FEATURE

Re-envisioning district energy at Sheridan College

Systems on two campuses are being implemented and optimized according to European standards.

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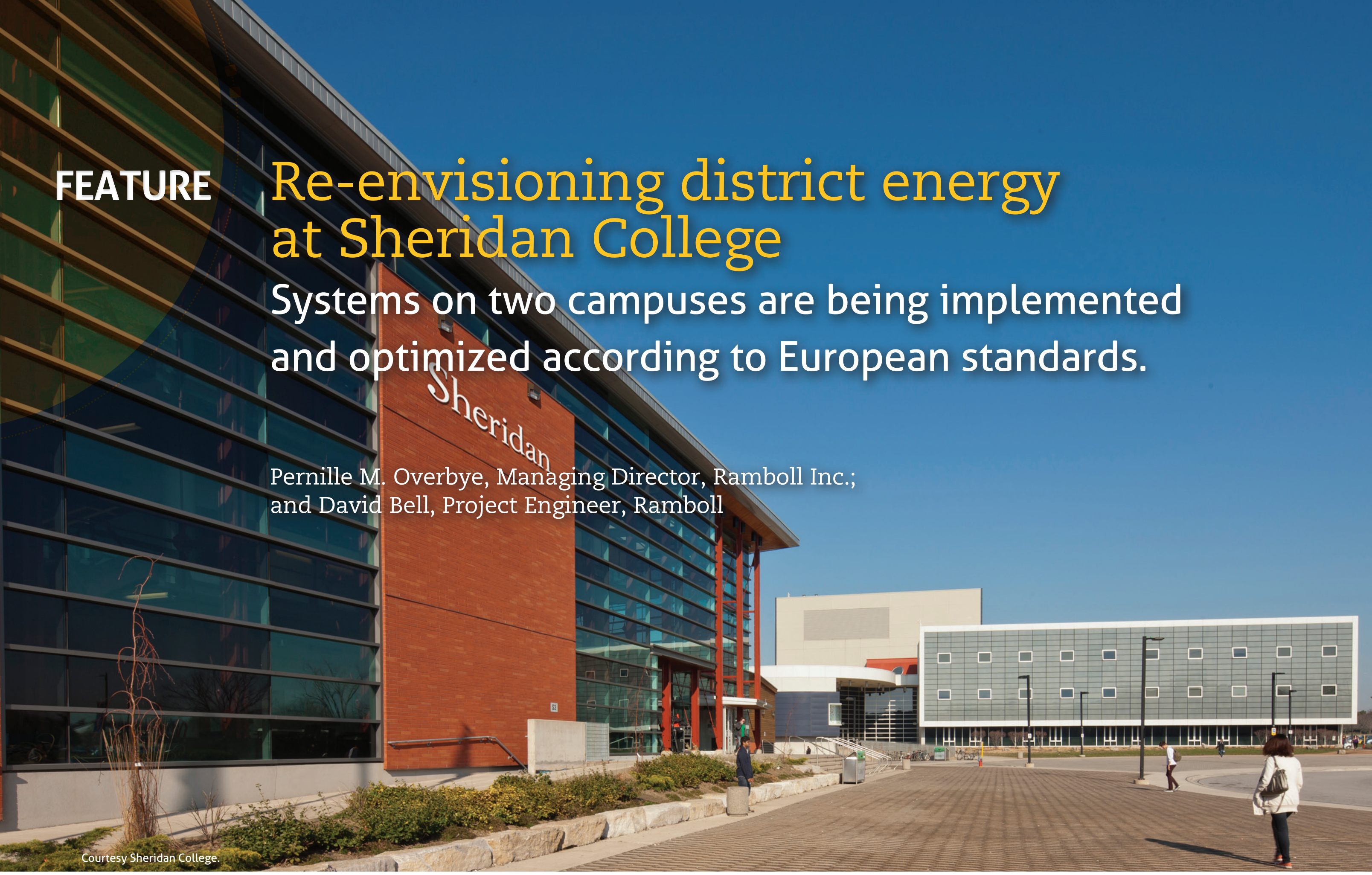


Sheridan College's Trafalgar Campus in Oakville, Ont.

Sheridan College in Ontario, Canada, is one of the province's leading postsecondary institutions. Founded in 1967, Sheridan currently educates more than 50,000 students on four campuses in three Greater Toronto Area cities – Oakville, Brampton and Mississauga. The college is home to Canada's largest arts school and one of the top animation programs in the world in addition to offering studies in business, community services, health, technology and the skilled trades.

It is part of Sheridan's mission to foster a culture of creativity and innovation – values that extend to its sustainability initiatives. In 2011, the college embarked on a project to study campus energy use and re-envision its energy future. It developed an integrated energy and climate master plan that aims to make Sheridan College a role model of world-class energy performance. A significant part of the plan involves upgrading the production and distribution of district energy on Sheridan's Trafalgar Campus in Oakville and Davis Campus in Brampton.

THE WAY FORWARD

Sheridan's total building portfolio of 200,000 sq m (2.15 million sq ft) of space represents a wide range of energy efficiencies and construction practices. In 2010, Sheridan determined that it spent CAN$4.4 million ($3.28 million) annually on natural gas and electricity, reflecting a 42 percent increase since 2005. Given the uncertainties about future energy prices, Sheridan forecast that its annual energy cost could rise to between CAN$7.5 million and CAN$10.6 million by 2030. While this level of energy consumption is comparable to that of similar institutions in Canada and the U.S., it is between 40 percent and 100 percent higher than European best practices, indicating the potential for greater energy efficiency.

In response, the college outlined the following goals in its integrated energy and climate master plan, finalized in 2013: to reduce primary energy use by at least 65 percent and greenhouse gas emissions by 47 percent, both by 2030 from 2010 levels, and to achieve acceptable economic returns on the total investment.

The pathway to achieving these goals as outlined in the plan included such campus energy system improvements as

- upgrading and standardizing building controls and metering,
- retrofitting all existing buildings to LEED Gold energy efficiency standards,
- installing new modern hot water district heating networks,
- selectively implementing local area district cooling networks,
- upgrading on-site heat supply utilizing combined heat and power engines and high-efficiency boilers,
- upgrading on-site cooling supply

utilizing waste heat absorption and high-efficiency compressor chillers, and
- installing solar photovoltaics.

In 2014, a preliminary design was completed by Garforth International for upgrading the Trafalgar and Davis campuses' district energy networks. In 2015, the Danish firm Ramboll was engaged to provide more detailed production and distribution system design, which is still onging and will be implemented by 2018.

DISTRICT ENERGY AT SHERIDAN

Just west of Toronto in Oakville, the Trafalgar Campus is partially supplied with steam for heating and domestic hot water by a central steam system with condensate return. Two small groups of buildings share hot water boilers, effectively forming very small islanded district heating networks; other buildings are heated by individual boilers or gas-fired rooftop units. The average age of the steam piping is 25-30 years, with average network heat losses estimated to be 25 percent. According to Sheridan's energy plan, these losses can be reduced by a factor of roughly 3 through a steam-to-hot water conversion.

Plans call for Trafalgar's existing steam boilers to be replaced by new gas-fired hot water boilers. The steam piping will be replaced with hot water piping and energy transfer stations to serve a total of 140,000 sq m (1.5 million sq ft) via a 1.6-km (approximately 1-trench-mile) network. The conversion of the steam distribution will be a multiyear process coordinated with the implementation of building efficiency measures.

A new energy center will replace an existing chiller plant and all the old boilers on campus. The energy center will house

- a CHP plant with 1 MW (3.41 MMBtu/hr) of thermal capacity and 0.85 MW electrical capacity, provided by a rich-burn natural gas CHP engine;
- 6 MW (20.47 MMBtu/hr) of peaking/backup gas condensing boilers;
- 100 cu m (3,531 cu ft) of hot water storage;
- 3 MW (850 tonnes) of electric chiller cooling capacity; and
- 50 cu m (1,766 cu ft) of chilled-water storage.

The Trafalgar Campus cooling system, which supplies chilled water to part of the campus, will serve 42,735 sq m (460,000 sq ft) through the existing piping network.

The Davis Campus in Brampton already has a relatively efficient hot water-based district heating system, but it is heavily interconnected between primary and secondary systems and operates at a fairly low delta T. Most Davis buildings are connected to this system.

Upgrades on the Davis Campus will include connection of a presently islanded building and a new student residence to the new network as well as construction of a new energy center to be located in a new engineering building. The facility will contain

- a CHP plant with 0.52 MW (1.77 MMBtu/hr) of thermal capacity and 0.4 MW electrical capacity, provided by two rich-burn natural gas CHP engines;
- 3 MW (10.24 MMBtu/hr) of peaking/backup gas condensing boilers;
- 50 cu m (1,766 cu ft) of heat storage (technology to be determined);
- 2.69 MW (765 tonnes) of combined absorption and electric chiller cooling capacity and
- 50 cu m (1,766 cu ft) of cold storage (technology to be determined).

The upgraded 1.5-km (0.93-trench-mile) hot water network will serve 93,000 sq m (approximately 1 million sq ft) of building space; and the 0.35-km (0.22-trench-mile) chilled-water network will supply 25,000 sq m (269,098 sq ft).

Extension of a new, pressurized hot water network at each campus will allow the heating plants to be optimized and operate at higher levels of efficiency. The heat supply portfolio can be adapted over time, eliminating the least efficient sources as more efficient or less-polluting alternatives are added.

TRAFALGAR SYSTEM REDESIGN

The new Trafalgar Campus energy center is being designed to maximize the operation and heat contribution of a new primary CHP plant. This will be achieved by minimizing return temperatures via a variable-flow network and through the utilization of thermal storage.

CHP and thermal storage

The design and sizing of the Trafalgar CHP plant and thermal storage required energy modeling that uses predicted heat demand profiles on an hour-by-hour basis for a full year. Energy modeling of the campus heat demand has therefore been performed using EMD International's energyPro software to optimize CHP and thermal storage size (fig. 1).

Optimizing thermal storage size enables the Trafalgar campus system to realize a number of benefits, including limited starting and stopping of CHP units, reducing operation and maintenance costs; the ability of the CHP plant to operate during times of higher electricity price (daytime) and to shut down at times of low electricity price (nighttime); leveled daily variation in heat demand, which reduces the use of peak boilers – normally beneficial in shoulder season months; and the ability of the plant to operate at full output for fewer hours rather than at part load where it would be less efficient.

Optimization of the CHP operation in summer has also been assessed. A comparison was made between the difference in energy consumption and operating costs when the CHP is operated either (1) according to the summer cooling demand, i.e., driven by the absorption chillers, or (2) not according to the summer cooling demand, i.e., driven by domestic hot water demand only.

Primarily this allowed the design team to assess the benefit of running the CHP more in summer to satisfy the cooling demand versus letting the electric chillers run in place. Examples of the production outputs for each scenario in heating and cooling mode are shown in figure 2.

Distribution network

The design team also aimed to maximize distribution network efficiency while minimizing costs.

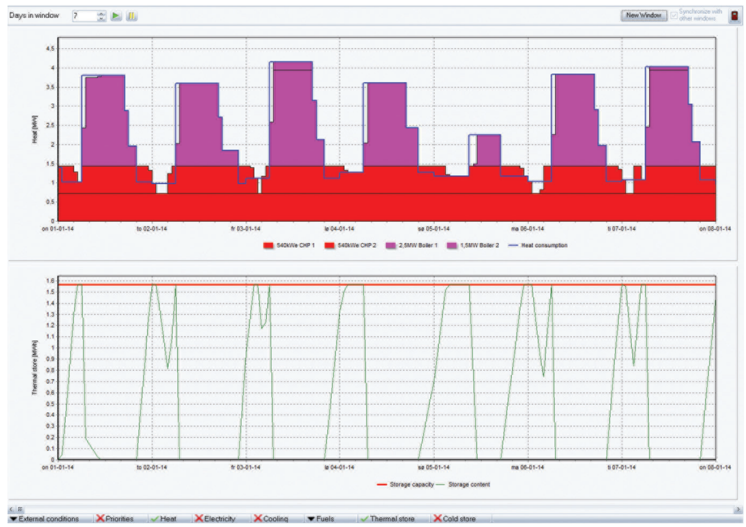
At Sheridan College, as elsewhere, lower hot water system operating temperatures will result in lower heat losses. However, pumping energy and the capital cost of the network will be lower if flow rates are reduced by increasing the difference between supply and return temperatures. As these two requirements cannot both be satisfied, it is necessary to optimize the temperatures within any heat network.

The network cannot be analyzed in isolation from the building services within connected buildings and the heat source(s). Lower operating temperatures and lower return temperatures can be achieved through appropriate building services design, i.e., by using larger heat emitters and selecting suitable approaches to controls. This may lead to higher costs for the building services but lower costs overall. The operating temperatures selected for the network can have an impact on the efficiency of the heat source and hence its cost and carbon dioxide content.

The main goals for the network design at both the Trafalgar and Davis campuses can therefore be summarized as follows:

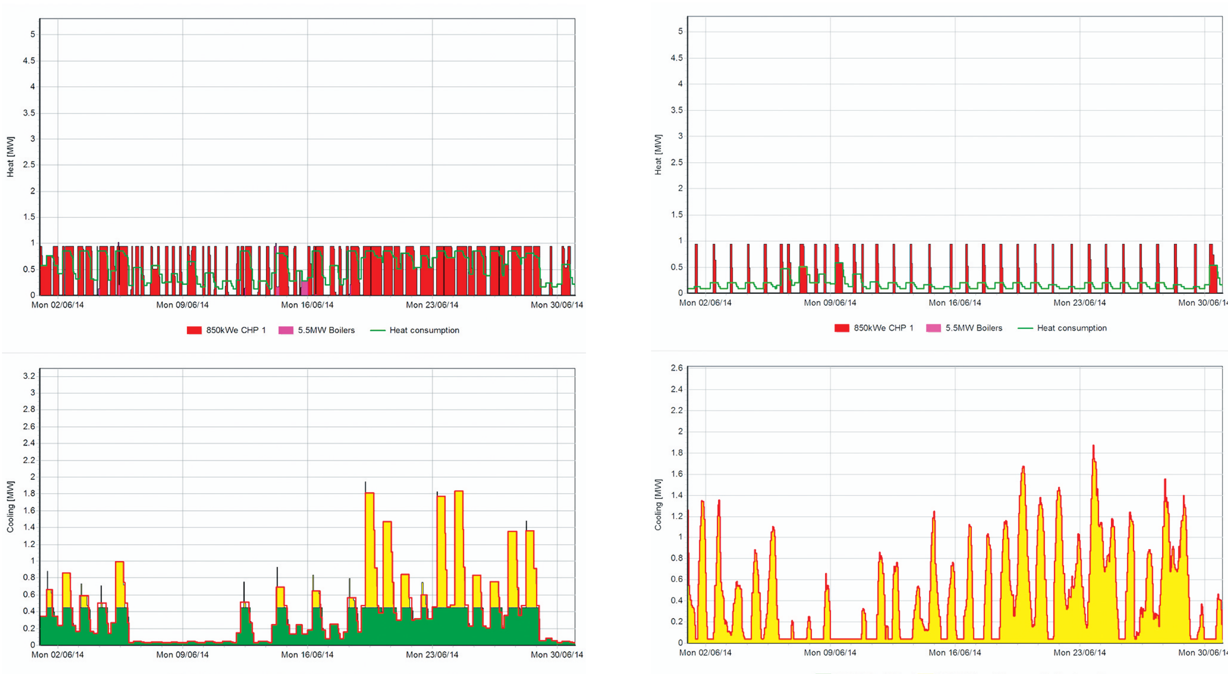
1. low operating supply temperature for minimal heat/energy loss, which reduces operating costs;
2. maximum delta T at energy transfer stations for maximum energy transfer and maximum value for pumping costs, which reduces operating costs; and

Figure 1. Simulated winter CHP and thermal storage capacities, Trafalgar Campus, energyPro modeling software.



Source: Ramboll.

Figure 2. Simulated summer CHP operation, Trafalgar Campus, energyPro modeling software.



Source: Ramboll.

3. maximized pipe flow capacity to allow for smaller pipes, which reduces capital investment.

HYDRAULIC OPTIMIZATION

Besides being a very important part of feasibility studies for investigating the potential for district heating or district cooling networks in different areas, hydraulic calculations and thermal analysis are prerequisites for their correct dimensioning and efficient operation. This applies as much to the expansion or renewal of existing networks as it does to new district energy schemes. The design team performed hydraulic calculations and thermal analysis in optimizing the district energy networks on both Sheridan campuses.

The hydraulic calculations ensure that pipe dimensions are optimized both technically and economically. With an optimized hydraulic system, the pipeline dimensions can often be made smaller than in a system that is not optimized, without a loss of capacity. Reducing dimensions can save money – both capital and operating costs. When integrated with a geographical information system (GIS) (fig. 3), hydraulic analysis can also be a very powerful tool for maintenance and planning for upgrades and expansion, as the GIS data from the pipeline registry can be quickly combined with an analysis of the impact on the network of capacity, heat loss and price.

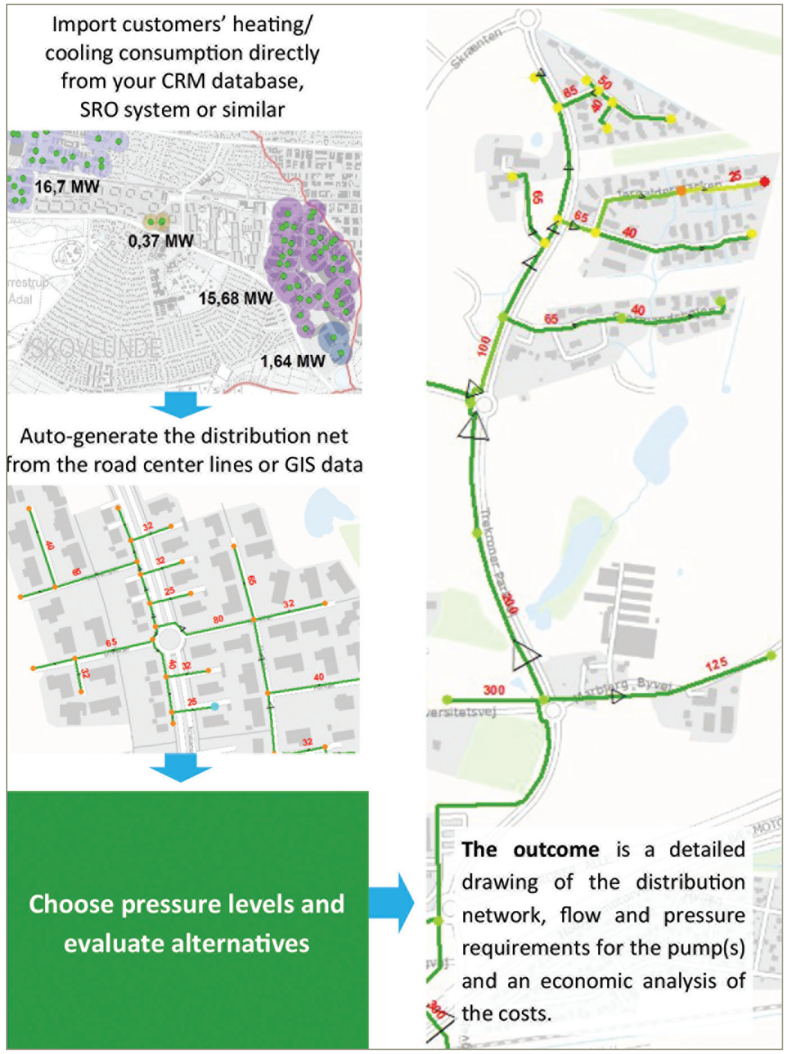
Defining the costs

The design of district heating and cooling networks also involves optimizing project economics, i.e., minimizing the total cost during a network's lifetime. The costs can be divided into the following categories:

- Construction costs, network (C_{CN})
- Construction costs, pump (C_{CP})
- Heat/chill loss costs (C_{HL})
- Maintenance costs (C_M)
- Pumping costs (C_P)
- Production costs (C_{PROD})

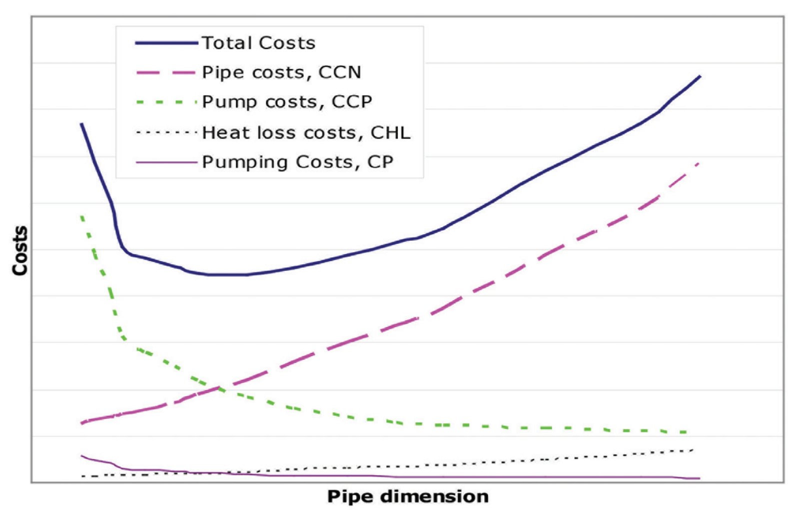
The construction costs, heat/chill loss, maintenance and pumping costs are a function of the layout of pipes, pipe dimension and redundancy. The

Figure 3. Integration of GIS with hydraulic analysis.



Source: Ramboll.

Figure 4. Illustration of district heating costs as a function of pipe dimension.



Source: Ramboll.

Figure 5. Proposed district heating networks, Davis and Trafalgar campuses.

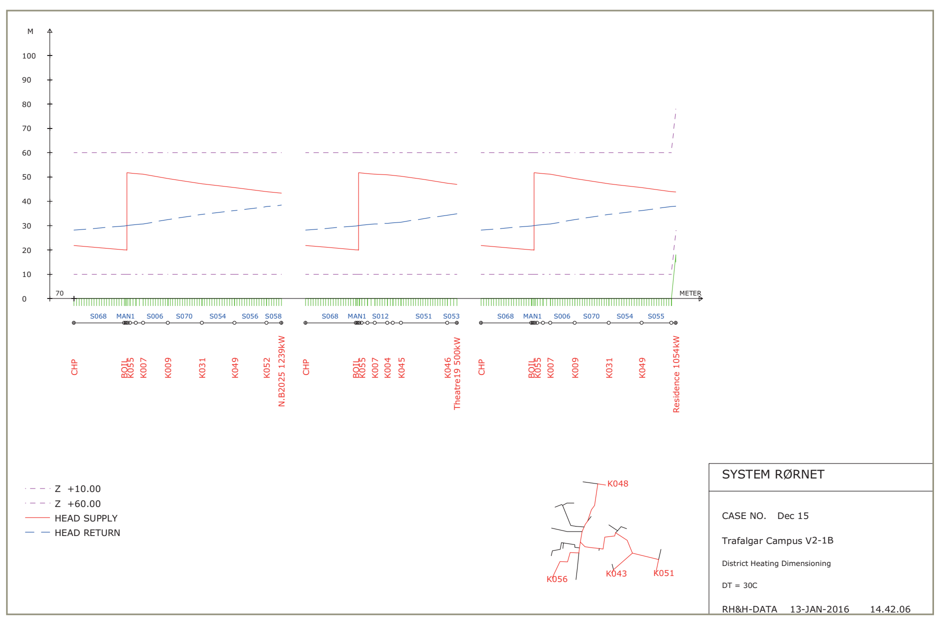
Source: Ramboll.

production costs are among other things a function of the required flow temperature.

To make construction and annual costs comparable, the net present value (NPV) method of analysis is used. The annual costs are discounted in the NPV method with an interest rate from the time the district heating or cooling network is constructed. In connection with the NPV method, the time horizon for the economic analysis should be defined; often a horizon between 20 and 30 years is used.

The network construction costs and the heat/chill loss costs will increase with the diameter of the pipes. On the other hand, the construction costs of the pumps and pumping costs will decrease for increasing pipe diameters because there is less hydraulic resistance in larger pipes. Therefore the task is to find the size of the network where the total costs or the total NPV are minimized. See figure 4 for an example of costs in district heating as a function of the pipe dimension.

Figure 6. Pressure loss analysis of the proposed Trafalgar Campus district heating network, System Rørnet software.



Source: Ramboll.

System Rørnet

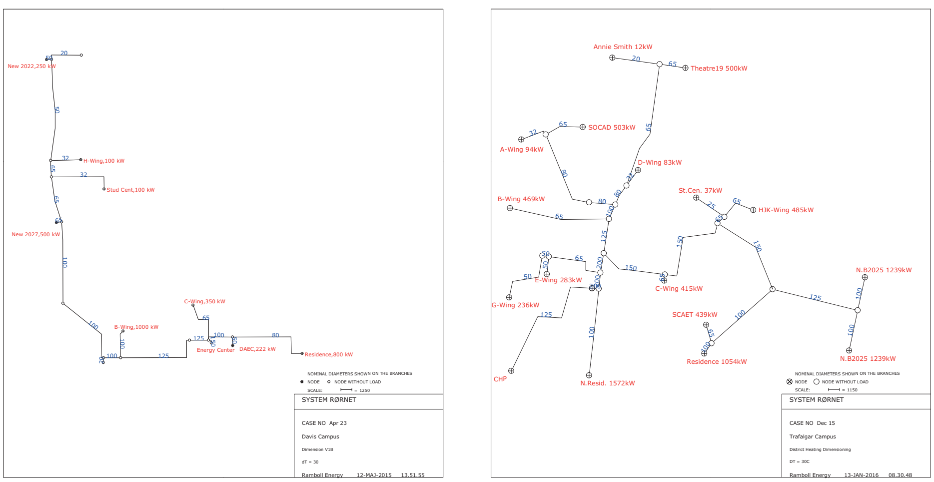
To optimize the proposed district energy networks on both Sheridan campuses (fig. 5), Ramboll used its specialized System Rørnet software tool that it developed in-house over the past 20 years. This allowed a highly detailed hydraulic analysis of the networks to be conducted including analysis of flows; pressure losses (fig. 6); temperature losses; optimum seasonal pressure and temperature operating characteristics; and sizing of distribution pumps, pressurization and expansion units, etc.

For each campus, possible network extensions were also assessed and developed. These different network scenarios were tested under different operating conditions to examine the impact on investment and operating costs. This enabled a cost-benefit assessment to be made to ensure certain pipe segments were oversized to accommodate possible future extension. As a result, the optimum dimensions of the pipes and components were determined based on consumption, design pressures and temperatures, and costs (fig.7).

PIPING INSTALLATION: BEST OF BOTH CONTINENTS

In designing the Sheridan distribution networks, Ramboll applied its extensive experience in Denmark with the installation of preinsulated district heating and cooling piping, a relatively new product in North America. Installation to European Standards (ENs) while complying with local regulations required the design team to maintain a greater focus on and higher accuracy in such aspects of the installation as welding and pressure testing. Based on Ramboll's recent experience with another Canadian district energy project also designed to ENs, the team was able to identify some specific European approaches to installation that will stand the Sheridan project in good stead. One example is the more challenging welding alignment required in the EN standards. This requirement is important due to the fact that the steel casing of the preinsulated pipe (ca. 2 mm [0.079 inch]) is thinner than that of the steel pipe specified in accordance with ASME standards (ca. 4 mm [0.16 inch]). (See table 1 for a comparison of standards.)

Figure 7. Optimized pipe dimensions for the proposed district heating networks, Davis and Trafalgar campuses.



Source: Ramboll.

Table 1. Comparison of North American and European standards for installation of preinsulated district energy piping.

North American standards: Ontario Regulation 220, CSA B51, ASME B31.1, etc.	**EN 13941:** Design and installation of preinsulated bonded pipe systems for district heating
X-ray not required	X-ray required on 10% of welds
Alignment to be within 2 mm (approximately 0.079 inch)	Alignment to be within 1 mm (approximately 0.04 inch)
Hydrostatic pressure test to be 1.5 times the design pressure, held for 10 minutes, then reduced to design for leak test	Pressure test is not required, but weld leak tightness test of all welds is required

Source: Ramboll.

ENERGY TRANSFER STATIONS

In Denmark and Europe, the traditional way of converting an existing in-building oil-/gas-fired boiler installation to district heating is to replace the boiler with a prefabricated energy transfer station (ETS). In North America, the approach is generally to build the installation on-site, buying the individual components separately from different suppliers. In addition to a heat exchanger, the ETS units include all necessary control valves, gauges, filters and controls equipment and heat meters. The design team has specified the use of prefabricated ETS units in all current and future Trafalgar and Davis campus buildings to be connected to the campus heating and cooling systems. The firm is also working with European ETS manufacturers to help bring them to the Canadian market.

Domestic hot water can be heated either instantaneously via an additional plate heat exchanger or through a cylinder. The installation of hot water storage tanks for domestic hot water instead of instantaneous water heaters will reduce the domestic hot water heat demand. Subsequently this will have an effect on the dimensions of the district heating piping, especially the service pipes to each building – i.e., they can be reduced if there is a cylinder as a small storage tank. On the other hand, space is saved by not having a tank and instead having instantaneous supply. The best solution needs to be assessed on a building-by-building basis.

The advantage of the prefabricated ETS approach is that all is bought from one supplier, saving time and cost and reducing risk should something need replacing. The design team estimates that there is an overall cost saving of 30 percent to 40 percent by using the prefabricated ETS units compared to the more traditional North American building connection solution.

WORK IN PROGRESS

To assist Sheridan College in achieving its energy and climate plan goals, Ramboll has been working with the institution to complete the engineering design and preconstruction phases of the heating and cooling networks for both Davis and Trafalgar campuses, the central plant at Trafalgar and the tie-ins to new and existing building systems at both campuses. In the process, the firm has drawn on its experience in Denmark, Europe and beyond. On track for completion in 2018, the project will play a significant role in helping Sheridan re-envision its energy future – and further demonstrate the innovation for which the college is known.

__Pernille M. Overbye__ is managing director of the Canadian arm of Ramboll's Energy Systems division where she heads up district energy services for the North American market. With 20 years' industry experience, she has extensive energy process design expertise, specializes in CHP and district heating and has been project manager for a wide range of projects. She holds a Bachelor of Science in Mechanical Engineering degree from Copenhagen University's College of Engineering, supplemented by energy conservation and environment studies at Cranfield University, U.K. Overbye can be reached at pmo@ramboll.com.

__David Bell,__ project engineer with Ramboll, specializes in energy and district heating systems. He is responsible for producing and taking concept designs through to fully detailed construction information for project teams to install, operate and commission. Bell previously worked for an international multidisciplinary engineering consultancy and earlier for a market-leading district heating design-build contractor. He has a bachelor's degree in mechanical systems engineering from the University of Sheffield, U.K., and is a member of the Chartered Institution of Building Services Engineers. He may be contacted at davb@ramboll.com.