due to intermittent flows and low temperatures.
        - Inverted siphons, pressurized sewers, and force mains were not included.
    - These maps should be consulted during new development or redevelopment to investigate candidate locations.
    - The best technology for heat recovery depends on the sewer size, age, and configuration as well as the heat requirements of the building. The applicability of each technology is outlined in Table 1 of this memorandum, and is discussed in detail in the section "Sewage Heat Recovery Technology Assessment."
- Potential Candidate Locations for Sewer Heat Recovery Based on Existing Land Use
    - These maps highlight areas where potential candidate sewers pass within 500 feet of a potential candidate land use type. These potential candidate land use types are outlined below:

        - Residential: Multi-Family, 4 stories or greater (land use code 142)
        - Government and Institutional: Administrative, Safety, and Assembly (land use codes 611, 612)
        - Government and Institutional: Educational (land use codes 641, 642)
        - Government and Institutional: Group Quarters (land use codes 661, 662)
    - The highlighted areas should be investigated as potential candidate locations for heat recovery projects based on current land use.
    - Although most of the highlighted areas are not owned by the District, the District may consider partnering with these public and institutional facilities in support of broader greenhouse gas emission reduction goals.

MMSD Pump Stations

In addition to reviewing general applicability of sewer heat recovery within the District's system, Pirnie/ARCADIS reviewed applicability for several facilities operated by the District. Three pump stations in the District system were identified as constant-use stations, as opposed to wet weather pump stations with intermittent flows. These are the Beach Road, Ravine Lane, and Port Washington Road pump stations.

The Beach Road pump station is located on a 10-inch sewer in a sparsely developed residential area. Based on the small diameter of this sewer, flow rates at this location may be insufficient to support sewage heat recovery. In addition, the catchment for this sewer is a sparsely-developed residential community. This indicates that the sewer heat may be lower than average. There may not be sufficient flow or heat available in this sewer to sustain a sewer heat recovery system. If flows are generally greater than 150 gpm, then building heat may be provided by heat recovered from wastewater.

The Ravine Lane pump station is not located on a District sewer, but on a local municipally-owned 10-inch sewer. Similar to the Beach Road pump station, the catchment for the Beach Road Pump Station is a sparsely-developed residential community. There may not be sufficient flow or heat available in this sewer to sustain a sewer heat recovery system. If flows are generally greater than 150 gpm, then building heat may be provided by heat recovered from wastewater.

The Port Washington pump station is located at the intersection of a 39-inch sewer and a 20-inch sewer. The catchment area for the pump station is residential, along with several schools. The catchment area for the Port Washington pump station is more densely populated than the Beach Road and Ravine Lane pump stations, and is likely a better location for sewer heat recovery due to the higher volume of flow. If flows are generally greater than 150 gpm, then building heat may be provided by heat recovered from wastewater.

The flows to the pump stations should be reviewed to determine if sufficient heat is available for a heat recovery system to heat the pump stations. If the sewers are in good condition and sufficient space is available, a modular system or an in-pipe heat exchange liner could be implemented. If influent sewers are determined to need repair, then an integrated in-pipe heat exchanger should be considered.

Wastewater Treatment Plant

The scope of this assessment was limited to heat recovery strategies for the District's conveyance system. Additional opportunities for heat recovery at the District's wastewater treatment facilities are not addressed in detail in this report, but they warrant further investigation for several reasons:

- Wastewater treatment facilities receive wastewater with a more consistent base flow and temperature than the collection system, likely resulting in a more robust heat recovery system.
- Heat exchangers could be incorporated atthe wastewater treatment facility influent or effluent.
- There are usually higher heating loads at the wastewater treatment facilities that would directly utilize recovered heat.

Economics appear to be more favorable for heat recovery at a wastewater treatment facility. Electricity rates are lower at the wastewater treatment facilities than within the collection system, yielding lower operating costs.

APPENDICES

Appendix A – Memorandum, Selection of Five Manufacturers/Technologies for Evaluation

Appendix B – Manufacturer Information

Appendix C –Triple Bottom Line Technology Comparison Tool

Appendix D – Payback Calculations

Appendix E – Maps

MALCOLM PIRNIE | ARCADIS

Appendix A

Memorandum, Selection of Five Manufacturers/Technologies for Evaluation

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MEMO

To:
Debra Jensen (MMSD)

Copies:
Mike Harvey (Pirnie/ARCADIS)
David Railsback (Pirnie/ARCADIS)

From:
Rob Ostapczuk (Pirnie/ARCADIS)

Date:
4/29/13

ARCADIS Project No.:
05193010.0000

Subject:
Milwaukee MSDS Sewage Heat Recovery
Selection of Five Technologies for Evaluation

INTRODUCTION

This memorandum provides an overview of the five technologies which have been selected for comprehensive evaluation under Task B of the *Assessment of Sewage Heat Recovery Technology and Applicability to the Milwaukee MSD System*.

Pirnie/ARCADIS developed a broad listing of commercially available heat recovery systems for both wastewater treatment facility effluent and decentralized deployment within conveyance systems. This listing of technologies was submitted to the District for consideration and is presented in Table 1. Technologies are generally grouped in one of six categories – wet well or modular heat exchanger, in-sewer heat exchanger, commercial/industrial, residential, laundry or not applicable. Table 1 provides a brief description of each technology.

Table 1 – Commercially Available Heat Recovery Technologies

Category	Company Name	Product Name	Description/Applicability
Wet Well or Modular Heat Exchange	International Wastewater Systems	SHARC	The SHARC system utilizes a wet well, and it filters wastewater. The system uses conventional heat exchangers and heat pumps.
	Huber Technology	ThermWin	ThermWin is Installed in a wet well, and filters wastewater using "ROK 4" screen. Heat is transferred with the "RoWin" modular heat exchanger. RoWin uses a discharge screw to transport debris to the sewer.
	KASAG	Double	Sewage passes through the inner tube of 2-tube modular heat exchanger. It is intended for "buildings, sewers or sewage works."
	KASAG	Clean	Heat exchange and filtering is performed in a 500-10,000 liter SS container. Designed for multi-family dwellings, residential building groups, community buildings, and hotels.
	EnviroSep		EnviroSep manufactures modular heat transfer systems for industry, including wastewater heat recovery, cooling water return, and hot water systems.
In-Sewer Heat Exchange	Huber Technology	TubeWin	In-pipe heat exchange liner for existing sewers.
	KASAG	GravityTube	GravityTube is a sewer pipe with integrated heat exchange.
	KASAG	PressurePipe	PressurePipe is similar to GravityTube, except the heat exchange elements are above the sewer pipe rather than beneath it.
	KASAG	Sewer	In-pipe heat exchange liner for existing sewers.
	Rabtherm Energy Systems	Rabtherm Series	Heat recovery systems for new or existing sewers, as well as pressure pipe, flat panel, or custom configurations.
	SewerVision	Therm-Liner	In-pipe heat exchange liner for existing sewers.
	Frank Der Vorsprung	PKS - Thermpipe	Thermpipe is a sewer with integrated heat exchange. The heat exchange element is arranged in circumfrential loops around pipe.
Commercial, Industrial, Laundry	Ellis Corporation (Ludell Manufacturing)		Ellis Corporation designs and fabricates standard and custom heat exchange systems.
	RenewABILITY Energy Inc.	Power-Pipe	The Power-Pipe system transfers drain water heat to incoming fresh water. Residential or Commercial applications. Available in 2-6" diameter.
	ReTherm		ReTherm transfers drain water heat to incoming fresh water. Available in 3-4" diameter.

Table 1 (continued)

Category	Company Name	Product Name	Description/Applicability
Residential	RenewABILITY Energy Inc.	Power-Pipe	The Power-Pipe system transfers drain water heat to incoming fresh water. Residential or Commercial applications. Available in 2-6" diameter.
	ReTherm		ReTherm transfers drain water heat to incoming fresh water. Available in 3-4" diameter.
Laundry	Kemco Systems		Laundry heat recovery systems.
	Thermal Engineering of Arizona		Laundry heat recovery systems.
NA	WaterFilm Energy	GFX	More Information Required
NA	NoveThermal Energy		More Information Required

From this list, five technologies have been identified for comprehensive evaluation. During the evaluation, Pirnie/ARCADIS will assess physical requirements, need/opportunity for pre-treatment, cost, reliability, construction materials, maintenance requirements, parasitic energy use, etc. Internet searches and correspondence/interviews with manufacturers, industry associations and users will be relied upon to gather data.

SELECTED TECHNOLOGIES

The five selected technologies are outlined in Table 2. The selected technologies fall into two main categories. The first category, “Wet Well or Modular Heat Exchange” are systems which remove wastewater from the sewer to perform heat exchange. The heat exchange either occurs in a wet well adjacent to the sewer, or in a structure installed near the sewer. This technology could be utilized at an existing wet well location such as a pump station, though the presence of a pump station is not required. The second category, “In-Sewer Heat Exchange” are systems which utilize a heat exchanger within the sewer pipe. These technologies may be further subcategorized into plates, internal tubes and external tube heat exchangers. Wastewater is not removed from the sewer with these technologies.

Table 2: Five Technologies for Comprehensive Evaluation

Category	Company Name	Product Name	Description/Applicability
Wet Well or Modular Heat Exchange	International Wastewater Systems	SHARC	The SHARC system utilizes a wet well, and it filters wastewater. The system uses conventional heat exchangers and heat pumps.
	Huber Technology	ThermWin	ThermWin is Installed in a wet well, and filters wastewater using "ROK 4" screen. Heat is transferred with the "RoWin" modular heat exchanger. RoWin uses a discharge screw to transport debris to the sewer.
In-Sewer Heat Exchange	Huber Technology	TubeWin	TubeWin is an in-pipe heat exchange liner for existing sewers.
	Rabtherm Energy Systems	Rabtherm Series	Rabtherm provides heat recovery systems for new or existing sewers, as well as pressure pipe, flat panel, or custom configurations.
	Frank Der Vorsprung	PKS - Thermpipe	Thermpipe is a sewer with integrated heat exchange. The heat exchange element is arranged in circumfrential loops around pipe.

Several factors influenced the selection of these five technologies. Each of the technologies appear applicable to the District’s collection system, and the manufacturers have implemented projects in the United States or abroad. The manufacturers also have sales representatives in the United States or responsive technical specialists to facilitate the comprehensive evaluation. Based on the District’s needs, ARCADIS selected three in-sewer heat exchange technologies and two wet well or modular heat exchange technologies for in-depth review. Some of the in-sewer heat exchange technologies are more applicable to new sewer installation and others are more suited to rehabilitation projects in existing systems. ARCADIS has selected a variety of options from the most promising technologies. The availability of adequate after the sale support in the United States was a factor in the selection.

Appendix B

Manufacturer Information

Manufacturer Information:

ThermWin

Huber Technology

HUBER RoWin Heat Exchanger

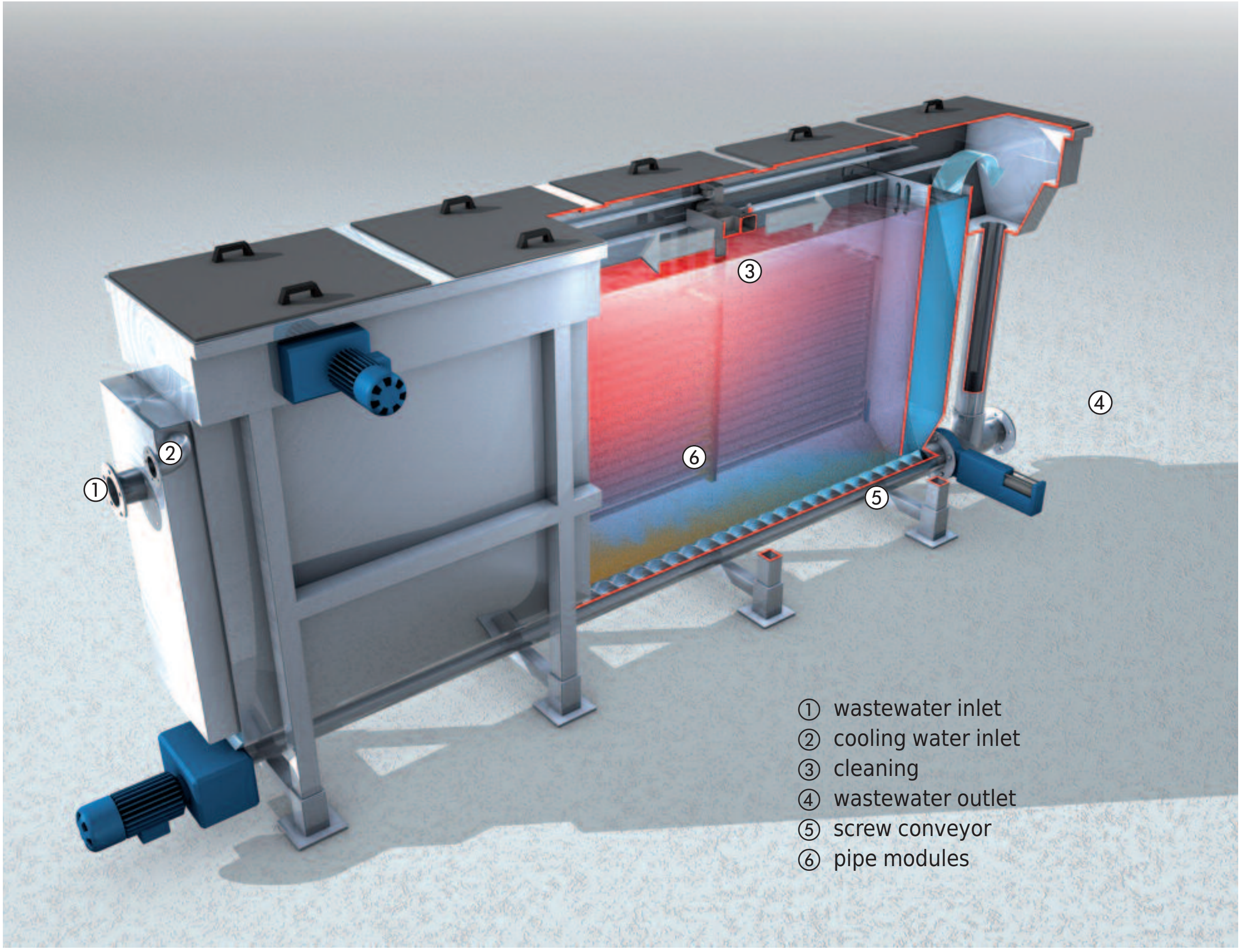
- Modular design
- Developed especially to be used with wastewater and sludge
- Not easily affected by coarse and floating material
- Odour-tight
- Low maintenance requirements
- Self-cleaning

Design and function of the HUBER RoWin Heat Exchanger

The HUBER RoWin Heat Exchanger consists of a welded stainless steel construction in which horizontal pipe modules are arranged in parallel. The pipe modules are made of stainless steel to achieve maximum heat transfer efficiency. The pre-screened wastewater flows through the heat exchanger and, via the compactly arranged pipes, gives off its thermal energy to the cooling water. The energy for the heat pump is supplied through the heated cooling medium. Due to the specific chemical-biological properties of wastewater a biofilm is developed over time on the heat transfer surfaces that significantly impairs heat transfer. Preventive cleaning of the heat transfer surfaces therefore is applied to ensure the maximum heat transfer capacity is permanently maintained. Sediments and solids settling on the tank floor are removed by a screw conveyor and returned to the sewer along with the cooled wastewater.

Due to the enclosed tank design and return of solids thermal energy is the only emission from wastewater.

The HUBER RoWin Heat Exchanger is available, as required, with an outer insulation for particularly exposed sites. Installed above ground, the system offers the benefits of easy maintenance and operation. Due to its modular design the HUBER RoWin Heat Exchanger can be tailored to suit specific site requirements. In combination with a heat pump up to several hundred kilowatts of thermal output can be generated, depending on the unit size. With the optimal combination of both systems municipalities or industrial enterprises can cover up to 80 % of the heat required from wastewater as energy source.

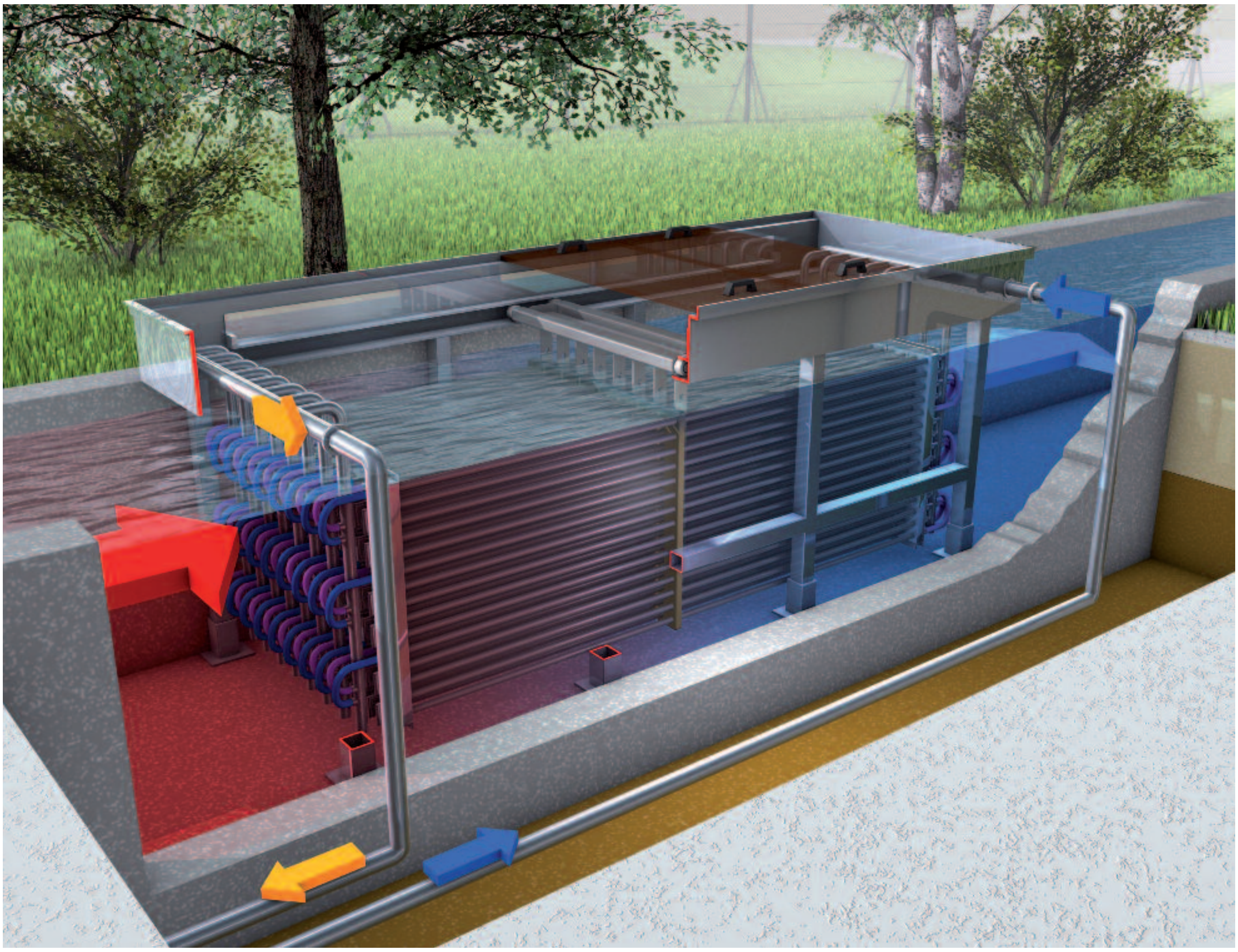


Schematic drawing of a HUBER RoWin Heat Exchanger

Heat exchanger for concrete tank and channel installation: HUBER RoWinB

The HUBER RoWinB Heat Exchanger can be used for installation in the outlet of the wastewater treatment plant or in buffer tanks. Installed directly in the wastewater flow, the heat exchanger modules are optimally surrounded by the flow. Due to the biological processes taking place, the temperature of effluents from sewage treatment plants is on average by 1 K higher than the inlet temperature. Furthermore, higher amounts of thermal energy can be extracted from WWTP effluents than with heat recovery plants installed in sewer systems. The biological processes in the sewage treatment plant are not impaired and the introduction of the cool WWTP effluent outlet is beneficial for the flowing water biology. In addition, temperature and oxygen conditions in the waters are significantly improved. If installed in the channel, no additional pumps are required as the wastewater flow normally runs off by gravity. This avoids costs and significantly improves the economic efficiency of such plants.

Due to its compact design and installation in a channel or tank, no additional installation space is required and the available space utilised at an optimum. But biofilm growing on the heat exchanger surfaces cannot completely be ruled out with the use of the WWTP effluent. Integrated cleaning of the heat transfer surfaces therefore is of great importance to continuously maintain the maximum heat transfer capacity. Several HUBER RoWin Heat Exchanger units can be installed in parallel or in series for perfect adjustment to specific site conditions and customer requirements. Combined with load-bearing covers the units can also be installed under parking areas for example.



HUBER RoWinB Heat Exchanger installed in a concrete tank. The flow streams through the heat exchanger by gravity.

Options of heat recovery from wastewater

1. Utilisation of raw wastewater from sewers by means of HUBER ThermWin®

- Installation near the consumer
- Independent of sewer dimensions and shape
- Continuously stable hydraulic conditions
- Possibility to control the entire plant at any time

2. Installation in the WWTP outlet

- No pre-screening required
- Constant volume flow by gravity
- High energy output
- Improved biological conditions in water courses
- Utilisation of recovered heat for sewage sludge drying

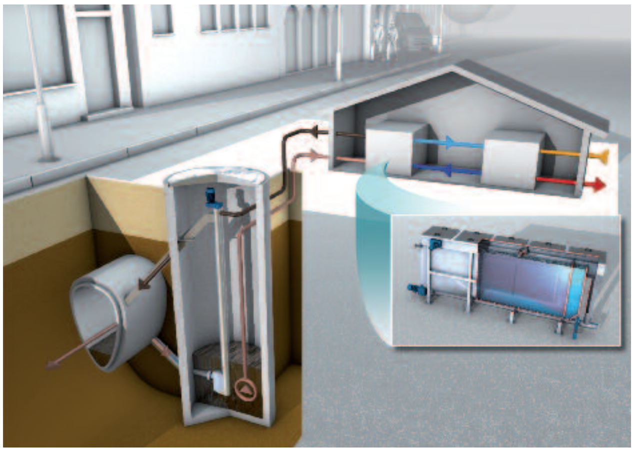
3. Filtrate from sewage sludge treatment

- High temperatures of approx. 30 °C
- Optional sewage sludge drying
- Very high energy potential
- All-year-round utilisation without interruption

4. Industrial plants

- Continuous flow of energy-rich production wastewaters
- High temperatures due to chemical-physical processes
- Supplier = consumer
- Compliance with sewer discharge standards

The benefits of HUBER Heat Exchangers



Eco-friendly heat supply for buildings: HUBER ThermWin® with HUBER RoWin Heat Exchanger

- Compact, enclosed tank design
- Continuous maximum heat transfer capacity
- Stable hydraulic conditions
- Fully automatic operation, minimum maintenance requirements
- Unsusceptible to grease, floating and coarse material
- Automatic removal of sediments
- Modular design for tailored solutions that meet the customer’s specific requirements
- Various possible applications in both the municipal and industrial field

HUBER SE

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info@huber.de · Internet: www.huber.de

Subject to technical modification
0,5 / 4 – 3.2012 – 4.2004

ROTAMAT® RoK 4
Pumping Stations Screen

Automatically cleaned fine screen with vertical lifting, dewatering and compaction of screenings

– Prevents clogging and tressing in the pumping station
– Compact unit, easy to fit into confined spaces
– Dewatering and compaction of screenings
– Optional frost-protected unit for outdoor operation
– Sturdy, low-maintenance stainless steel design

The situation

Pumps and lifting units are used where wastewater needs to be lifted to a higher level so that it can be passed further on by gravity. However, the solids contained within the wastewater frequently lead to pump failure. Labour-intensive manual cleaning is required to restore the function of the units, or they may need to be replaced, both resulting in high long-term costs.

Reliable solids removal is therefore the only alternative to maintain the operating stability of the pumps.

The solution

The ROTAMAT® RoK 4 screen is the ideal solution for this task, whether for new structures or refurbishment. Contrary to conventional screening systems which require manual cleaning, the screen surface of the ROTAMAT® RoK 4 screen is cleaned automatically. The screen vertically lifts the screenings, and dewaters and compacts them at the same time. The compacted screenings are discharged into a container or endless bagger for further disposal thus eliminating odour nuisance and pump failure due to clogging.

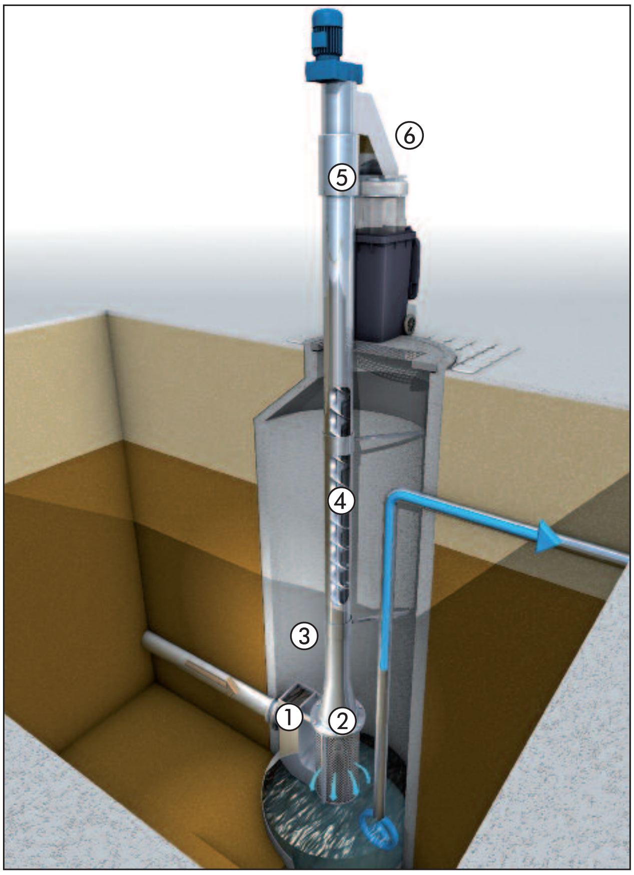
Features

The RoK 4 consists of a vertical perforated screen basket and a shafted auger in a vertical tube. The wastewater flows through an inflow connection and a chamber into the screen basket. Within the screen basket the flights of the screw are equipped with wear-resistant brushes for effective cleaning of the screen. As the screenings are gradually elevated by the auger, they are dewatered. The compacted screenings are discharged into a container or endless bagger thus eliminating odour nuisance.

The screened wastewater flows off by gravity or is pumped to a higher level. The filtrate drains through a hose back into the inlet chamber.

The top of the inflow chamber is open and serves as an emergency bypass so that the machine can be submerged without problems, e.g. in case of a power failure. The integrated bottom step prevents back-flooding into the sewer system and thus undesired deposits in the incoming sewer.

Clogged pumps caused by the solids within the medium to be delivered



① *Inflow connection with integrated invert step*
② *Screen basket*
③ *Emergency overflow*
④ *Dewatering in vertical auger*
⑤ *Press zone for the compaction of screenings to up to 40 % DS*
⑥ *Discharge chute*

The installation conditions

The ROTAMAT® Pumping Stations Screen RoK 4 is directly connected to the sewer pipe by means of a flanged joint. The wastewater enters the screen through the optimized inflow chamber with integrated bottom step. As the water streams through the perforated plate into the pump sump, the screenings are retained. An auger, with a brush attached on its flights, rotates within the screen basket and cleans the screen. As the screenings are elevated by the auger, they are dewatered to a degree of up to 40 %. The compacted screenings are discharged into a container. As an option, the RoK 4 is available as a pull screen that allows the screen to be lifted out of the structure, for maintenance purposes for example.

The applications

ROTAMAT® Pumping Stations Screens RoK 4 are used for solids retention in the following applications for example:

- In pump stations
- Upstream of pond plants
- In the headworks of wastewater treatment plants

The user’s benefits

ROTAMAT® Pumping Station Screens RoK 4 offer outstanding advantages:

- Automatic screening, lifting and compaction in a single compact unit
- Optimal solids retention by means of two-dimensional screening (perforated plate)
- Prevent clogging and tressing in pump stations and manholes
- Integrated bottom step to prevent deposits in the incoming sewer
- Easy to install into existing structures
- Availability of completely submerging the screen

Technical data

- Screen basket diameter: 300, 500, 700 mm
- Capacity: up to 650 m3/h
- Dewatering efficiency: up to 40 % DS

ROTAMAT® Pumping Stations Screen RoK 4 being lifted into a pumping station

ROTAMAT® Pumping Stations Screen RoK 4 in operation

HUBER TECHNOLOGY
WASTE WATER Solutions

Installation examples

A selection of installation examples will convince you of the ROTAMAT® Pumping Stations Screen RoK 4.

Frost protected outdoor installation

Installation upstream of a pond plant

Screenings discharge into a bagger for odour-free disposal

Indoor installation on a small footprint

HUBER SE

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Subject to technical modification
1,0 / 5 – 8.2010 – 4.2004

Manufacturer Information:

SHARC

International Wastewater Systems

HUBER ThermWin® - Easy Check

HEAT RECOVERY FROM SEWAGE

ACQUISITION OF BASIC DATA TOWARDS PRELIMINARY ESTIMATION

contact details

city/community:

contact person:

phone:

e-mail:

sewer-specific data

type of sewerage system [combined/separate]:

section shape [oval cross, circular cross etc.]:

nominal size [mm]:

mean daily dry weather flow $\mathbf{Q}_{24}$ [l/s]:

minimum dry weather flow $\mathbf{Q}_{min}$ [l/s]:

average annual temperature $\mathbf{T}_{WW,\ annualØ}$ [°C]:

average winter temperature $\mathbf{T}_{WW,\ winterØ}$ [°C]:

distance between sewer and building [m]:

base of duct below top ground surface [m]:

consumer-specific data

kind of building [e.g. block of flats, hospital etc.]:

building [new/old]:

heating power requirement [kW]:

quantity of heat required [kWh/a]:

heating demand [yes/no]:

supply temperature [°C]:

cooling demand [yes/no]:

domestic hot water demand [yes/no]:

chloride content [mg/l]:

potentials analyses

sewer-specific data

consumer-specific data

remarks

contact person

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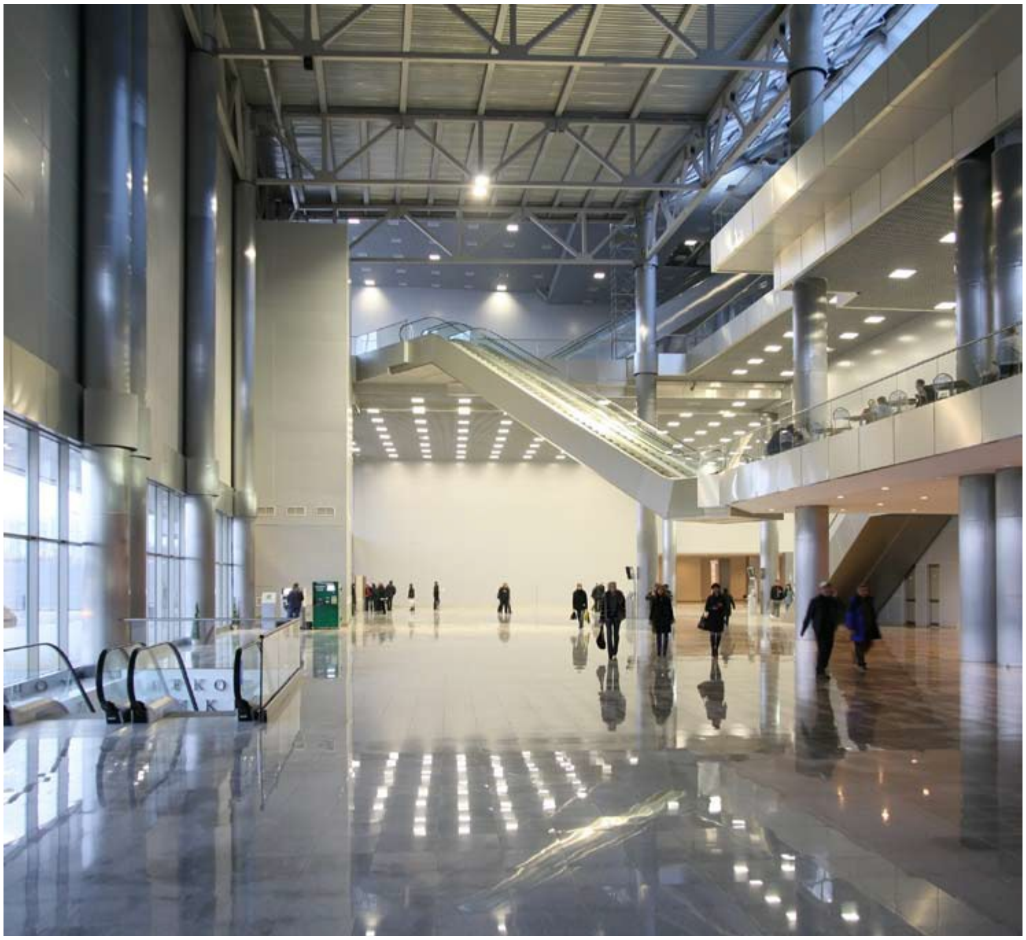
INTERNATIONAL WASTEWATER HEAT EXCHANGE SYSTEMS INC.

THE ULTIMATE RENEWABLE ENERGY SOURCE



The Sewage SHARC allows for environmentally friendly, energy efficient, trouble- free transfer of energy to and from the raw sewage leaving almost every building in the world

SIMPLIFYING WASTE HEAT RECOVERY

Provides the highest efficiencies in heating, cooling, and domestic hot water applications in the Industry

CREATING LOCAL OPPORTUNITIES FOR GLOBAL IMPROVEMENT

CONCEPT

Waste water is a constant inexhaustible energy source and it exists in the waste water streams of residential , commercial, and industrial buildings. It is higher in temperature than most other regenerative energy sources such as well water or geo-exchange, reaching an average temperature of over 25°C (77°F) when exiting buildings. In septic drains the average temperature is 15 °C (59°F).

Traditionally, waste water heat could only be extracted after being purified at the treatment facilities. However, modern heat pump technology allows for extraction of sufficient energy from raw sewage streams for the space conditioning requirements of most buildings. Wastewater heat recovery can be used in both the winter for space and domestic water heating, as well as in summer for efficient operation of air conditioning systems.

ENERGY SAVINGS

- COP's in heating 5.3 and higher
- Cooling EER's over 20.0
- Primary energy cost reduction: 30-75%
- CO_2 reduction: 30-75%
- Return on Investment: 1-5 years
- Capital cost reduction

OTHER ADVANTAGES

- Potential LEED credits due to very high energy efficiency
- Architectural flexibility—reduce, or eliminate requirement for Cooling Tower
- Physical space savings versus other sewage heat recovery technologies
- Retrofit and new construction adaptability

CLOG PROOF RAW SEWAGE FILTERING

The Sewage *SHARC* filters the raw sewage and intercepts the suspended solids. It allows the filtered sewage water to enter a heat exchanger where heat is either rejected to or extracted from the filtered sewage water. The filtered sewage water then returns to the intercepted solids and is discharged back to the sewage main pipe. Vast quantities of heat can be moved to and from the raw sewage without clogging the Sewage *SHARC*.

INSTALLATION BENEFITS

- Clog proof design
- Full backup capability for zero down time
- Modular, ready to install
- 4 pipe and 6 pipe connections available
- Available in Heat Recovery and Heat Pump applications
- Fully automated, DDC controls with BACnet interface
- LCD display with display lights and ongoing energy monitoring
- Minimal system intrusion on setup—tie into existing sewer lines
- Factory maintenance and warranty for 5 years available

GRAPHIC DISPLAY CONTROL PANEL

AUTOMATED LOGIC CONTROL SYSTEM AND DISPLAY PANEL

- 15 ” monitor—touch screen interface
- BACnet interface
- Internet accessible
- Standalone operation
- Cooling and heating staging
- Optimizing control
- Security access to prevent unauthorized change of setpoints
- Automatic switchover for redundant applications

MONITORED POINTS

- Temperatures in and out of process and source water
- Pressure drops across system and heat exchangers
- Pump control and monitoring of pump ampacity
- Ongoing graphical tracking of power consumption of entire system
- Instantaneous calculations of COP and Energy Consumption and Greenhouse gas savings
- Trending of all energy consumption, temperatures, COP to compare over time
- System status screen
- Alarm tie in—both software and hardware points

SEWAGE *SHARC* — NON-HP OPTION

MODEL No.	220	440	660	880	1100	1320
PERFORMANCE						
Nominal Capacity (MBH)	800	1600	2400	3200	3950	4750
Source						
- Flow Rate (GPM)	150-290	300-500	550-750	750-980	1000-1200	1200-1450
- Pressure Drop (ft/head)	6	8	8	8	10	10
- Connection Size (inches)	4	6	6	8	8	10
Load						
- Flow Rate (GPM)	175	350	525	700	875	1050
- Pressure Drop (ft/head)	6	8	8	8	10	10
- Connection Size (inches)	4	6	6	6	8	8
ELECTRICAL						
Power	120/1/60	120/1/60	120/1/60	120/1/60	120/1/60	120/1/60
FLA- (Amps)	12	12	12	17	17	17
Min. Circuit Amps- (Amps)	16	16	16	21	21	21
kW	2.5	2.5	2.5	5.67	5.67	5.67

MODEL No.	1760	2200	2640	3080	3520
PERFORMANCE					
Nominal Capacity (MBH)	6350	8000	9500	11000	12700
Source					
- Flow Rate (GPM)	1500-2000	2000-2400	2400-3000	3000-3350	3350-3900
- Pressure Drop (ft/head)	10	10	10	10	10
- Connection Size (inches)	10	12	12	12	14
Load					
- Flow Rate (GPM)	1400	1750	2125	2450	2800
- Pressure Drop (ft/head)	10	10	10	10	10
- Connection Size (inches)	8	10	10	12	14
ELECTRICAL					
Power	120/1/60	120/1/60	120/1/60	120/1/60	120/1/60
FLA- (Amps)	17	32	32	32	32
Min. Circuit Amps- (Amps)	21	38	38	38	38
kW	5.67	7.2	7.2	7.2	7.2

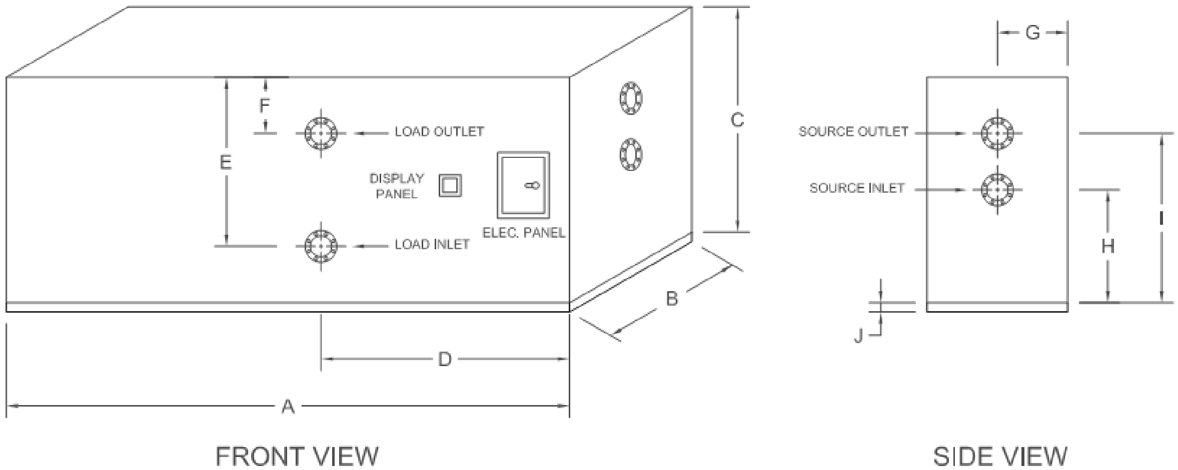
NOTE: All nominal capacities are based on the following:

<u>HEATING</u>

* Source entering / leaving - 62°F/55°F
* Load entering / leaving - 52°F/59°F

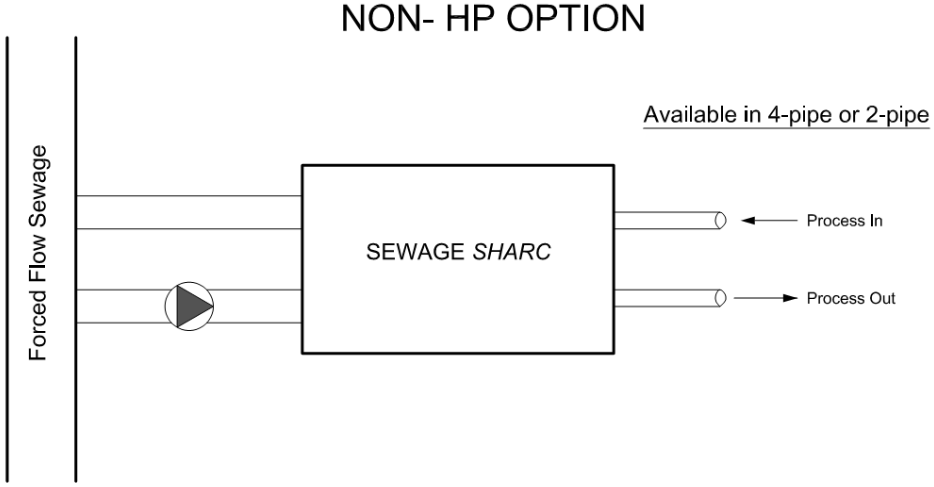
<u>COOLING</u>

* Source entering / leaving - 67°F/74°F
* Load entering / leaving - 78°F/70°F Cooling Mode



MODEL No.	220	440	660	880	1100	1320	1760	2200	2640	3080	3520
WEIGHTS (lbs)											
Shipping Weight	5350	5350	5450	5525	5900	6000	6025	8850	8900	12500	12500
Operating Weight	5750	5750	5850	5925	6500	6600	6625	9650	9700	13300	13300
DIMENSIONS (in)											
A- Unit Length	127	137	147	173	187	214	229	255	269	295	309
B- Unit Width	59	59	59	62	62	72	72	74	81	83	85
C- Unit Height	66	66	66	66	78	90	90	120	120	120	120
D- Load Inlet/Outlet	100	100	106	108	110	112	115	120	120	126	126
E- Load Inlet	72	72	72	72	74	74	74	80	80	84	84
F- Load Outlet	24	24	24	24	26	26	26	32	32	36	36
G- Source Inlet/Outlet	30	30	30	31.5	31.5	34	34	37	37	40	40
H- Source Inlet	38	38	38	38	48	56	58	58	60	60	60
I- Source Outlet	52	52	52	52	58	68	70	74	80	84	82
J- Base Rail Height	4	4	6	6	8	8	8	10	10	12	12

HEAT/COOL + DOMESTIC HW SYSTEM
NON- HP OPTION



SEWAGE *SHARC* — HP OPTION

MODEL No.	220-HP	440-HP	660-HP	880-HP	1100-HP	1320-HP	1760-HP	2200-HP	2640-HP	3080-HP	3520-HP
PERFORMANCE											
Source											
Flow Rate (GPM)	150-290	300-500	550-750	750-980	1000-1200	1200-1450	1500-2000	2000-2400	2400-3000	3000-3350	3350-3900
Pressure Drop (ft/head)	5-15	5-15	5-15	5-15	5-15	5-15	5-15	5-15	5-15	5-15	5-15
Connection Size (inches)	4	6	6	8	8	10	10	12	12	12	14
Load- *Cooling*											
Cooling Capacity (tons)	75	150	225	300	375	450	600	725	900	1000	1200
Cooling Efficiency (EER)	22.7	22.7	22.7	22.7	22.7	22.7	22.7	24.2	24.2	24.2	24.2
EWT/LWT (°F)	53/44	53/44	53/44	53/44	53/44	53/44	53/44	53/44	53/44	53/44	53/44
Flow Rate (GPM)	200	400	600	800	1000	1200	1600	2000	2500	2750	3250
Pressure Drop (ft/head)	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20
Connection Size (inches)	6	6	6	6	8	8	8	10	10	12	14
Load- *Heating*											
Heating Capacity (MBH)	878	1756	2634	3512	4390	5268	7024	8504	10630	11693	13819
Heating Efficiency (COP)	5.32	5.32	5.32	5.32	5.32	5.32	5.32	5.21	5.21	5.21	5.21
EWT/LWT (°F)	99.1/110	99.1/110	99.1/110	99.1/110	99.1/110	99.1/110	99.1/110	99.4/110	99.4/110	99.4/110	99.4/110
Flow Rate (GPM)	200	400	600	800	1000	1200	1600	2000	2500	2750	3250
Pressure Drop (ft/head)	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20	15-20
Connection Size (inches)	6	6	6	6	8	8	8	10	10	12	14
ELECTRICAL											
Power	Amperage shown as 460/3/60 - 575/3/60										
Min. Circuit Amps	133/106	266/213	398/319	531/425	664/531	797/638	1063/850	963/770	1203/963	1324/1059	1564/1252
RLA (Amps)	118/94.5	236/189	354/284	472/378	590/473	708/567	944/756	853/686	1067/857	1173/943	1387/1114
L.R.A (Amps)	313/258	431/353	549/447	667/542	785/636	903/731	1139/920	1118/895	1332/1067	1438/1152	1652/1324

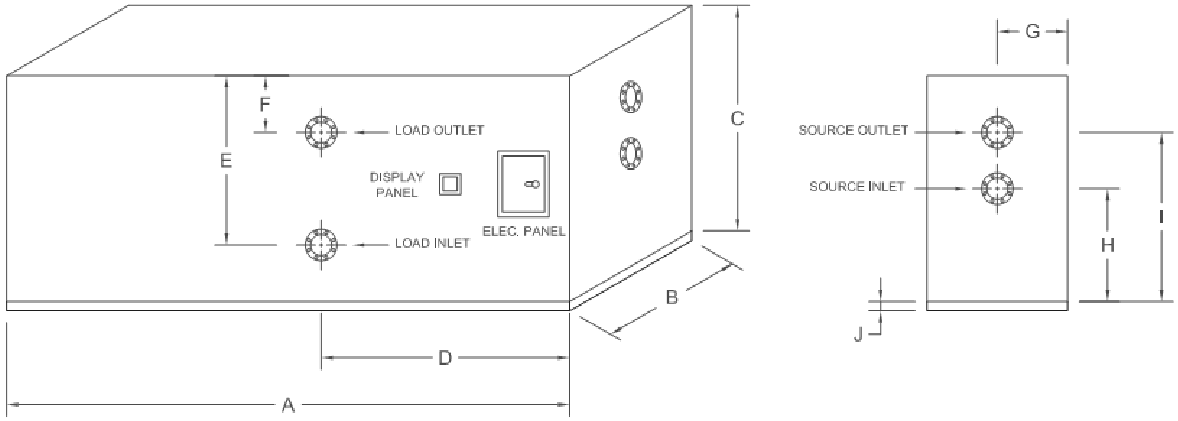
NOTE: All nominal capacities are based on the following:

HEATING

* Source entering / leaving - 62°F/55°F
* Load entering / leaving - 52°F/59°F

COOLING

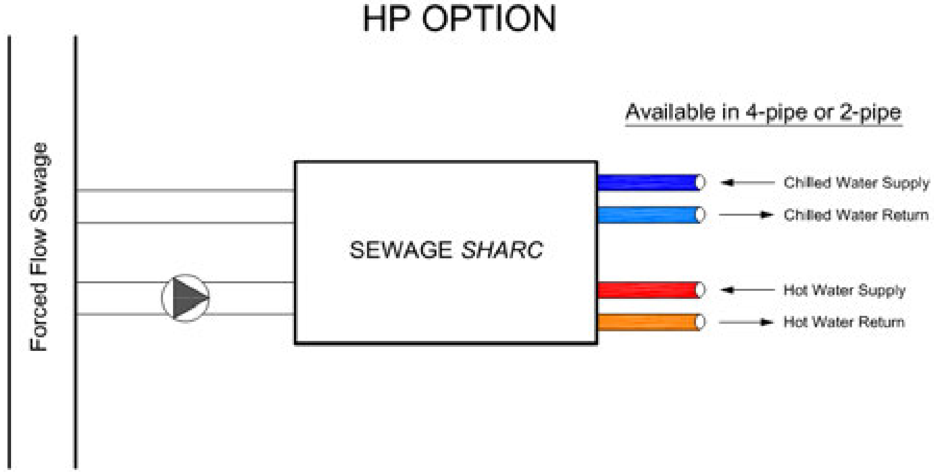
* Source entering / leaving - 67°F/74°F
* Load entering / leaving - 78°F/70°F



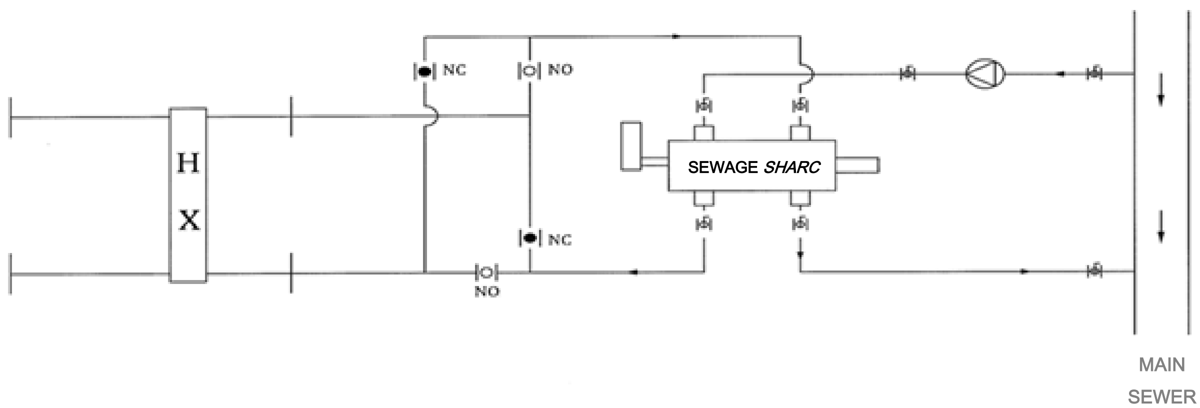
FRONT VIEW SIDE VIEW

MODEL No.	220-HP	440-HP	660-HP	880-HP	1100-HP	1320-HP	1760-HP	2200-HP	2640-HP	3080-HP	3520-HP
WEIGHTS (lbs)											
Shipping Weight	5350	5350	5450	5525	5900	6000	6025	8850	8900	12500	12500
Operating Weight	5750	5750	5850	5925	6500	6600	6625	9650	9700	13300	13300
DIMENSIONS (in)											
A- Unit Length	127	137	147	173	187	214	229	255	269	295	309
B- Unit Width	59	59	59	62	62	72	72	74	81	83	85
C- Unit Height	66	66	66	66	78	90	90	120	120	120	120
D- Load Inlet/Outlet	100	100	106	108	110	112	115	120	120	126	126
E- Load Inlet	72	72	72	72	74	74	74	80	80	84	84
F- Load Outlet	24	24	24	24	26	26	26	32	32	36	36
G- Source Inlet/Outlet	30	30	30	31.5	31.5	34	34	37	37	40	40
H- Source Inlet	38	38	38	38	48	56	58	58	60	60	60
I- Source Outlet	52	52	52	52	58	68	70	74	80	84	82
J- Base Rail Height	4	4	6	6	8	8	8	10	10	12	12
HP MODULE											
Unit Length	55	92	129	166	203	240	314	314	388	425	500
Unit Width	56	56	56	56	56	56	56	70	70	70	70
Unit Height	60	60	60	60	60	60	60	72	72	72	72

HEAT/COOL + DOMESTIC HW SYSTEM
HP OPTION



SEWAGE FILTER NO STORAGE FORCE FLOW MAIN OR GRAVITY MAIN



CONTACTS

INTERNATIONAL WASTEWATER

HEAT EXCHANGE SYSTEMS INC.

4638 Hastings St.

Burnaby, B.C. V5C 2K5

LYNN MUELLER

Phone: 604-569-0313

Fax: 604-294-0042

Cell: 604-219-2838

Email: lynn@sewageheatrecovery.com

Website: www.sewageheatrecovery.com

International Wastewater Systems

Sewage SHARC

S-660 Data Sheet

Wastewater Heat Recovery Concept

Wastewater is a constant, inexhaustible energy source and it is produced by residential, commercial, and industrial buildings. It is higher in temperature than most other regenerative energy sources such as well water or geo-exchange, reaching an average temperature of over 21°C (70°F) when exiting buildings. In septic drains the average temperature is 15°C (59°F).

Traditionally, wastewater heat could only be extracted after being purified at the treatment facilities. However, modern heat pump technology allows for extraction of sufficient energy from raw sewage streams for the space conditioning requirements of most buildings. Wastewater heat recovery can be used in both the winter for space and domestic water heating, as well as in summer for efficient operation of air conditioning systems.

The sewage SHARC system processes incoming raw sewage delivered by the primary sewage pump from a collection tank (wet well) or sewer trunk line to the SHARC system. The processed sewage is then pumped through a heat exchanger where heat is either rejected to, or extracted from the sewage water to process fluid in a heat pump loop. A heat pump (if equipped) in turn processes this fluid for use in domestic hot water supply or HVAC systems. Processed sewage flows back through the SHARC unit, flushes out remaining particles and is sent back out to the collection tank or sewer trunk line. Vast quantities of heat can be moved to and from the raw sewage without clogging the Sewage SHARC.

System Benefits

Energy Savings:

- ✓ Heating COP of 5.3 and up
- ✓ Cooling EER over 20.0
- ✓ Primary energy cost reduction of 30-75%
- ✓ CO_2 reduction of 30-75%
- ✓ Return on Investment: 1-5 yrs
- ✓ Capital cost reduction

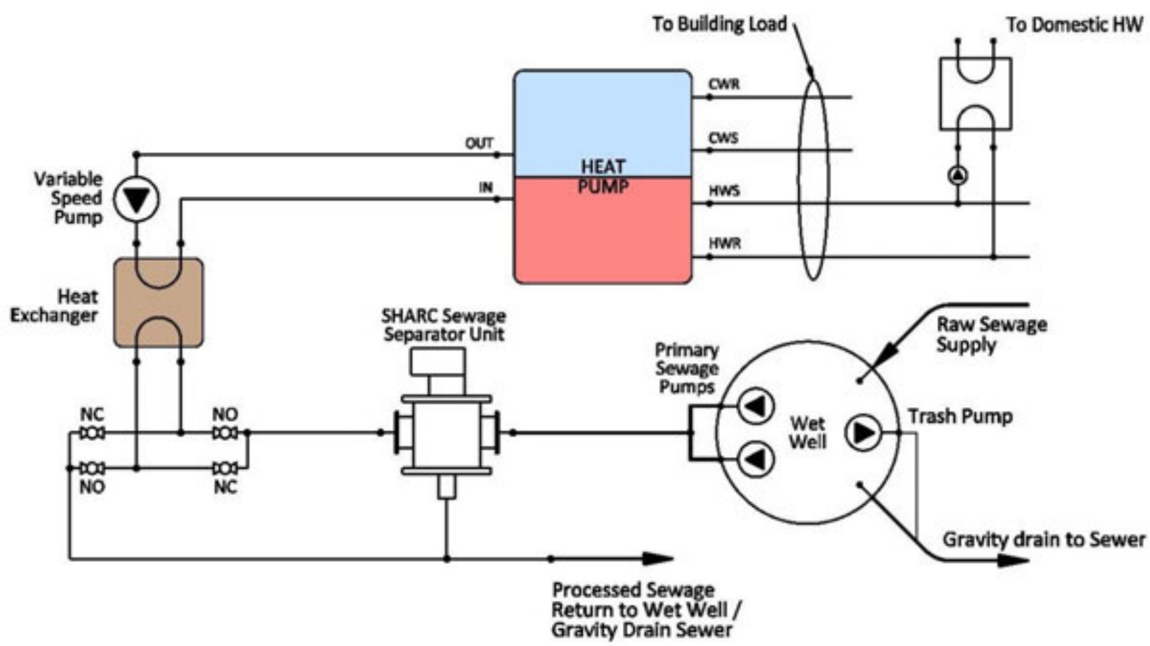
Project Advantages:

- ✓ Potential LEED credits due to high efficiency
- ✓ Reduce or eliminate cooling tower
- ✓ Physical space savings vs. other sewage heat recovery technologies
- ✓ Retrofit & new construction adaptability

Installation Advantages:

- ✓ Modular System, ready to install
- ✓ Clog Proof Design
- ✓ Full backup capability = zero downtime
- ✓ Automated logic control system:
  - -BACnet interface
  - -monitored points & trending data
- ✓ Extended warranty & factory maintenance available

SHARC System Schematic

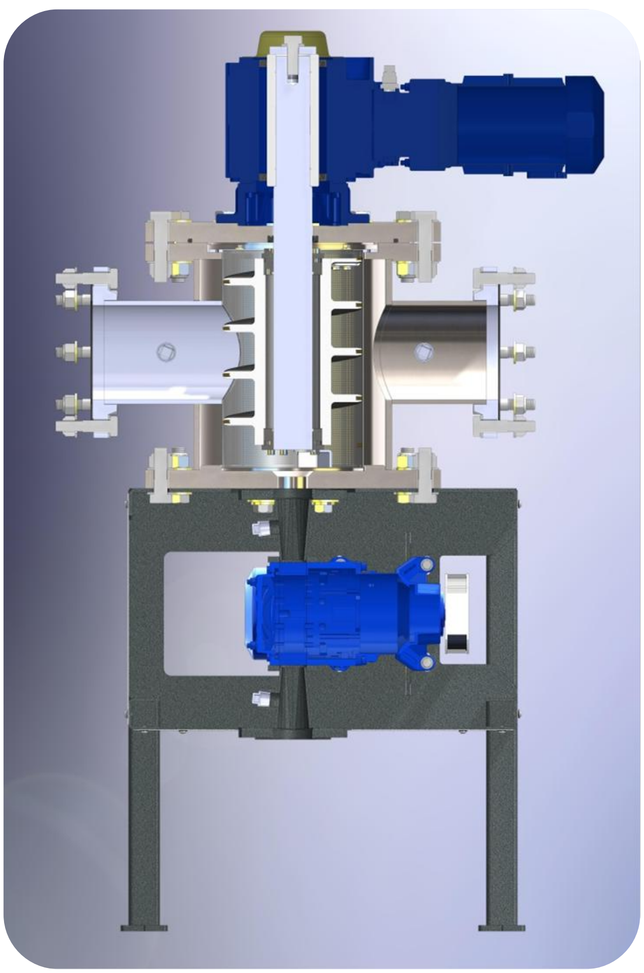


*Note: Shown with optional Wet Well and Heat Pump.
Base system includes SHARC Sewage Separator, Heat Exchanger & DDC Controls.

SHARC Data

	MODEL NUMBER
PERFORMANCE	**660**
Nominal Capacity (MBH)	3200
SOURCE	
Flow Rate (GPM)	150-525
Pressure Drop (ft/head)	8
Connection Size (in)	6
LOAD	
Flow Rate (GPM)	500
Pressure Drop (ft/head)	8
Connection Size (in)	6
ELECTRICAL	
Motor1-Auger(HP)	0.75
Motor2-Solids Pump (HP)	0.5

	MODEL NUMBER
PHYSICAL	**660**
Dry Weight (lb)	988
Dimensions (in)	
Height	58
Width	32.5
Depth	29.5



Warranty

SHARC Units are provided with a 2 Year Parts & Labor warranty. Neglecting to follow maintenance schedules for provided equipment will void warranty.

Maintenance Schedule

SHARC Unit

Daily/Weekly

Visual Inspection (if desired)	Verify if there is any visible damage to the equipment, piping or electrical cables/wiring. Note any damage in a maintenance log. Check control panel for any alarms indicating possible problems with equipment. If any alarms are indicated, please reference the "Troubleshooting" section of this manual.

Quarterly

Reverse Flush HX (automatic)	Run a reverse flush cycle on the heat exchanger to clear any accumulated debris.
Check Trends	Review trend charts to verify consistent performance Note: Will be monitored in-house by IWHES also.

Annually

Auger	Replace auger blade & spring with new part Inspect Auger for excessive corrosion/wear
Screen	Replace screen
Check Fluids	Check oil in gear reducer
Pump Maintenance	Perform annual maintenance on integral solids pump (see mfgr documents)

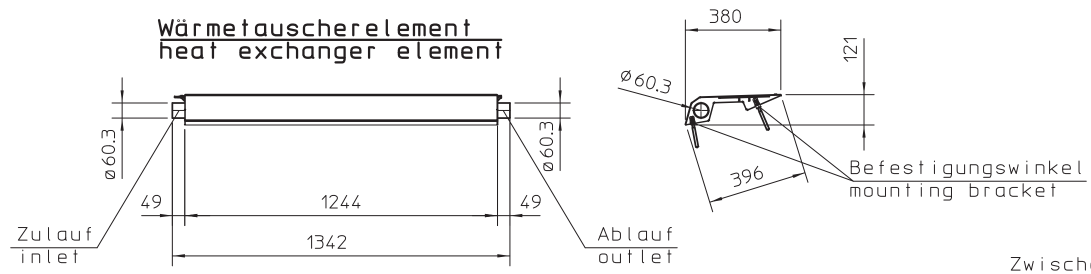
Manufacturer Information:

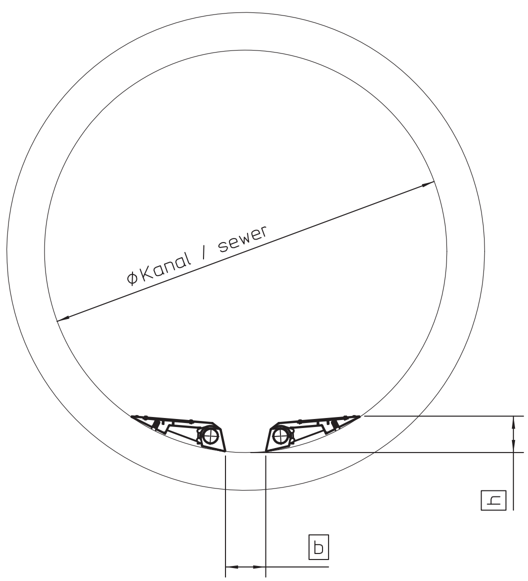
TubeWin

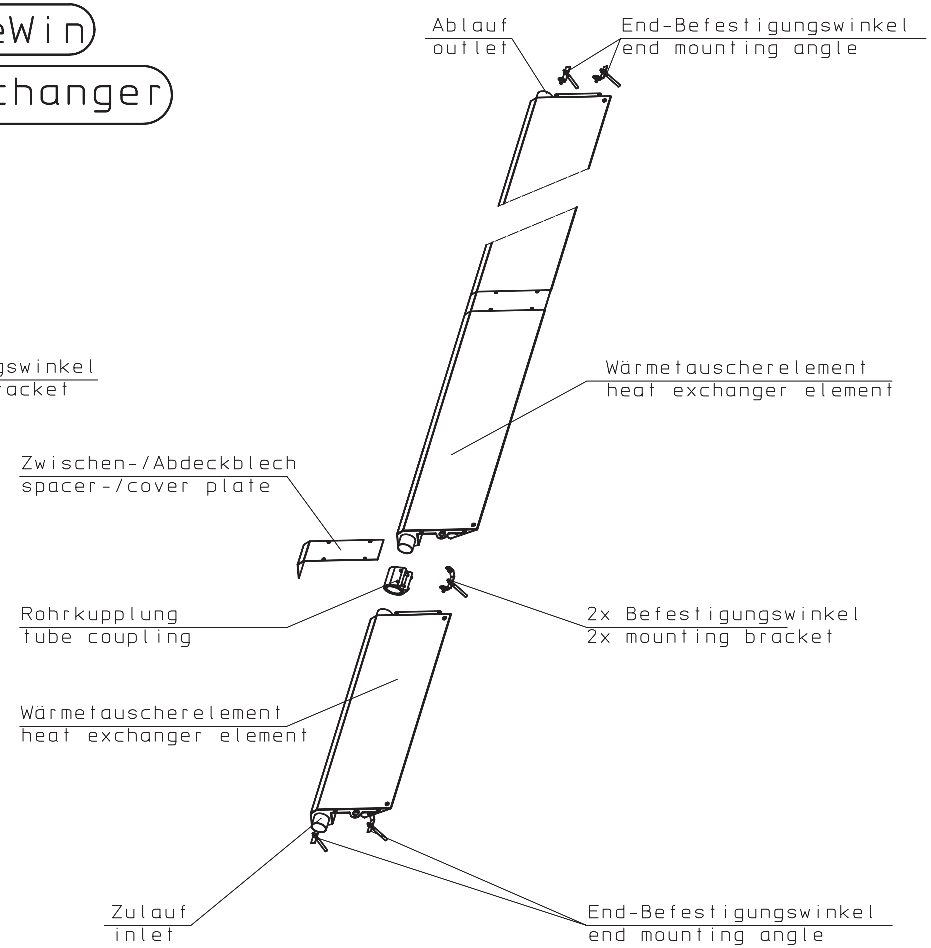
Huber Technology

Massblatt - Kanalwärmetauscher TubeWin

sheet of dimensions - TubeWin Heat Exchanger







Die Wärmetauscherelemente werden mittels Befestigungswinkel direkt auf die Kanalsohle montiert.
The heat exchanger elements are fastened directly on the sewer bottom

Kanal Sewer	ø 1000	ø 1200	ø 1400	ø 1600	ø 1800	ø 2000
h (mm)	201	176	158	145	135	127
b (mm)	100	120	140	160	180	200

Anzahl der Wärmetauscherelemente muss an bauseitige Gegebenheiten angepasst werden.
Number of the heat exchanger elements must be arranged to the channel.

Pos. Item	Menge Quantity	Bezeichnung Specification	Werkstoff/Lieferant Material/Supplier	Bemerkung Annotations
-	-			

HUBER TECHNOLOGY
D-92334 Berching / Tel.:08462/201-0

Technische Aenderungen vorbehalten / Subject to modification | ISO 2768-mk

				Datum/Date	Name
			Bear./Rev.	29.11.2012	plei
-	-	-	- Gepr./Appr.		
			Norm.		
Ver-sion	Aenderung Modified	Datum Date	Name	Massstab/Scale: -	

Kanalwärmetauscher TubeWin
TubeWin Heat Exchanger

Projektbez.: / Project Name: Massblatt - sheet of dimensions

Projekt / Project	Art.-Code / Item Code	Blatt / Sheet
-	010_000918__	-/-

MALCOLM PIRNIE | ARCADIS

Manufacturer Information:

Rabtherm Series

Rabtherm Energy Systems

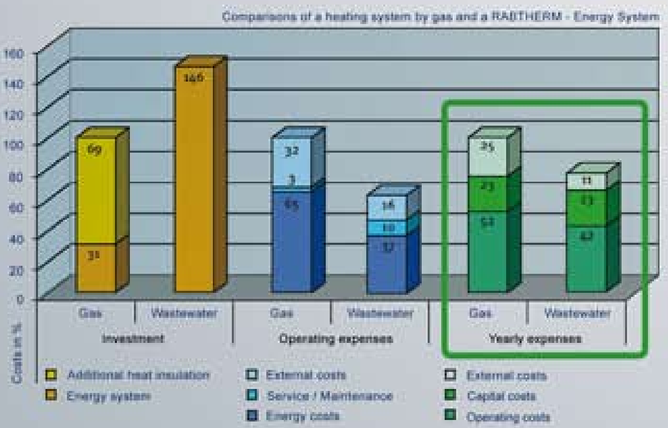
Rabtherm-Series

E	Installation in existing sewers	
I	Integration in new sewers	
DR	Pressure pipe	
F	flat	
G	shaped	
Z	attached water pipes	
-	separate water pipes	

Costs

The system costs may vary according to sewer and local prevailing circumstances. As an average one can assume 2900 $ for heating and domestic hot water supply of one apartment. Annual maintenance costs of the heat exchanger are minimal, maintenance of heating system components can reach 2 % of the investment costs.

Contracting is becoming a most attractive form of financing.



Encouragement / State fundig

Financial encouragement can be reached by the fact that this new technology is environmentally friendly and leads to lower energy costs compared to fossil fuels:

- Project implementation of RABTHERM-systems allows for claiming financial encouragement or funding
- Attractive or encouraged loans (CO_2-loans)
- Bonus for complying with energy and thermal insulation standards
- CO_2 trading
- Exemption of future environmental protection fees

Contact

RABTHERM® ENERGY SYSTEMS

RABTHERM AG
Dennlerstrasse 41
CH-8047 Zürich

Tel: +41(0)44 400 21 21 (01141 USA, CA)
Fax: +41(0)44 401 07 27 (01141 USA, CA)
Email: info@rabtherm.com

RABTHERM® ENERGY SYSTEMS

Energy from waste water

The regenerative energy source for heating and cooling

- CO_2-reduction
- renewable
- wide-spread energy source
- sought-after by joint proprietors
- no fine dust

Basic Idea

The last big "heat leek" in the building envelope can be sealed with the patented system of RABTHERM. Wastewater leaves the buildings with up to 77°F (25°C), and even in strong winters temperatures in the sewers seldom fall below 54-59°F (12-15°C). With heat exchangers integrated in the sewer this heat can be extracted. This type of energy recovery is therefore extremely environmentally friendly.

Depending on the system of electricity generation used to drive the heat pump, output of CO_2 can be reduced by 30 to 85 percent. RABTHERM-systems considerably participate to energy savings and environmental protection. Total heat in sewer lines exceeds the sum of solar, wood and biomass energy potential.

Wastewater is a constant renewable energy source at a high temperature level, which can be exploited at the sites where it originates – with the aid of heat exchangers locally installed in the sewers. RABTHERM heat exchangers can be implemented in existing sewers or can be integrated in new pipe elements.

Application

Extracting heat from wastewater and increasing the temperature level by use of heat pumps for:

- Heating, drying
- Hot water, process water

Additionally, with the respective design of the heat pump, the energy can be transferred in the opposite direction, using wastewater as a heat sink for:

- Cooling water, air conditioning

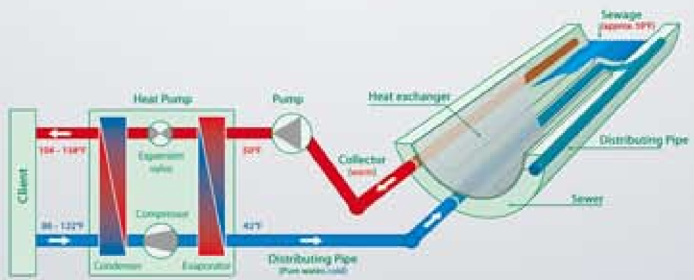
Market

Buildings with high heating and/or cooling demand, such as:

- Public and administration buildings, schools, sports facilities, swimming pools
- commercial and industrial facilities, shopping malls
- Condominiums

Product and Technology

The heat exchanger cools down the wastewater by 3.5°F (2°C) (max. 1°F (0.5°C) as a 24 hour average). The energy is transferred with water pipes to the boiler rooms. Here the heat pumps raises the temperature for heating and hot water purposes to max. 150°F (65°C) and eventually feed into district heating systems.



Centerpiece is the heat exchanger in variable shape, designed for maximum heat transfer performance. All components to be installed in the sewer are made of stainless steel and are protected against the detrimental fouling effects by a patented method.

Customer Value

Compared with conventional energy sources, Rabtherm systems provide advantages such as:

- Independence from foreign, fossil energy sources
- Primary energy cost reduction: 20-30 %
- CO_2 reduction: 30-85 %
- Fine dust: none
- Return on investment: 1 to 6 years

Basics

Criteria for optimum performance of RABHTERM - Systems:

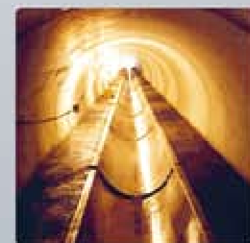
- Main sewer (min. diameter)
  - installation in existing sewer > 800
  - installation in new sewer > 400
- Wastewater flow (dry weather flow) min. 12 l/s
- Wastewater temperature (winter) min. 47°F (8°C)
- Installed heating power min. 60 kW
- Distance boiler room - sewer max. 200 m

Performance

Heat extraction capacity of heat exchangers depends on:

- Wastewater flow
- Sewer slope
- Fouling
- Wastewater temperature

Specific heat extraction may vary from 2 to 6 kW per 1 m² of heat exchanger surface.



Future-oriented further developments:
Waste water heat utilization plants
with a return on investment (ROI) of 2 - 6 years

Sewage is dirty and stinks. Out of sniffing distance – out of mind. Up until the 1980s sewage was taboo and not given the attention it deserves.
One cold winter morning in 1988, 23 years ago, Urs Studer stopped beside a steaming manhole cover and wondered how such a source of heat could go untapped. Ever since he has been dedicating himself intensively to the recycling of sewage heat. At the time of the first oil crisis the heat loss as a result of discharged sewage amounted to approx. 12-15 %. In new buildings the loss of waste water heat already amounts, in accordance with the applicable energy regulations, to 45-50 % and this proportion will increase.
Today the heat contained in waste water fortunately no longer simply goes down the drain, or sewer, until it is utilized for the cultivation of bacteria in the sewage treatment plants.
Dirt became gold.

Insertion into existing sewer

Integral heat exchanger for new sewers

That is all very well – but is that all? Well, Urs Studer would not be Urs Studer if he was satisfied with this. The plants have to be economical. Let us again turn the clock back a few years and pose ourselves the following question:

What happens to the heat exchangers in the sewage on its way through the sewerage network? Organic substances are deposited on the moistened heat transfer exchangers. As a thin, viscous layer they help the microorganisms in the sewage to adhere to the heat exchanger surface. In this way an up to 5 mm thick biofilm gradually develops. This layer of what is called sewer slime has an

insulating effect on the heat exchangers.
Clearly it can be flushed away with high pressure. But what a recurrent effort.

Here again a stroll in the fresh air triggered another ingenious idea: This biofilm is missing on rooftops which are, for example, fitted with copper-edged chimneys; the roof tiles remain clean:

This gave rise, in 2004, to the development of the anti-fouling system, which prevents the heat extraction rate from dwindling by up to 50% as the thickness of the biofilm increases:
Every 3 meters thin copper strips are integrated into the heat exchanger chain:

Measurements carried out at sewage treatment plants of various sizes demonstrate that the anti-fouling system is absolutely harmless for the treatment plants. The results of the measurements can be requested at info@rabtherm.com.

So heat exchangers do not have to be slimey and insulating. They have to conduct heat well. With a lot of time and money a new ferritic steel was developed which makes it at least as suitable for withstanding corrosion and erosion as the previously used material. In addition, it was possible to increase the thermal conductivity by over 80%.

Sewage is also suitable for recooling cooling plants. Normally Waste water heat recovery plants are constructed bivalently to meet peak demands. Industrial plants whose production yields very warm cooling water can by the way be heated and cooled 100% with sewage energy, monovalently, thanks to our new, scientifically precise software. In such cases it is essential to employ the pressure pipe with a heat extraction **rate of 7 - 20 kW/m^2** which is specially suitable for industrial operations:

Pressure pipe

Thanks to all these new developments it was possible to increase the heat extraction rate by up to 40%. That means, without the anti-fouling system and without the new ferritic steel, the heat exchanger chains would have to be 40% longer.

Together with a bivalent process control system, sewage heat recovery plants now score with a **ROI of 2 - 6 years**.

How come our system does not utilize the heat until the sewage reaches the public sewers rather than at the house itself, directly where it arises? Only the public network guarantees a steady, lasting discharge. Sewage heat recycling is possible upstream, in or downstream of the treatment plant. A power range of between 40 and 4000 kW is possible with a specific output of 3 - 9 kW/ m^2.

How can such sewage heat recovery systems be implemented?

- Components / System
  The heat extraction (heat exchangers with intermediate medium pipes) is only one component in a sewage heat recovery system with in addition
  - connecting pipes and circulation pump
  - heat pump / cooling unit
  - peak boiler
  - infrastructure energy centre with piping, insulation, appliances, regulation
  - process control / I&C

- The owner (private, local authority, energy service provider) wants a turnkey facility with the manufacturer's guarantees regarding
  - power
  - temperature
  - utilizaton coefficient
  - timelines
  - costs

→ Rabtherm offers the following solutions:
  - as general contractor for the owner
  - as general for contractors

→ supplementary services
  - supervision with optimization
  - facility management

→ The owner does not want to be supplied with components. He wants a coordinated compound system with a comprehensive guarantee.

The Rabtherm Energy Systems team would be pleased to answer your questions at any time.

Contact person:
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Urs Studer, CEO, Dipl. Ing.
Mail: info@rabtherm.com
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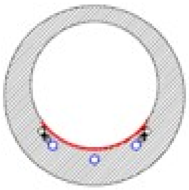
Tel. (mob.) +41 (0)79 312 75 44

24.10.2011

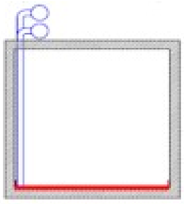
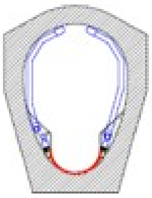
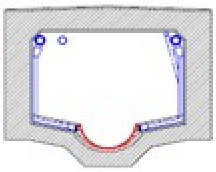
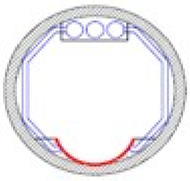
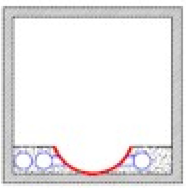
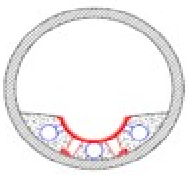
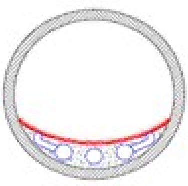
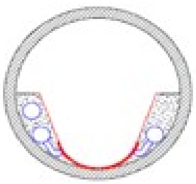
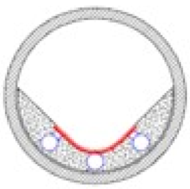
SEWER

Reduction in flow area with the installation of a heat exchanger and the piping.

1. New sewer (gravity type or pressure pipe)

  	Reduction: 0

2. Existing sewer

	Reduction: 2%
 	Reduction: 5%
	Reduction: 7%
	Reduction: 10%
   	Reduction: 12-18%

Manufacturer Information:

PKS-Thermpipe

Frank Der Vorsprung

PKS-THERMPIPE®

Geothermal and waste water warmth

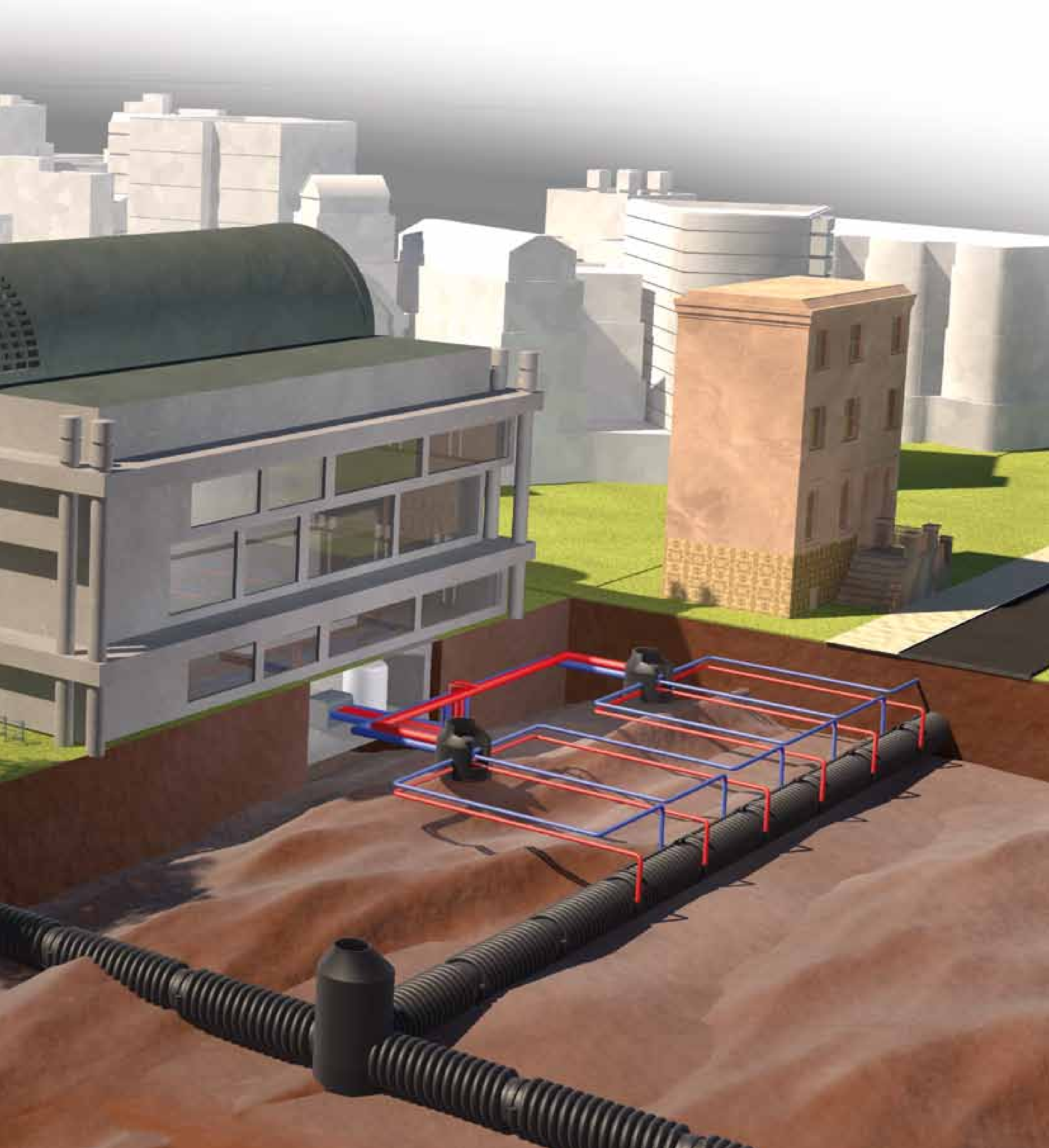
FRANK

Der Vorsprung.

Energy recovery from the ground and waste water: a practical circuit

With the aim of conserving the environment, it is our task to handle the resources available to us as economically and efficiently as possible. Thanks to modern thermal insulation and the targeted use of energy, it has been possible to reduce heating energy consumption, for example, in Germany's residential sector by an average of 22% since 2002. But there is still an energy leak which has been given little attention to date: waste water. Originally a "waste product" of our society, this resource is disposed of by the cubic metre through the sewage system every day, whereby waste water harbours an enormous energy potential which should be no means be simply "thrown out with the bathwater": residual heat of 15 °C on average which can be used for cooling or heating buildings. The process of recovering waste water heat is quite simple: after all, waste water is always available wherever people live and work.

In addition to the waste water energy, the same system can also be used for the surrounding earth. Geothermal/ Waste water warmth is simply drained off from the sewage pipe and harnessed via a heat pump, for example. The energy can then be utilised directly on site without incurring any high losses associated with transport. Enabling up to 50% of the primary energy to be saved. A highly-efficient process!



Safe and durable

Our PKS sewage pipes made of polyethylene – the basis for energy recovery

PKS sewage pipes made of polyethylene (PE) offer maximum safety and durability. For more than 40 years, PE sewage pipes have proven their worth in the chemicals industry and in the municipal sector. And no wonder: after all, PE avails of the requisite properties which are indispensable for modern waste water systems: good chemical resistance as well as durability. Ideal for extreme loads: PE waste water systems are unbreakable and even capable of withstanding earthquakes. Thanks to the welding features displayed by PE, homogeneous waste water systems are possible from a single package principally dispensing with plug connections and sealing rings entirely. And root intrusions can be safely eliminated.

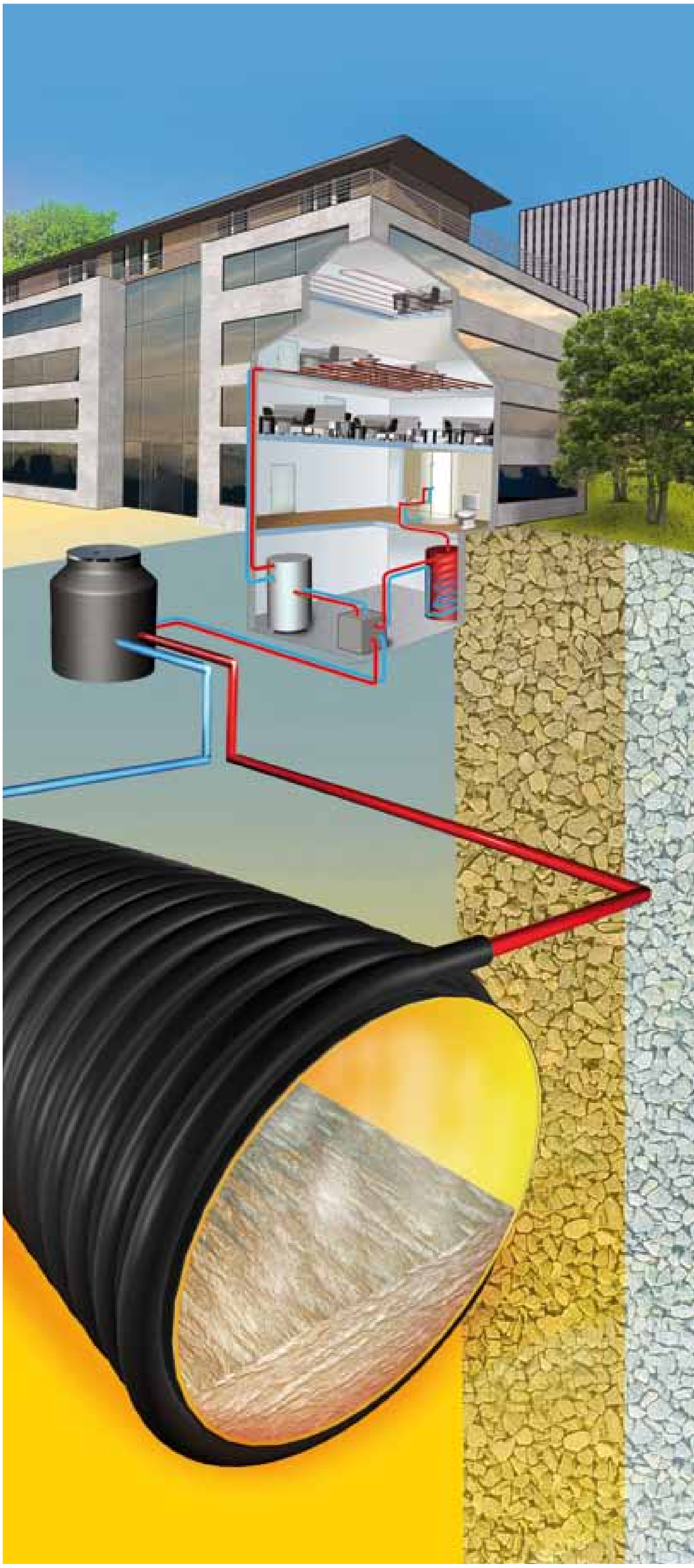
When compared to standard solid-wall pipes, the hollow, lightweight support pipes on the outside of the PKS sewage pipe ensure significant savings in terms of weight while guaranteeing easy handling during installation. PKS sewage pipes: the perfect basis for sustained energy recovery.

PKS sewage pipe in the production process

3-in-1 function

PKS sewage pipe + waste water heat + geothermics = PKS-THERMPIPE® system

The PKS sewage pipe forms the basis for the PKS-THERMPIPE® system. The system not only ensures safe waste water transport. As a "horizontal geothermal probe", the PKS-THERMPIPE® system has the additional task of deflecting thermal energy: waste water warmth and geothermal warmth. The advantage of utilising two heat sources at the same time is obvious. Apart from the sewage pipe, the waste water also heats up the surrounding earth which is repeatedly charged by the waste water energy along the same principle as a power pack. Otherwise lost within the earth, this energy is harnessed by the PKS-THERMPIPE® system. The conventional support pipe available on the outer pipe serves as a heat dissipater for both energy sources and through which a heat transfer medium flows. By additionally recovering the energy from the surrounding ground, the PKS-THERMPIPE® system is independent of diurnal lines or irregular waste water lines, thereby ensuring a constant supply of energy.



PKS-THERMPIPE®-System

How it works: geothermal probe with waste water turbocharger

The static and thermal design of the PKS-THERMPIPE® system depends on the project and is oriented towards the structural conditions on site, the available energy potential (waste water, geothermics) and the energy required by the units to be supplied. The system draws the lion's share of energy available from the ground. The number of PKS-THERMPIPE® pipes to be integrated depends on the requisite energy volume and the extraction outputs to be realised by the sub-systems comprising "waste water heat" and "geothermal heat". The PKS-THERMPIPE® pipes welded together are connected to the FRANK-PKS® distribution shaft using standard moulded parts and pipes made of PE-100 materials. The lines are directed from the shaft into the building, e.g. to a heat pump for energy realisation.

Reference values for extraction output by the PKS-THERMPIPE® system

DN	Q [W/m]	DN	Q [W/m]
300	350	1100	1130
400	450	1200	1220
500	550	1300	1320
600	640	1400	1420
700	740	1500	1520
800	840	1600	1610
900	930	1800	1810
1000	1030	-	-

Advantages of PKS-THERMPIPE® pipes

- Constant energy supply
  Use of waste water warmth PLUS continually available geo-thermal warmth
- Easy installation:
  no installations required inside the conduit
- High degree of tightness:
  no weak spots caused by plug connections
- Efficient utilisation:
  low pressure losses thanks to tightly-welded thermal conduction circuit
- Durable material: service life of all pipe components > 50 years
- Variable range of application:
  current range of application from DN 300 to DN 1800
- Consistent deflection of energy: consistent feeding of the heat pump
- No transport losses:
  heat is extracted from the waste water and pipeline zone on site
- Maintenance-friendly:
  low formation of sewer film

Planning with foresight for sustainable savings!

Plan the option of energy recovery when installing new sewage pipes and save up to 50% primary energy.
Have you already opted for a PKS sewage pipe when installing a new sewage system? Then make the most of your advantage now and keep your options open for energy recovery if new extensions are pending. After all, the energy cost benefits of PKS-THERMPIPE® pipes are unbeatable when it comes to new installations! At little extra expense, PKS pipes can be converted in the factory to highly-efficient PKS-THERMPIPE® pipes. Larger buildings in the vicinity or still planned which reveal higher energy requirements can be heated or cooled using energy from waste water or geothermal heat in future. See for yourself: compare the extra financial expense associated with energy recovery with the costs of conventional PKS pipes in the chart provided.

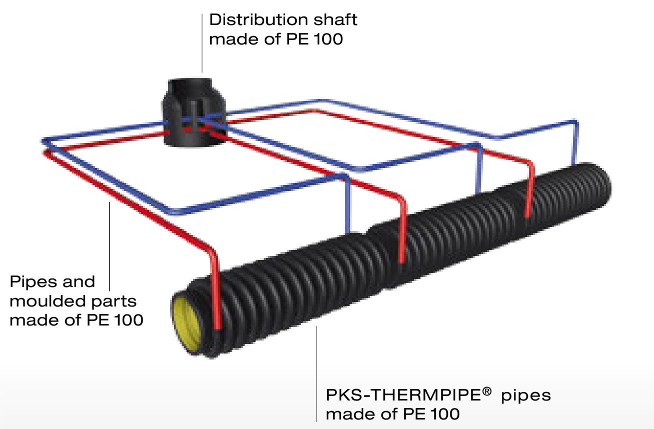
PKS-THERMPIPE® pipes and their energy utilisation costs*

DN [mm]	Costs [€/kW]
300	206
400	163
500	135
600	120
700	110
800	102
900	94
1000	86
1100	81
1200	77
1300	77
1400	74
1500	74
1600	72
1800	70

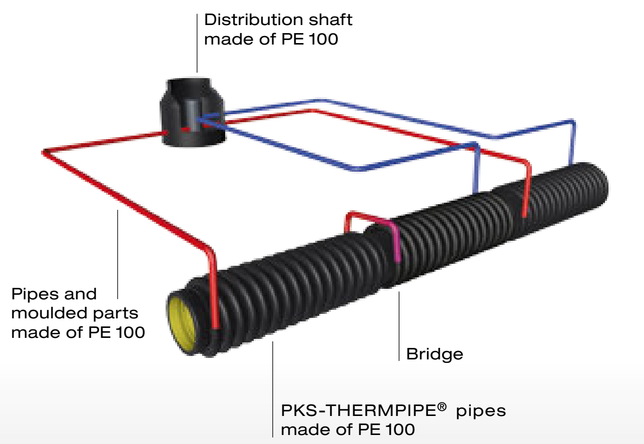
* Cost comparison: Additional costs compared to conventional PKS pipes

Higher energy efficiency thanks to variable installation

The individual 6-metre pipes are connected in parallel with the distribution shaft to achieve higher energy efficiency: low pressure losses are guaranteed; it is possible to connect and disconnect individual circuits.



Combinations of parallel and series switching are possible with small nominal widths: minimisation of installation costs owing to shorter mathematical constant and heat transfer pipelines.



Practical applications

Site report PKS-THERMPIPE®
Wimaria Stadion (Weimar)

Within the framework of a research project, a section (36 m) of an existing concrete duct was fitted with the PKS-THERMPIPE® pipe system in Weimar. The heat output comprises approx. 22 kW. The heat is used in a sports facility (for heating and warming service water). The existing gas heating system was extended to include the heat pump technology.
The pipes are installed at a depth of approx. 4.5 metres and transport the waste water generated by approx. 5,000 inhabitants in Thuringia's fourth-largest city.

The waste water volume is approx. 14 l/s at temperatures of 15 to 20 °C. Apart from the components already outlined which were installed in the ground, additional investments were also made in the area of the heating system. Along with an SWP 270 H high-temperature heat pump (heat output: 26.5 kW) and 2 multifunctional storage tanks (MFS 830 S) each with a capacity of 830 litres for drinking water supplies and a separating buffer storage tank of the same size, various measurement devices were also installed to document the efficiency of the plant.

Scope of supply

- 36 m PKS-THERMPIPE® DN 500 (6 pipes, 1 adapter incl. shaft connecting sleeve and wall collar)
- Electro-fusion coupler d 560 mm
- Type 1 distribution shaft with horizontal distribution trunk
- 300 m PE-100 pipe d 50 mm, SDR 11
- Electro-fusion moulded parts d 50 mm in SDR 11 for heat circuits

Services offered by FRANK

- Planning and design of the sewage pipe section
- Site support including training of installation personnel

External service

- Insulation design and optimisation of the system parameters by the Forschungsinstitut für Tief- und Rohrleitungsbau Weimar e. V. (FITR)

Responsibility and sustainability

How a "waste product" becomes an energy source

Global energy requirements are continually on the rise. Our modern society is no longer conceivable entirely without the free availability of energy - whether in private households, the commercial sector or industry. But the resources available are limited. For this reason, it is our task to utilise regenerative energies sustainably as well as the energy available to us in a more targeted fashion. Energy is often not fully used where it is applied. Resulting in unused residual energy. Or conversion into another form of energy demands energy losses which are too high. Larger buildings in particular such as residential and office complexes, hospitals, homes for the elderly, indoor swimming pools, sports facilities, commercial and industrial buildings could be heated and cooled using a particularly environmentally-friendly application of energy: geothermal heat and waste water energy. Geothermal heat is available everywhere and at all times. Waste water is always available wherever people live and work.

Using our PKS-THERMPIPE® system, we have succeeded in utilising energy where is is available: on site. Without any transport losses. And by dual utilisation of waste water AND geothermal heat, you are guaranteed constant and clean energy supplies.

At FRANK GmbH, we are delighted to be able to contribute towards conserving our environment in the form of our PKS-THERMPIPE® system.

... for official authorities

... for shopping centres

... for schools

... for swimming pools

... for hospitals

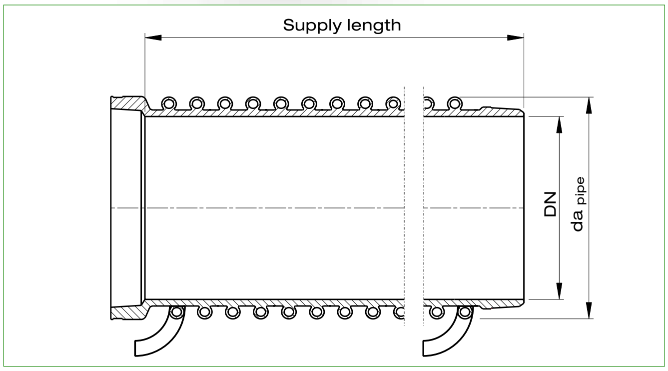
... for hotels ...

Prerequisites for utilising waste water warmth

1. Dense residential buildings or industry with a correspondingly high supply of waste water (dry weather flow ≥ 15 l/s).
2. Consumers with correspondingly high heat requirements (≥ 50 - 200 kW). These can include schools, kindergartens, official authorities and shopping centres, hospitals, hotels, swimming pools, larger residential complexes etc.
3. Relatively short distances (approx. 100 m, max. 500 m) between the heating system and the sewage conduit.
4. The system temperatures for heat utilisation (return pipe) are max. 50 °C (the lower the better).

Range of supply

DN mm]	SR 24 ≥ 4 kN/m² da pipe [mm]	SR 24 ≥ 4 kN/m² Weight [kg/6 m]	SR 24 ≥ 8 kN/m² da pipe [mm]	SR 24 ≥ 8 kN/m² Weight [kg/6 m]	SR 24 ≥ 16 kN/m² da pipe [mm]	SR 24 ≥ 16 kN/m² Weight [kg/6 m]	SR 24 ≥ 31.5kN/m² da pipe [mm]	SR 24 ≥ 31.5kN/m² Weight [kg/6 m]
300	426	103	426	103	426	103	426	103
400	526	133	526	133	526	133	526	133
500	626	163	626	163	626	163	626	163
600	726	193	726	193	726	193	726	193
700	826	222	826	222	826	222	826	222
800	926	252	926	252	926	252	926	252
900	1026	282	1026	282	1026	282	1026	282
1000	1126	312	1126	312	1126	312	1132	399
1100	1226	342	1226	342	1226	342		
1200	1326	372	1326	372	1332	475		
1300	1426	402	1426	402	1432	513		
1400	1526	432	1526	432				
1500	1626	461	1626	461				
1600	1726	491	1732	628				
1800	1926	562						



PKS-THERMPIPE® pipes

Within the framework of static calculation to ATV-DVWK A 127, pipe rigidity (SR_{24}) is calculated in accordance with DIN 16961. The PKS-THERMPIPE pipe manufacturing process also enables the manufacture of other SR classes than those indicated here.

Project-related design and/or co-ordinated manufacturing guarantees the user a pipe system with economical dimensions and optimum rigidity.

- Standard length 6 m
- Special lengths on request
- Made of PE 100
- Form A:
  yellow interior with electro-fusion socket and spigot
  (DN 300 to DN 2400)
- Form B:
  yellow interior with extrusion-welding socket and spigot
  (DN 300 to DN 3500)

Prerequisites for PKS-THERMPIPE® pipes

1. Refurbishment / New installation
2. Collectors with no/few building connections (introductions poss. via shafts)
3. Waste water volume (15 l/s)
4. Bivalent heating system at consumer's

PKS-THERMPIPE® distribution shafts

The connection lines for the individual THERMPIPE brine circuit sections are combined at one or more central points in distribution shafts.
Fully prefabricated in the factory, the distribution shafts facilitate system connection and commissioning. All of the requisite shut-off and regulating valves are already pre-mounted. This facilitates flushing and ventilating as well as hydraulic adjustment of the system. High-quality balancing valves allow exact hydraulic adjustment at various lengths of the connection lines as well as ensuring optimum thermal utilisation of each pipe section.

The distribution shaft dimensions depend on the respective project. At increased static requirements - from pressing groundwater through to use by trucks - suitability is documented by verifiable statics.
The adaptable designs of the distributions therefore mean that a suitable solution can be found for any plant size.

- Shaft shell and base made of PE
- Shaft dimensions from DN 300 mm to 2000 mm
- Overall length or height from 3 to 6 m
- Passable/Navigable variants can be supplied.

Connecting line at distribution shaft in horizontal design

Distribution components in the distribution shaft

FRANK

Der Vorsprung.

FRANK GmbH
Starkenburgstraße 1
64546 Mörfelden–Walldorf
Tel.: +49 6105 4085–0
Fax: +49 6105 4085–249
E-mail: info@frank-gmbh.de
Internet: www.frank–gmbh.de

5. Reference
Weimar (Germany) Sports Center „Wimaria“

6 PKS-Thermpipe DN 500
with 6 m length

5. Reference
Weimar (Germany) Sports Center „Wimaria“

PKS-Thermpipe DN 500 with fitting adaptet to the length.

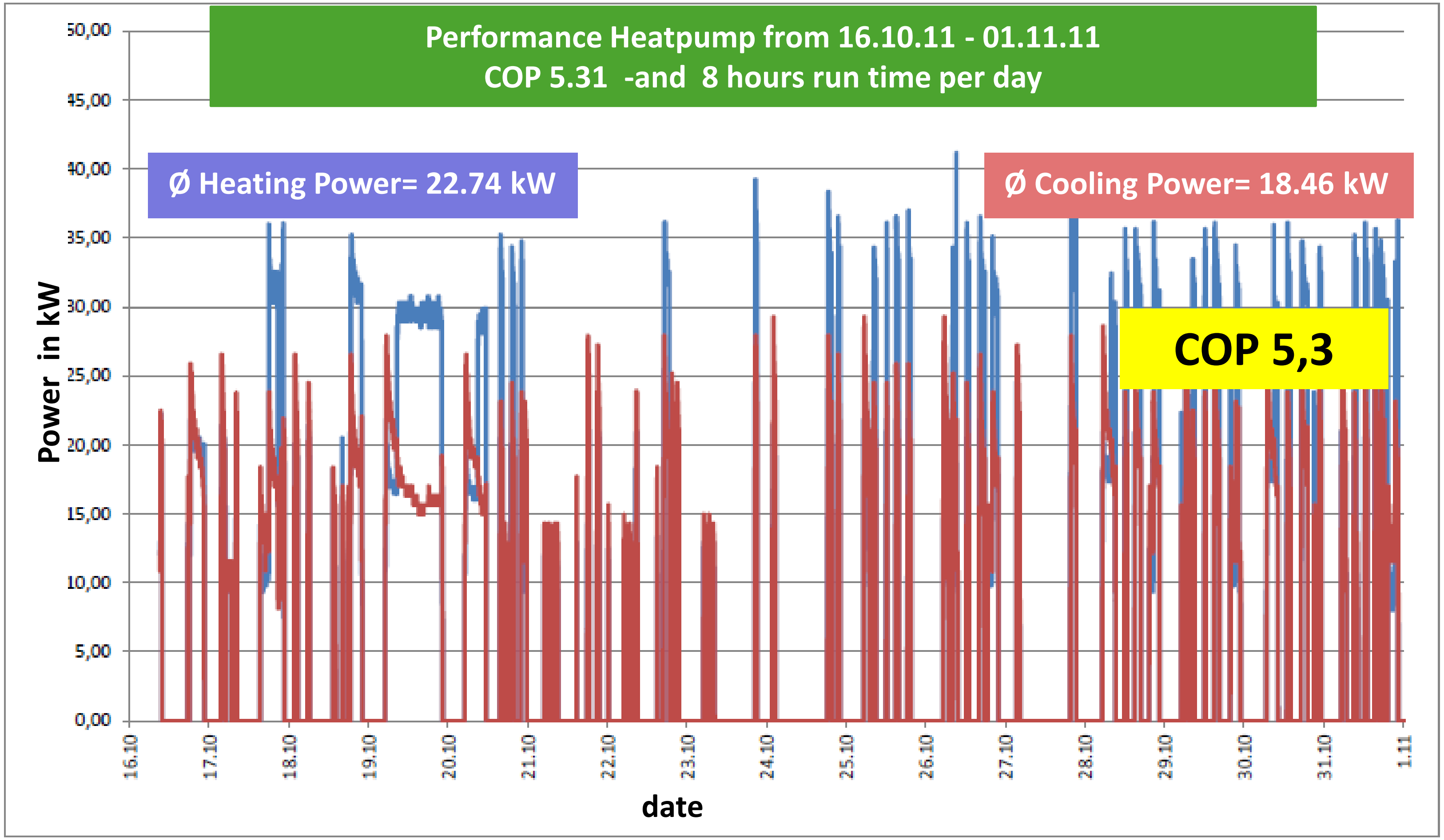
Modular plastic brine manifold inside the manhole

Manhole System Frank

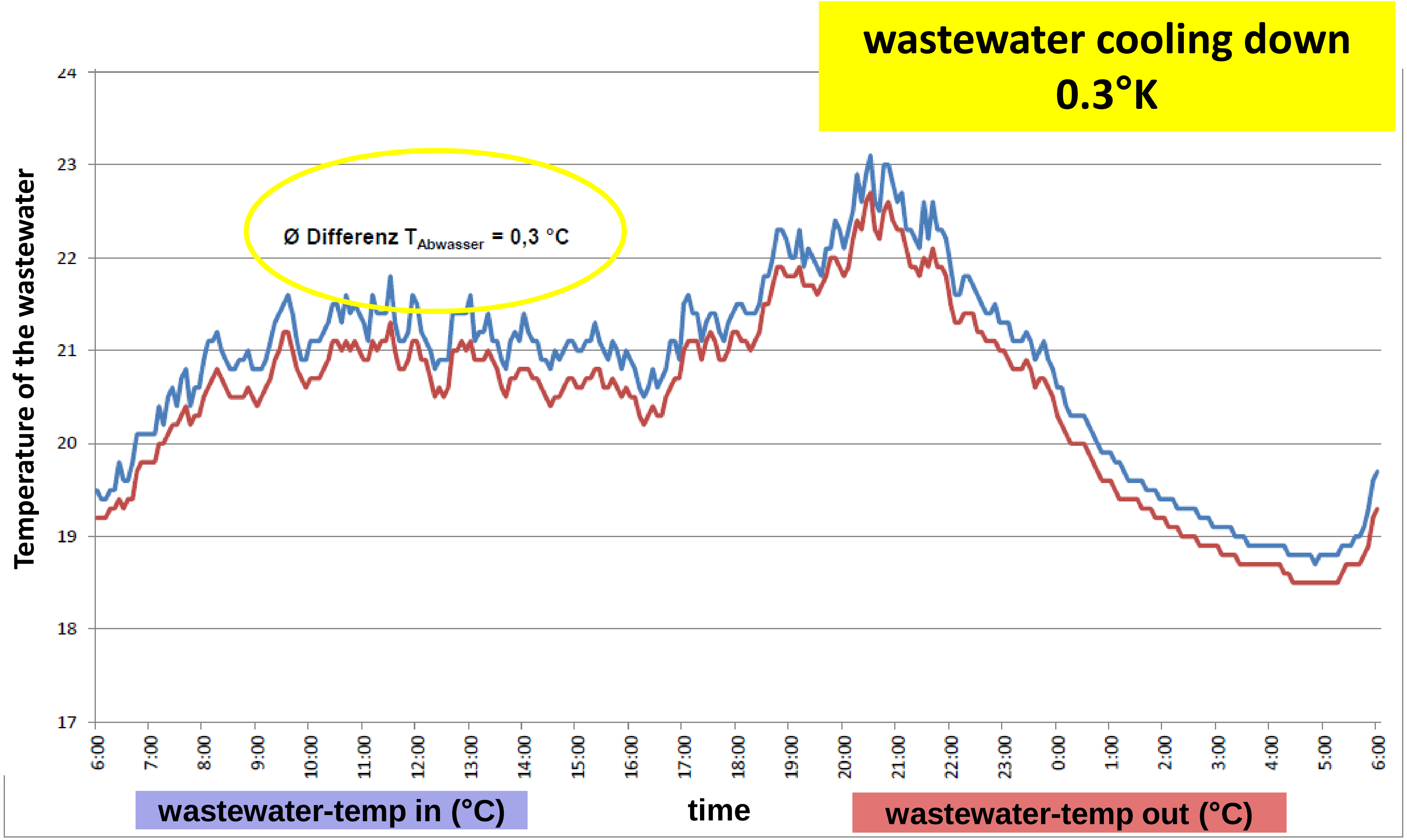
36 m PKS-Thermpipe DN 500
7.5 l/s dry weather flow at night
3 Heating Circuits
Heating Power: 22.7 kW
Cooling Power: 18.5 kW
COP: 5.3

PKS-Thermpipe covered with sand in the trench

5. Reference
Weimar (Germany) Sports Center „Wimaria“



5. Reference
Weimar (Germany) Sports Center „Wimaria“



FRANK

5. Reference Germany Winnenden Treatment plant

PKS-Thermpipe:
Wastewater energy for heating a treatment plant, animal Shelter and a greenhouse

Heatpump-house

Manhole with manifold inside

Heatpump-house

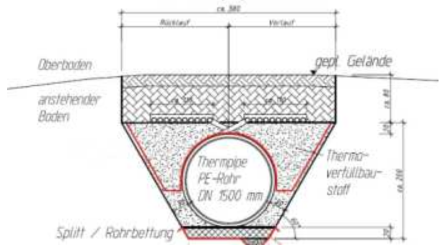
5. Reference Germany Winnenden Treatment plant

Thermally optimized filling material: better heat storage capacity

60 m PKS-Thermpipe DN 1500
10 Heat Circuits
Dry weather flow: 40 l/s
Wastewater temp in winter: 13°C
Heating power: 43 kW
Cooling power: 34.4kW
Heatpump flowtemp.: 45°C
Heatpumpe returntemp.: 40°C
Brinetemp in: 6°C
Brinetemp out: 3°C
Wastewater cooling down: 0.2°K
COP: 4.9

trench with liquid filling material
sod laid curing

manifold



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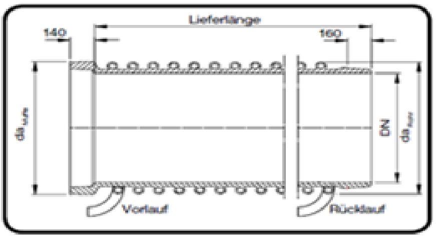
Richtpreisliste Thermpiperohr:

FRANK
Der Vorsprung.

PKS-THERMPIPE®

Kanalrohrsystem mit zusätzlicher Nutzung der Energie aus Boden und Abwasser.

Maße und Toleranzen nach DIN 16961
Standardlänge 6 m (Sonderlänge auf Anfrage)
gelbe Innenfläche, mit Elektroschweißmuffe und Spitzende
inkl. werkseitig vorkonfektioniertem Vor- und Rücklauf
(DN300 bis DN1600) aus PE100



DN	Profil	SN	VK PKS- Thermpipe [€/Rohr]	[€/m]
300	PR 54-6.0	181,7	1.023,40	170,60
400	PR 54-6.0	84,1	1.182,70	197,10
500	PR 54-6.0	45,6	1.297,50	216,30
600	PR 54-6.0	27,4	1.433,80	239,00
700	PR 54-6.0	17,7	1.655,20	275,90
800	PR 54-6.0	12,1	1.725,40	287,60
900	PR 54-6.0	8,7	1.876,60	312,80
1000	PR 54-6.0	6,4	1.942,80	323,80
1100	PR 54-6.0	4,9	2.076,40	346,10
1200	PR 54-6.0	3,8	2.208,70	368,10
1300	PR 54-7.8	3,9	2.635,30	439,20
1400	PR 54-7.8	3,1	2.787,90	464,70
1500	PR 54-9.3	3,0	3.001,20	500,20
1600	PR 54-9.3	2,5	3.334,60	555,80

Preisbindung: Preis gültig bis 31.03.2013
Lieferung: Ab Werk 61200 Wölfersheim zzgl. Frachtkosten.

Stückzahlen für Transport

PKS- Rohre pro LKW	DN [mm]	St./LKW [12 Lademeter]
	300	50 St.
	400	40 St.
	500	32 St.
	600	18 St.
	700	18 St.
	800	8 St.
	900	8 St.
	1000	8 St.
	1100	8 St.
	1200	4 St.
	1300	4 St.
	1400	4 St.
	1500	2 St.
	1600	2 St.

Einbaubedingungen

Statische Annahmen für Rohre und Bauteile		
	Verkehrslast:	SLW 60 (Straße)
	Grundwasser ü. Rohrsohle:	keins
	Überdeckung ü. Rohrscheitel	von 0,5 m bis 2,50 m
	Bodenart bzw. Bettung:	g = 20,00 KN/m³; E1 – E2,
		E20, G1=97% Dpr, E3,
		G2=95% Dpr, E4=10xE1
	Auflagerwinkel Bettung:	120°
	Einbaufall:	A1/B1
	Grabenbreite:	nach DIN EN 1610
	Böschungswinkel:	90°
	Rohrtemperatur:	20°C
	Sicherheitsklasse A:	Sicherheitsbeiwert 2,0

Checklist PKS-THERMPIPE®

FRANK & KRAH Wickelrohr GmbH

General

Date: ______________

Project: ______________

Street: ______________

Town: ______________

Building: ______________

Heat consumer

Demand heating capacity building ______________ kW

Temperature level heating system ______________ °C

Distance to canal ______________ m

Planned new construction / revision? yes ☐ no ☐

Advice for heat consumer:

____

____

Sewer and ground conditions

Dimension DN ______________

Use ☐ mixed water ☐ waste water
☐ rain water ☐ industrial waste water

Sewer base slope ______________ ‰

Dry weather flow minim value: ______________ l/s

Drain maximum value: ______________ l/s average value: ______________ l/s

Sewage temperature: minimum value: ______________ °C

maximum value: ______________ °C average value: ______________ °C

Available canal length ______________ m

New construction? yes ☐ no ☐

Laying depth ______________ m

Soil type: ______________

Geological survey at hand? yes ☐ no ☐

Canal lies in groundwater? yes ☐ no ☐

Notes to canal and soil:

____

Frank & Krah Wickelrohr GmbH www.frank-krah.de
Dieselstraße 11 61200 Wölfersheim
Tel. 0 60 36 / 98 98-0 Fax 0 60 36 / 98 98-579
Geschäftsführer Matthias Haese
Groß-Gerauer Volksbank BLZ 508 925 00 / Kto. 1 400 819 IBAN: DE85 5089 2500 0001 4008 19 BIC: GENODE51GG1
Amtsgericht Friedberg HRB 6130

RABTHERM ENERGY SYSTEMS

Checklist

Heat recovery from sewage

Please answer as many questions as possible

Question / criteria	unit	example	answer
General			
New building	-		
Existing building (renovation)	-	√	
Energy plant (reconstruction)	-	√ H	
New sewer	-		
Existing sewer (reconstruction)	-		
Date of project realisation		2011	
Sewer (city, sewer authority)			
years in operation	years	40	
sewer shape and dimensions			
circular Ø	mm	1000	
egg-shaped height / width	mm/mm		
rectangular height / width	mm/mm		
slope	‰	1	
average sewage flow (dry weather)	ℓ/s	60	
sewage temperature			
average year	°C / °F	15 / 59	
minimum	°C / °F	8 / 46	
drainage area	population	20000	
User of energy (proprietor, contractor)			
Buildings			
number	-	1	
type	-	school	
Size	m^3	10000	
persons / working places	-	50	
Existing plants			
Heating (G gas / O oil / other)	-	O	
Domestic hot water	-	√	
Cooling	-		
Power / energy consumption			
Heating power	kW	50	
energy Gas m^3/a, Oil l/a		O 70000	
Heating temperature	°C	50	
Distance sewer to building / heating plant	m	50	
free f / overbuilt o	-	u	
Energy tariffs			
Gas / oil	€/MWh		
electrical power	€/MWh	50	
district heating	€/MWh	120	

Send us the completed checklist by fax: +41 (0)44 401 07 27 **or by mail:** info@rabtherm.com

Appendix C

Triple Bottom Line
Technology Comparison Tool

Milwaukee Sewer Heat Recovery Alternatives Comparison Matrix - Triple-Bottom-Line Evaluation

	Social									
Criteria	**Heat Source Flexibility**		**Disruption to Community**		**LEED Ratings**		**Community Cohesion**		**Efficiency**	
	S1		**S2**		**S3**		**S4**		**T1**	
	Weight	**6.25%**	**Weight**	**6.25%**	**Weight**	**2.60%**	**Weight**	**3.65%**	**Weight**	**4.69%**
Technology 1: ThermWin by Huber Tech (Modular Heat Exchange)	Moderate Improvement	80.0	Minor Disruption	80.0	N/A	0.0	Significant Improvement	80.0	Average Efficiency	50.0
Technology 2: SHARC by International Wastewater Systems (Modular Heat Exchange)	Moderate Improvement	80.0	Minor Disruption	80.0	N/A	0.0	Significant Improvement	80.0	Above Average Efficiency	80.0
Technology 3: TubeWin by Huber Tech (Pipe Liner Heat Exchange)	Moderate Improvement	80.0	Moderate Disruption	60.0	N/A	0.0	Significant Improvement	80.0	Least Efficient	0.0
Technology 4: Rabtherm Energy Systems Series E - Liner for Existing Pipe Series I - Integrated in New Pipe	Moderate Improvement	80.0	Severe Disruption	20.0	N/A	0.0	Significant Improvement	80.0	Below Averge Efficiency	20.0
Technology 5: PKS Thermpipe by Frank Der Vorsprung (Circumfrential loops integrated in new pipe)	Moderate Improvement	80.0	Severe Disruption	20.0	N/A	0.0	Significant Improvement	80.0	Average Efficiency	50.0

Technical & Environmental											
Constructability		Cross-Contamination Risk		Operations & Maintenance		Upstream Impacts		Downstream Impacts		Greenhouse Gas Reduction	
T2		T3		T4		T5		T6		T7	
Weight	3.79%	Weight	3.35%	Weight	6.25%	Weight	4.46%	Weight	3.79%	Weight	6.92%
Minor Risks and Impacts	80.0	High Risk	20.0	Moderate Additional Constraints and Effort	40.0	No Impact	60.0	Slight Impact to Downstream Conditions	20.0	Significant Emissions Reduction	100.0
Minor Risks and Impacts	80.0	High Risk	20.0	Moderate Additional Constraints and Effort	40.0	No Impact	60.0	Slight Impact to Downstream Conditions	20.0	Significant Emissions Reduction	100.0
Moderate Risks and Impacts	60.0	High Risk	20.0	Minor Additional Effort	60.0	Slight Impact to Upstream Conditions	20.0	Slight Impact to Downstream Conditions	20.0	Moderate Emissions Reduction	80.0
Moderate Risks and Impacts	60.0	Low Risk	80.0	Standard O&M (No Change in Effort)	80.0	Strong Improvement over Existing Conditions	100.0	No Impact	60.0	Moderate Emissions Reduction	80.0
Moderate Risks and Impacts	60.0	Low Risk	80.0	Standard O&M (No Change in Effort)	80.0	Strong Improvement over Existing Conditions	100.0	No Impact	60.0	Moderate Emissions Reduction	80.0

		Economy											
Adaptability for Future Improvements		Capital Costs		Operations & Maintenance Costs		Asset Renewal Integration Opportunities		Economic Development & Job Creation		Property Values			
T8		E1		E2		E3		E4		E5			
Weight	4.24%	Weight	11.17%	Weight	12.10%	Weight	7.45%	Weight	9.31%	Weight	3.72%	Total	Rank
Significant Upgrades Required	30.0	Moderate Cost	80.0	High Cost	50.0	Minor Opportunity	20.0	Minor Opportunity	20.0	Moderately Increases Property Values	60.0	53.7	5.0
Significant Upgrades Required	30.0	Moderate Cost	80.0	High Cost	50.0	Minor Opportunity	20.0	Minor Opportunity	20.0	Moderately Increases Property Values	60.0	55.1	3.0
Moderate Upgrades Required	60.0	High Cost	50.0	Moderate Cost	75.0	Moderate Opportunity	60.0	Moderate Opportunity	60.0	Moderately Increases Property Values	60.0	55.0	4.0
Significant Upgrades Required	30.0	Very High Cost	20.0	Low Cost	100.0	Major Opportunity	100.0	Moderate Opportunity	60.0	Moderately Increases Property Values	60.0	63.2	1.0
Significant Upgrades Required	30.0	Very High Cost	20.0	Low Cost	100.0	Moderate Opportunity	60.0	Moderate Opportunity	60.0	Moderately Increases Property Values	60.0	61.6	2.0

SOCIAL

Heat Source Flexibility	6.25%
Increases to infrastructure resilience, redundancy, durability.	
N/A	0.0%
Degrades Existing Conditions	0
No Improvement	20
Minor Improvement	60
Moderate Improvement	80
Very Beneficial and Exceeds Objectives	100

Disruption to Community	6.25%
Duration of construction. Traffic and service impacts. Permanent structures that might impact views/access.	
N/A	0.0%
Extreme Disruption	0
Severe Disruption	20
Moderate Disruption	60
Minor Disruption	80
No Disruption	100

LEED Ratings	2.60%
Likelihood for improvement to LEED building ratings.	
N/A	0%
Does Not Improve Rating	0
Minimal Improvement over Baseline Rating	20
Moderate Improvement over Baseline Rating	60
Significant Improvement over Baseline Rating	80
Very Beneficial and Exceeds Objectives	100

Community Cohesion	3.65%
Provides opportunities for public awareness and education.	
N/A	0%
Decrease in Community Cohesion	0
Minimal Improvement	20
Moderate Improvement	60
Significant Improvement	80
Very Beneficial and Exceeds Objectives	100

TECHNICAL & ENVIRONMENTAL

Efficiency	4.69%
Heat Transfer Efficiency	
N/A	0.00%
Least Efficient	0
Below Averge Efficiency	20
Average Efficiency	50
Above Average Efficiency	80
Most Efficient	100

Constructability	3.79%
Potential for construction difficulties, including conflicts with existing infrastructure or contaminated sites.	
N/A	0.00%
Severe Risk and/or Impacts	0
Major Risks and Impacts	20
Moderate Risks and Impacts	60
Minor Risks and Impacts	80
Standard/Stable Conditions	100

Cross-Contamination Risk	3.35%
Potential for sewer contamination affecting building systems.	
N/A	0.00%
Significant Risk	0
High Risk	20
Moderate Risk	60
Low Risk	80
No Risk	100

Operations & Maintenance	6.25%
Complexity/Simplicity of O&M.	
N/A	0%
Significant Additional Constraints and Effort	0
Moderate Additional Constraints and Effort	40
Minor Additional Effort	60
Standard O&M (No Change in Effort)	80
Less Effort than Traditional Tech.	100

Upstream Impacts	4.46%
Impacts to the upstream flow capacity.	
N/A	0%
Detrimental to Upstream Conditions	0
Slight Impact to Upstream Conditions	20
No Impact	60
General Improvement over Existing Conditions	80
Strong Improvement over Existing Conditions	100

Downstream Impacts	3.79%
Impacts to the downstream temperature.	
N/A	0%
Detrimental to Downstream Conditions	0
Slight Impact to Downstream Conditions	20
No Impact	60
General Improvement over Existing Conditions	80
Strong Improvement over Existing Conditions	100

Greenhouse Gas Reduction	6.92%
Reduction of emissions.	
N/A	0%
Increase in Emissions	0
No Impact	20
Minimal Emissions Reduction	60
Moderate Emissions Reduction	80
Significant Emissions Reduction	100

Adaptability for Future Improvements	4.24%
Works can be expanded or adapted to operate more effectively.	
N/A	0%
Not Flexible, New Works Required	0
Significant Upgrades Required	30
Moderate Upgrades Required	60
Minor Upgrades Required	100

ECONOMIC

Capital Costs	11.17%
Near-term affordability.	
N/A	0.00%
Not Affordable	0
Very High Cost	20
High Cost	50
Moderate Cost	80
Low Cost	100

Operations & Maintenance Costs	12.10%
Long-term affordability.	
N/A	0.00%
Not Affordable	0
Very High Cost	25
High Cost	50
Moderate Cost	75
Low Cost	100

Asset Renewal Integration Opportunities	7.45%
Opportunity to integrate proposed works during previously scheduled maintenance or new construction.	
N/A	0.00%
No Opportunity	0
Minor Opportunity	20
Moderate Opportunity	60
Large Opportunity	80
Major Opportunity	100

Economic Development & Job Creation	9.31%
Promotes development and job creation.	
N/A	0%
No Opportunity	0
Minor Opportunity	20
Moderate Opportunity	60
Major Opportunity for the District	80
Major Opportunity for the District and the Community	100

Property Values	3.72%
Increase in property value	
N/A	0%
Degrades Existing Property Values	0
No Improvement to Property Values	20
Moderately Increases Property Values	60
Significantly Increases Property Values	100

Pairwise Comparison Method

Evaluation Criteria and Weightings

Criteria Y

Criteria X — in relation to

The first pairwise comparison is conducted for the three criteria to establish their weights. Subsequently, pairwise comparisons are performed for the elements within each criteria.

CRITERIA	Social	Technical & Environmental	Economic	Sum	Weight
Social		1	2	3	18.8%
Technical & Environmental	3		3	6	37.5%
Economic	4	3		7	43.8%

SOCIAL	Heat Source Flexibility	Disruption to Community	LEED Ratings	Community Cohesion	Sum	Weight
Heat Source Flexibility		4	5	3	12	6.3%
Disruption to Community	2		5	5	12	6.3%
LEED Ratings	1	1		3	5	2.6%
Community Cohesion	3	1	3		7	3.6%

TECHNICAL & ENVIRONMENTAL	Efficiency	Constructability	Cross-Contamination Risk	Operations & Maintenance	Upstream Impacts	Downstream Impacts	Greenhouse Gas Reduction	Adaptability for Future Improvements	Sum	Weight
Efficiency		3	2	3	4	3	2	4	21	4.7%
Constructability	3		4	1	2	2	2	3	17	3.8%
Cross-Contamination Risk	4	2		1	2	3	1	2	15	3.3%
Operations & Maintenance	3	5	5		4	5	2	4	28	6.3%
Upstream Impacts	2	4	4	2		4	1	3	20	4.5%
Downstream Impacts	3	4	3	1	2		1	3	17	3.8%
Greenhouse Gas Reduction	4	4	5	4	5	5		4	31	6.9%
Adaptability for Future Improvements	2	3	4	2	3	3	2		19	4.2%

ECONOMIC	Capital Costs	Operations & Maintenance Costs	Asset Renewal Integration Opportunities	Economic Development & Job Creation	Property Values	Sum	Weight
Capital Costs		2	3	2	5	12	11.2%
Operations & Maintenance Costs	4		5	4	5	13	12.1%
Asset Renewal Integration Opportunities	3	3		2	5	8	7.4%
Economic Development & Job Creation	4	2	4		5	10	9.3%
Property Values	1	1	1	1		4	3.7%

In order to establish the relative importance of each criterion, and assign weights to each, the pair-wise comparison is performed The pair-wise comparison is based on successively comparing the criteria in the left hand column with the other criteria and assessing their relative importance against one another on the basis of a total score of 6 where the following scores are assigned:

- **5** vs. **1** if one criterion is deemed to be much more important than the other;
- **4** vs. **2** if one criterion is deemed to be somewhat more important than the other; and;
- **3** and **3** if both criteria are deemed to be equally important.

Summing the scores for each criterion provides a measure of the relative importance of the criteria and provides the basis for establishing the relative weights to be applied for each criterion in the evaluation alternatives.

Appendix D

Payback Calculations

Milwaukee Sewer Heat Recovery
Performance Summary and Payback Analysis with Heat Pump

Prepared by: David Railsback
9/26/13

Heat Recovery Technology		Heat Exchanged Before HP			Capacity After HP (20% Increase)			Coefficient of Performance (COP)	Equipment Cost		Installed Cost		Electricity Demand	Cost of Electricity	Annual Electricity Cost [1]	Cost of Natural Gas	Annual Value of Heat Produced (Baseline) [1]	Net Annual Savings
		kW	BTU/hr	mBTU/hr	kW	BTU/hr	mBTU/hr	Q_{Heat}/Q_{Elec}	w/o HP	w/ HP	w/o HP	w/ HP	kW	$/kWh	$/yr	$/100,000 BTU	$/yr	$/yr
ThermWin (Modular)	small	100	341,214	341	120	409,457	409	5	$200,000	$250,000	$400,000	$500,000	24	0.13	$13,478	$0.54	$11,940	-$1,539
	med	200	682,428	682	240	818,914	819	5	$250,000	$325,000	$500,000	$650,000	48	0.13	$26,957	$0.54	$23,880	-$3,077
	large	300	1,023,643	1,024	360	1,228,371	1,228	5	$300,000	$400,000	$600,000	$800,000	72	0.13	$40,435	$0.54	$35,819	-$4,616
		417	1,421,726	1,422	500	1,706,071	1,706	5	$650,000	$750,000	$1,300,000	$1,500,000	100	0.13	$56,160	$0.54	$49,749	-$6,411
SHARC (Modular)	small	49	166,667	167	59	200,000	200	5	$140,000	$160,000	$350,000	$400,000	12	0.13	$6,584	$0.54	$5,832	-$752
	medium	542	1,848,244	1,848	650	2,217,892	2,218	5	$250,000	$400,000	$625,000	$980,000	130	0.13	$73,008	$0.54	$64,674	-$8,334
	large	1,083	3,696,487	3,696	1,300	4,435,785	4,436	5	$370,000	$650,000	$740,000	$1,350,000	260	0.13	$146,015	$0.54	$129,347	-$16,668
	very large	2,167	7,392,974	7,393	2,600	8,871,569	8,872	5	$685,000	$1,135,000	$1,370,000	$2,270,000	520	0.13	$292,031	$0.54	$258,695	-$33,336
TubeWin (Liner for Existing Pipe)	Small	30	102,364	102	36	122,837	123	5	$93,750	$113,750	$187,500	$227,500	7	0.13	$4,044	$0.54	$3,582	-$462
	Medium	75	255,911	256	90	307,093	307	5	$250,000	$290,000	$500,000	$580,000	18	0.13	$10,109	$0.54	$8,955	-$1,154
	Large	150	511,821	512	180	614,186	614	5	$450,000	$510,000	$900,000	$1,020,000	36	0.13	$20,218	$0.54	$17,910	-$2,308
Rabtherm Series E (Liner for Existing Pipe)	Medium	100	341,214	341	120	409,457	409	5	$188,034	$238,034	$213,540	$476,068	24	0.13	$13,478	$0.54	$11,940	-$1,539
Rabtherm Series I (Integrated in New Pipe at Invert)	Medium	100	341,214	341	120	409,457	409	5	$217,558	$267,558	$435,116	$535,116	24	0.13	$13,478	$0.54	$11,940	-$1,539
PKS-Thermpipe	Small	23	78,479	78	28	94,175	94	5	$26,514	$46,514	$53,029	$93,029	6	0.13	$3,100	$0.54	$2,746	-$354
(Integrated in New Pipe, Circumfrential	Medium	280	955,400	955	336	1,146,480	1,146	5	$201,740	$301,740	$403,480	$603,480	67	0.13	$37,739	$0.54	$33,431	-$4,308
Loops)	large	1,200	4,094,570	4,095	1,440	4,913,484	4,913	5	$518,760	$798,760	$1,037,520	$1,597,520	288	0.13	$161,740	$0.54	$143,277	-$18,463

Note 1 Operation is assumed as 6 months per year.
Note 2 Gray Font: Calculated Data
Black Font: Manufacturer Data

Milwaukee Sewer Heat Recovery
Performance Summary and Payback Analysis without Heat Pump

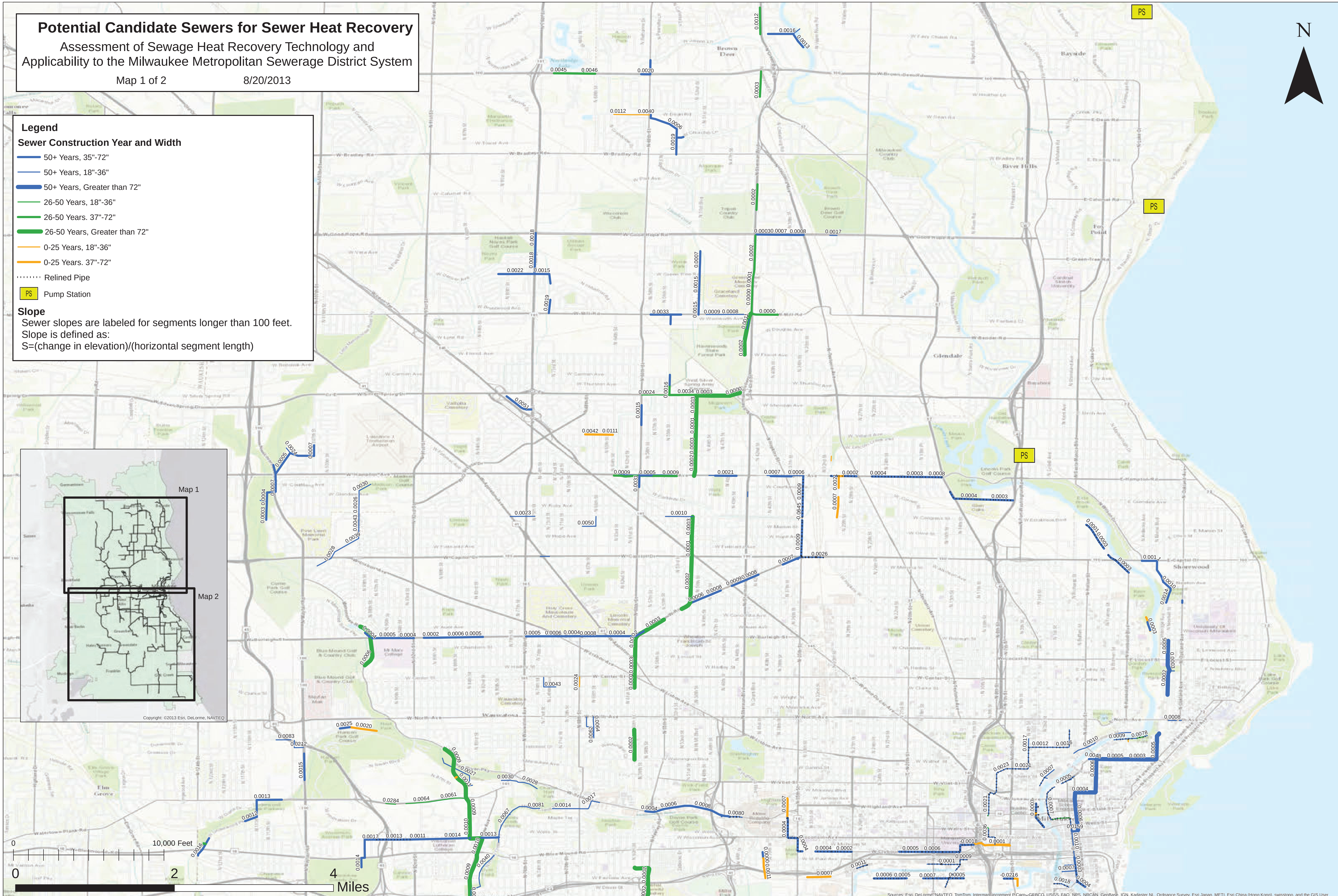
Prepared by: David Railsback
9/26/13

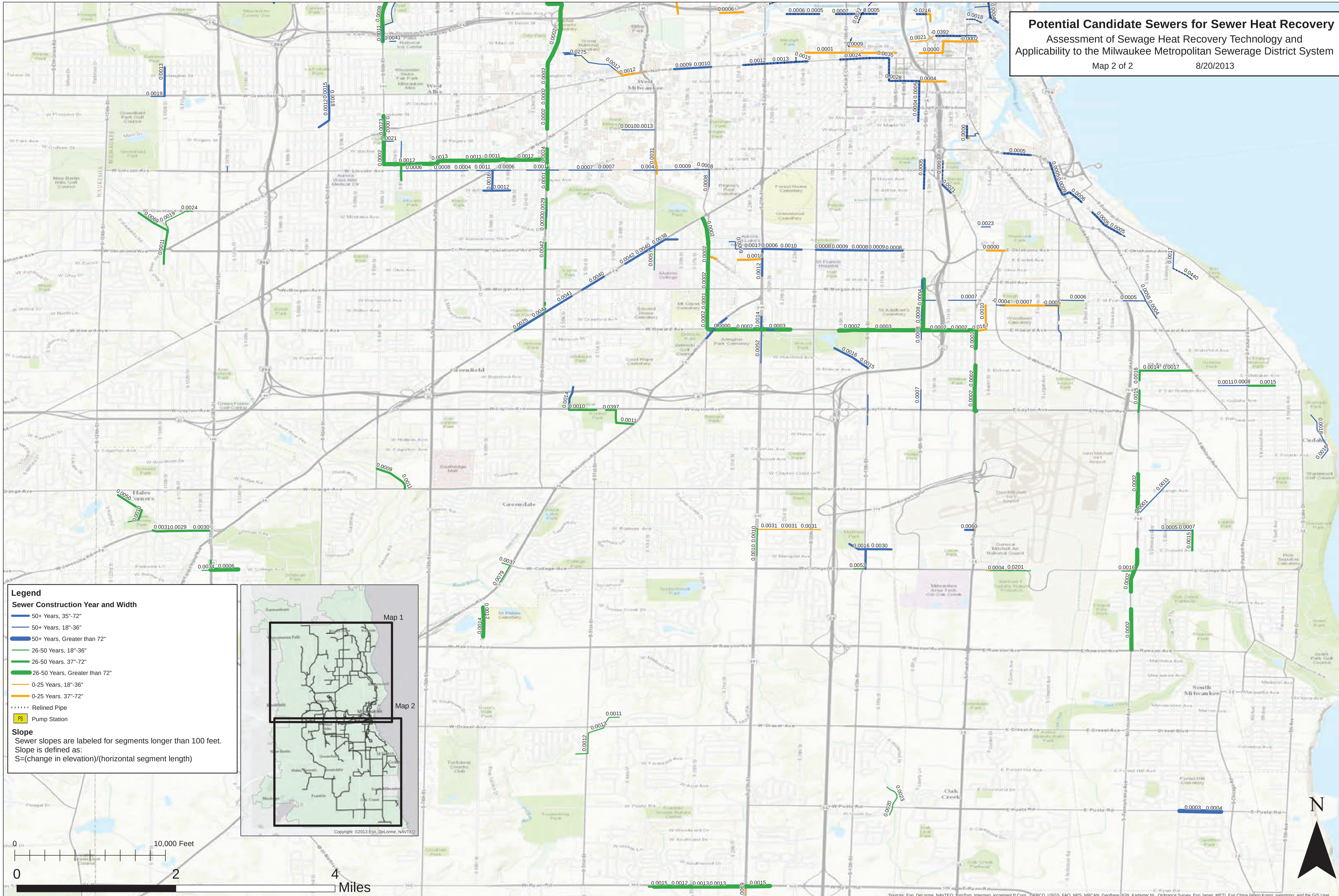
Heat Recovery Technology		Heat Exchanged Before HP			Capacity After HP (20% Increase)			Coefficient of Performance (COP)	Equipment Cost		Installed Cost		Electricity Demand	Cost of Electricity	Annual Electricity Cost [1]	Cost of Natural Gas	Annual Value of Heat Produced (Baseline) [1]	Net Annual Savings	Simple Payback
		kW	BTU/hr	mBTU/hr	kW	BTU/hr	mBTU/hr	Q_{Heat}/Q_{Elec}	w/o HP	w/ HP	w/o HP	w/ HP	kW	$/kWh	$/yr	$/100,000 BTU	$/yr	$/yr	yrs
	small	100	341,214	341	120	409,457	409	5	$200,000	$250,000	$400,000	$500,000	1.2	0.13	$674	$0.54	$9,950	$9,276	54
ThermWin	med	200	682,428	682	240	818,914	819	5	$250,000	$325,000	$500,000	$650,000	2.4	0.13	$1,348	$0.54	$19,900	$18,552	35
(Modular)	large	300	1,023,643	1,024	360	1,228,371	1,228	5	$300,000	$400,000	$600,000	$800,000	3.6	0.13	$2,022	$0.54	$29,849	$27,828	29
		417	1,421,726	1,422	500	1,706,071	1,706	5	$650,000	$750,000	$1,300,000	$1,500,000	5.0	0.13	$2,808	$0.54	$41,458	$38,650	39
	small	49	166,667	167	59	200,000	200	5	$140,000	$160,000	$350,000	$400,000	0.6	0.13	$329	$0.54	$4,860	$4,531	88
SHARC	medium	542	1,848,244	1,848	650	2,217,892	2,218	5	$250,000	$400,000	$625,000	$980,000	6.5	0.13	$3,650	$0.54	$53,895	$50,244	20
(Modular)	large	1,083	3,696,487	3,696	1,300	4,435,785	4,436	5	$370,000	$650,000	$740,000	$1,350,000	13.0	0.13	$7,301	$0.54	$107,790	$100,489	13
	very large	2,167	7,392,974	7,393	2,600	8,871,569	8,872	5	$685,000	$1,135,000	$1,370,000	$2,270,000	26.0	0.13	$14,602	$0.54	$215,579	$200,978	11
TubeWin	Small	30	102,364	102	36	122,837	123	5	$93,750	$113,750	$187,500	$227,500	0.4	0.13	$202	$0.54	$2,985	$2,783	82
(Liner for Existing Pipe)	Medium	75	255,911	256	90	307,093	307	5	$250,000	$290,000	$500,000	$580,000	0.9	0.13	$505	$0.54	$7,462	$6,957	83
	Large	150	511,821	512	180	614,186	614	5	$450,000	$510,000	$900,000	$1,020,000	1.8	0.13	$1,011	$0.54	$14,925	$13,914	73
Rabtherm Series E (Liner for Existing Pipe)	Medium	100	341,214	341	120	409,457	409	5	$188,034	$238,034	$213,540	$476,068	1.2	0.13	$674	$0.54	$9,950	$9,276	51
Rabtherm Series I (Integrated in New Pipe at Invert)	Medium	100	341,214	341	120	409,457	409	5	$217,558	$267,558	$435,116	$535,116	1.2	0.13	$674	$0.54	$9,950	$9,276	58
PKS-Thermpipe	Small	23	78,479	78	28	94,175	94	5	$26,514	$46,514	$53,029	$93,029	0.3	0.13	$155	$0.54	$2,288	$2,133	44
(Integrated in New Pipe, Circumfrential	Medium	280	955,400	955	336	1,146,480	1,146	5	$201,740	$301,740	$403,480	$603,480	3.4	0.13	$1,887	$0.54	$27,859	$25,972	23
Loops)	large	1,200	4,094,570	4,095	1,440	4,913,484	4,913	5	$518,760	$798,760	$1,037,520	$1,597,520	14.4	0.13	$8,087	$0.54	$119,398	$111,311	14

Note 1 Operation is assumed as 6 months per year.
Note 2 Gray Font: Calculated Data
Black Font: Manufacturer Data

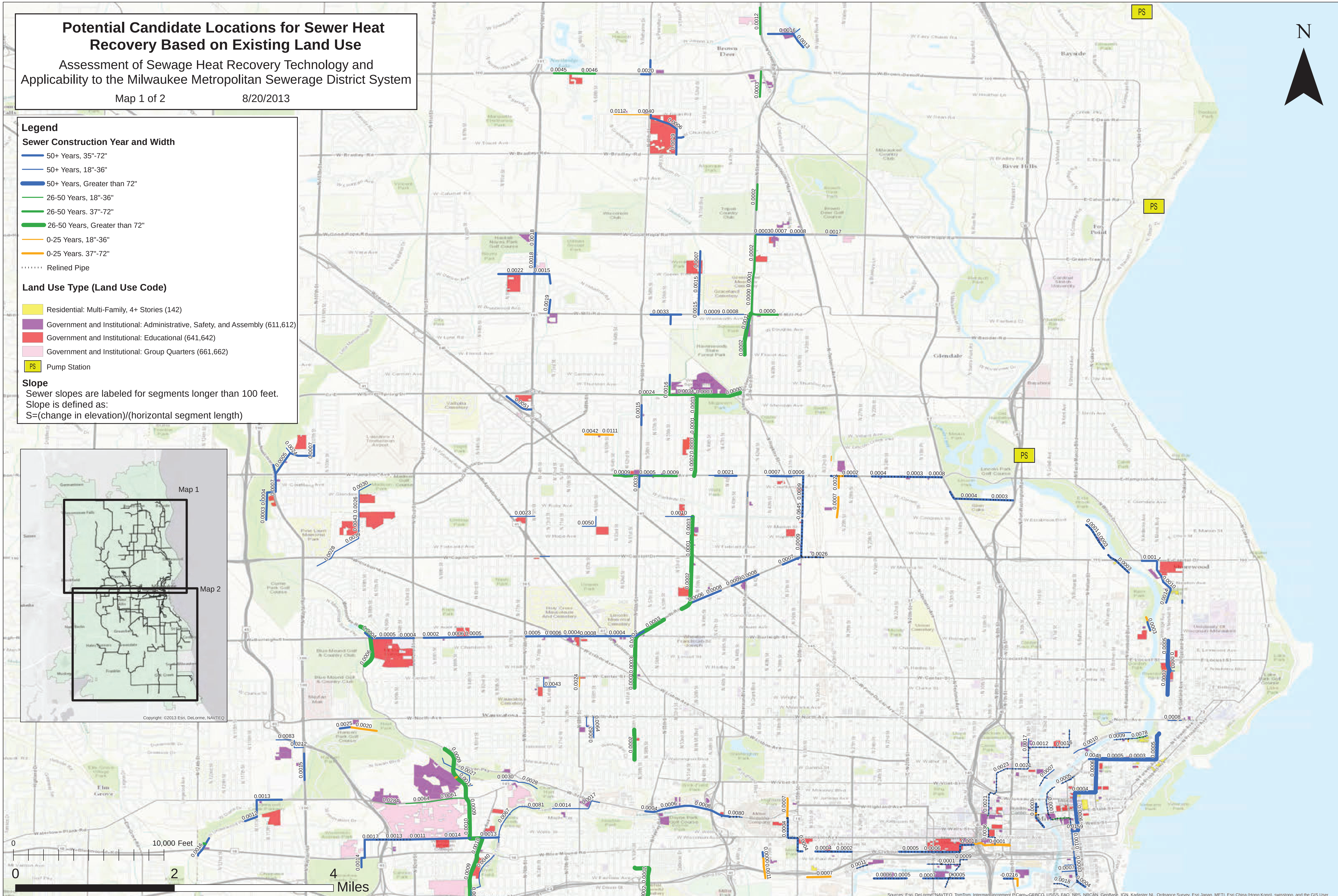
Appendix E

Maps

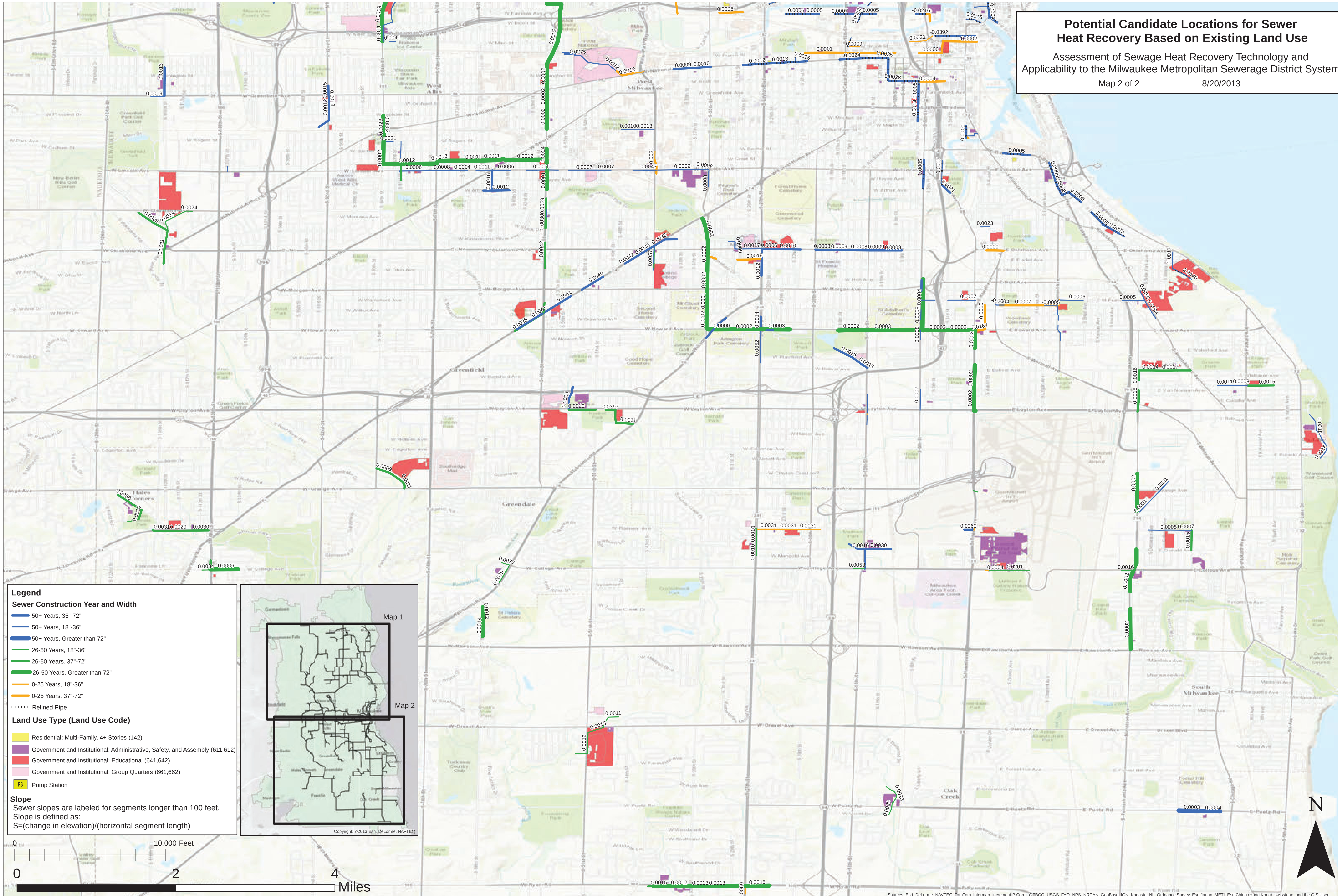

Potential Candidate Sewers for Sewer Heat Recovery
Assessment of Sewage Heat Recovery Technology and Applicability to the Milwaukee Metropolitan Sewerage District System
Map 1 of 2
8/20/2013
Legend
Sewer Construction Year and Width
50+ Years, 35"-72"
50+ Years, 18"-36"
50+ Years, Greater than 72"
26-50 Years, 18"-36"
26-50 Years. 37"-72"
26-50 Years, Greater than 72"
0-25 Years, 18"-36"
0-25 Years. 37"-72"
Relined Pipe
PS
Pump Station
Slope
Sewer slopes are labeled for segments longer than 100 feet.
Slope is defined as:
S=(change in elevation)/(horizontal segment length)
Map 1
Map 2
Copyright: ©2013 Esri, DeLorme, NAVTEQ
0
10,000 Feet
0
2
4
Miles
N
PS



Potential Candidate Sewers for Sewer Heat Recovery
Assessment of Sewage Heat Recovery Technology and
Applicability to the Milwaukee Metropolitan Sewerage District System
Map 2 of 2
8/20/2013
Legend
Sewer Construction Year and Width
50+ Years, 35"-72"
50+ Years, 18"-36"
50+ Years, Greater than 72"
26-50 Years, 18"-36"
26-50 Years. 37"-72"
26-50 Years, Greater than 72"
0-25 Years, 18"-36"
0-25 Years. 37"-72"
Relined Pipe
PS
Pump Station
Slope
Sewer slopes are labeled for segments longer than 100 feet.
Slope is defined as:
S=(change in elevation)/(horizontal segment length)
Map 1
Map 2
Copyright: ©2013 Esri, DeLorme, NAVTEQ
0
10,000 Feet
0
2
4
Miles
N
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community



Potential Candidate Locations for Sewer Heat Recovery Based on Existing Land Use
Assessment of Sewage Heat Recovery Technology and Applicability to the Milwaukee Metropolitan Sewerage District System
Map 1 of 2
8/20/2013
Legend
Sewer Construction Year and Width
50+ Years, 35"-72"
50+ Years, 18"-36"
50+ Years, Greater than 72"
26-50 Years, 18"-36"
26-50 Years. 37"-72"
26-50 Years, Greater than 72"
0-25 Years, 18"-36"
0-25 Years. 37"-72"
Relined Pipe
Land Use Type (Land Use Code)
Residential: Multi-Family, 4+ Stories (142)
Government and Institutional: Administrative, Safety, and Assembly (611,612)
Government and Institutional: Educational (641,642)
Government and Institutional: Group Quarters (661,662)
PS
Pump Station
Slope
Sewer slopes are labeled for segments longer than 100 feet.
Slope is defined as:
S=(change in elevation)/(horizontal segment length)
Map 1
Map 2
Copyright: ©2013 Esri, DeLorme, NAVTEQ
10,000 Feet
0
2
4
Miles
N
PS
PS
PS


Potential Candidate Locations for Sewer
Heat Recovery Based on Existing Land Use
Assessment of Sewage Heat Recovery Technology and
Applicability to the Milwaukee Metropolitan Sewerage District System
Map 2 of 2
8/20/2013
Legend
Sewer Construction Year and Width
50+ Years, 35"-72"
50+ Years, 18"-36"
50+ Years, Greater than 72"
26-50 Years, 18"-36"
26-50 Years. 37"-72"
26-50 Years, Greater than 72"
0-25 Years, 18"-36"
0-25 Years. 37"-72"
Relined Pipe
Land Use Type (Land Use Code)
Residential: Multi-Family, 4+ Stories (142)
Government and Institutional: Administrative, Safety, and Assembly (611,612)
Government and Institutional: Educational (641,642)
Government and Institutional: Group Quarters (661,662)
PS
Pump Station
Slope
Sewer slopes are labeled for segments longer than 100 feet.
Slope is defined as:
S=(change in elevation)/(horizontal segment length)
Map 1
Map 2
Copyright: ©2013 Esri, DeLorme, NAVTEQ
0
10,000 Feet
0
2
4
Miles
N
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community