DISTRICT ENERGY
IN
MONTPELIER – VERMONT
CONCEPTS & REVIEW

Prepared by
Community Energy Systems
CANMET, Natural Resources Canada

MARCH 2001

May 2007.

(1) construction Project cost index.
~~Jan~~ July 1992 = 100.

Dec. 2006 142.2.
March 2001 122.7
Jan 2000 120.1.
increase of 18.4%.

(2) chemical Engg plant Cost index
Jan 2000 → June 06
~~0.8"~~ ~~30"~~ ⇒ ~~3.75 times~~ ~~275% increase in 6 yrs.~~
395 485
~~46%/yr.~~ 22.78%

(3) Marshall Equip cost index
Jun 2000 → Jan 06 ~~2.56 times~~ ~~156% increase~~
~~1.25~~ ~~3.2~~
1040 1300
~~26%/yr.~~

25%

* We have used chemical Engg plant cost index for project cost estimates with 22.78% escalation.

EXECUTIVE SUMMARY

Biomass heating in the Capital Complex office buildings in Montpelier has been operational for over 50 years and it could easily be said to provide safe, reliable and inexpensive heating. The advancing age of the equipment and the desire of the City to revitalize the downtown and riverfront area suggest strongly the need for an examination of the role of the heating plant.

Current heating methods within the city core, excluding the Capital Complex, result in almost 2.1 $1.5 million leaving the community annually. A cooperative initiative involving City and State and the community could reduce this hemorrhage by developing an expanded district energy system for state and city buildings, generate environmental improvements for the community and enhance economic opportunities within the local area.

This report examines four district energy concepts that could each service 177 buildings, both existing and planned, using locally supplied woodchip products as the principal energy source. The systems would deliver heat to their customers at a price comparable to, or lower than the current cost of energy. Each option would have a connected load of 73 MMBTH. Several heating plant locations were considered, including National Life of Vermont and a new building, adjacent to the existing Capital Complex heating plant, architecturally compatible with the master plan.

The current heating plant at the Capital Complex is in good condition, but is aging and will inevitably be scheduled for major refurbishment. At the same time the City of Montpelier has considered implementation of its "Capital District Master Plan". The plan compares the cost of the status quo option - that of rebuilding the existing plant - against the opportunities available for district energy. The cost to the State of maintaining the status quo is estimated between $2 and $3 million. The cost of implementing district energy is estimated between $11.8 and $13.3 million, financed out of the project's future earnings.

$2.5 (add 22.78)

3.7 14.5 16.3

In establishing the economic impact of each option, the true cost of heating within Montpelier was determined. This cost included the cost of capital infrastructure (boiler, furnaces etc.), operations and maintenance. A methodology to derive this cost was developed and is described within the report. Energy data for the buildings too, were estimated using building floor area and associated environmental factors. Unit energy costs and environmental benefits could thereby be developed for current and proposed heating options.

Implementation of the project may be phased over several years using existing heating plants while integrating resource requirements with current City plans for infrastructure maintenance. The opportunity is therefore present to turn Montpelier into a showcase for eco-efficient, biomass district energy, with local resources being used to stabilize energy costs and enhance future business potential.

TABLE OF CONTENTS

Acknowledgments

The following individuals and organizations are thanked for their input to this study:

Tim Maker, **Energy Efficiency Associates**
Valerie Capels, **City of Montpelier**
Teigh Southworth, **Department of State Buildings Montpelier, VT**
Donn Blodgett, **National Life of Vermont, Montpelier, VT**
Don Lorinovich, **Montpelier School Department**
Steve Gray, **Montpelier Public Works Department**
Carey Brier and Dan Crockett, **Green Mountain Power, Montpelier, VT**
John Irving, **Burlington Electric Department, M^{c}Neil Generating Station**
Barry Bernstein, **Better World Energy**

1 INTRODUCTION

Heating for the Capital Complex of state buildings in the City of Montpelier is at present provided by a combination of biomass (i.e.woodchip) and oil boilers. The peak connected load for this network is approximately 12.2 MMBTH (3.57 MWt[1]). The system has operated effectively for 50 years but is approaching the point where major refurbishment or replacement will be worth serious consideration. An opportunity therefore exists for the system needs to be reassessed with the inclusion of additional load in the form of a district energy system. The effect of servicing adjacent buildings with the heating loop would be to increase the effectiveness of the system, reduce the use of fossil fuels within the community and gradually reduce the cost of heating for the connected buildings.

The Community Energy Systems group of CANMET Energy Technology Center, a division of Natural Resources Canada, itself a department of the Canadian Federal Government was therefore commissioned to undertake this pre-feasibility assessment that evaluates the impact of a revised district energy system within Montpelier.

The use of energy within a community is fast becoming recognized as a key instrument for the development of a sustainable or eco-efficient community. The manner by which energy is managed will impact on its environmental and economic goals. An expanded biomass based district energy system in Montpelier will have many benefits and advantages over current practices and include:

- the displacement of heating oil and a reduction in green house gas emissions;
- the increased employment level of the community, not only in short term construction jobs but also in long term maintenance and operation positions;
- the increased retained earnings brought about by increased utilization of local resources;
- the compatibility with the Capital District Master Plan to employ a "new layer of infrastructure" to recognize Montpelier's unique character and natural setting as well as the preservation of this image with the improvements needed in a modern State capital; and
- the fuel flexibility that such a system provides with its distribution network.

This report outlines potential concepts for district energy applications within the City that aim to bring together these benefits.

2 HEAT DEMAND

The original state owned and operated heating system is located on land adjacent to the Winooski River as indicated in Figure 1. The system encompasses the 16 key buildings identified in the graph. The system provides heating and domestic hot water for these buildings.

[1] See Appendix 1 for definitions of units

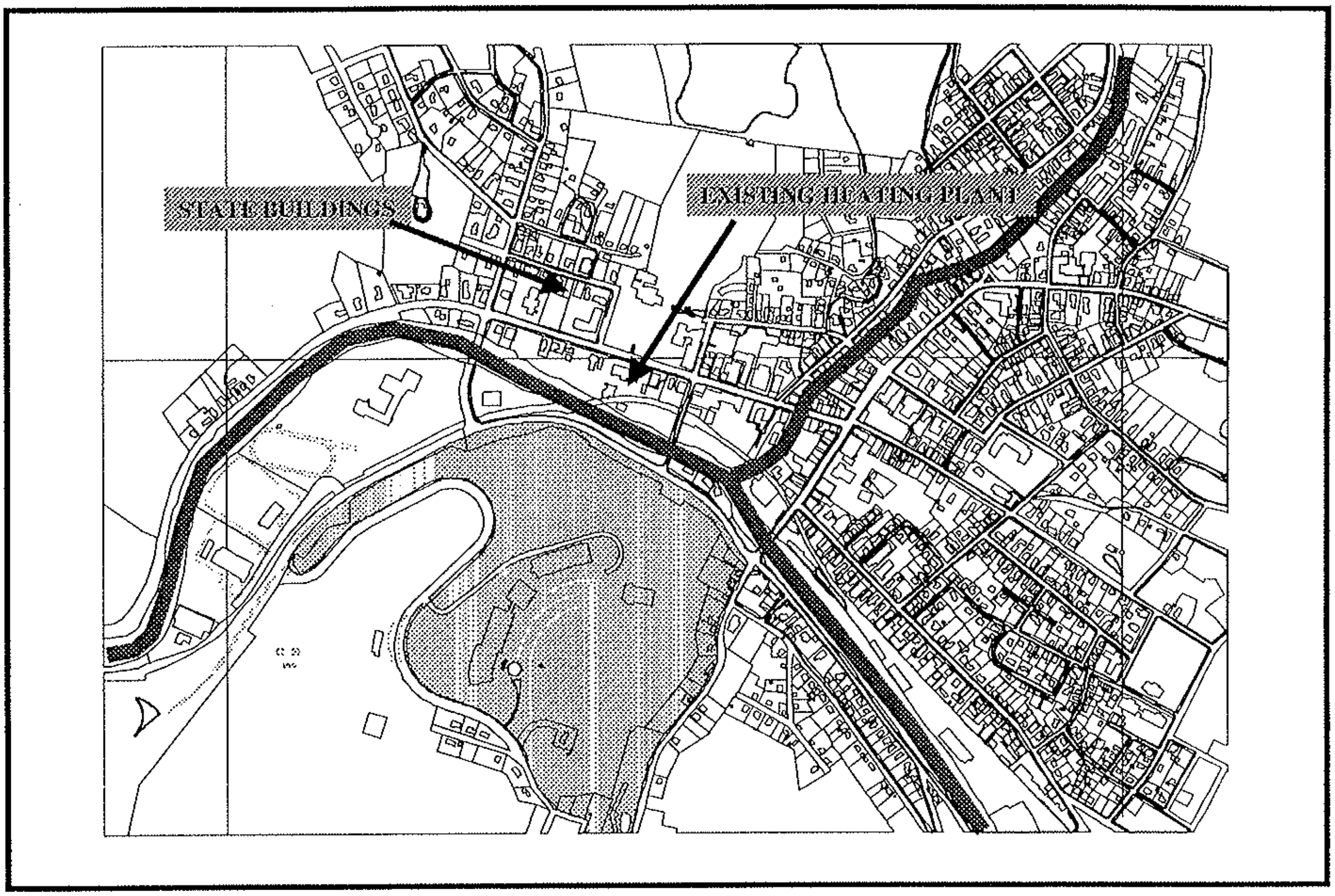


Figure 1: Montpelier, Vermont

To expand the existing system, the study assessed a number of buildings that were adjacent to the plant and exhibited heat demands large enough to warrant connection. Heating loads included both space heating and domestic hot water load and amounted to 177 buildings. These were primarily non-residential buildings within the core of the city and located along a corridor between State Street near Montpelier High School and East State Street, close to the East State School. Several larger loads outside this core area (National Life, Vermont College) were also included. A list of these buildings is given in Appendix 2.

19% 17%

The buildings themselves offer a mix of commercial, office, educational and large residential energy users. A preliminary survey estimated a peak connected load of 72.7 MMBTH (21.3 MWt) with the major consumers being the Capital Complex (12.2 MMBTH), Vermont College (4.68 MMBTH) and the schools (6.82 MMBTH). It is anticipated that new construction of State buildings will provide new office buildings, office additions, a transit center and museum and this was also included within the energy estimate (6.04 MMBTH). — 8% (state + other growth)

6%
57%
other 8%

All of these buildings exhibited the properties sought in district energy systems: they were either closely grouped or they were located in clusters. Superficially, three distinct districts could be created, separated by the Winooski River (Figure 2).

These are:

- Area 1: north of the river and west of the river's split;
- Area 2: north of the river and east of the river's split; and
- Area 3: south of the river.

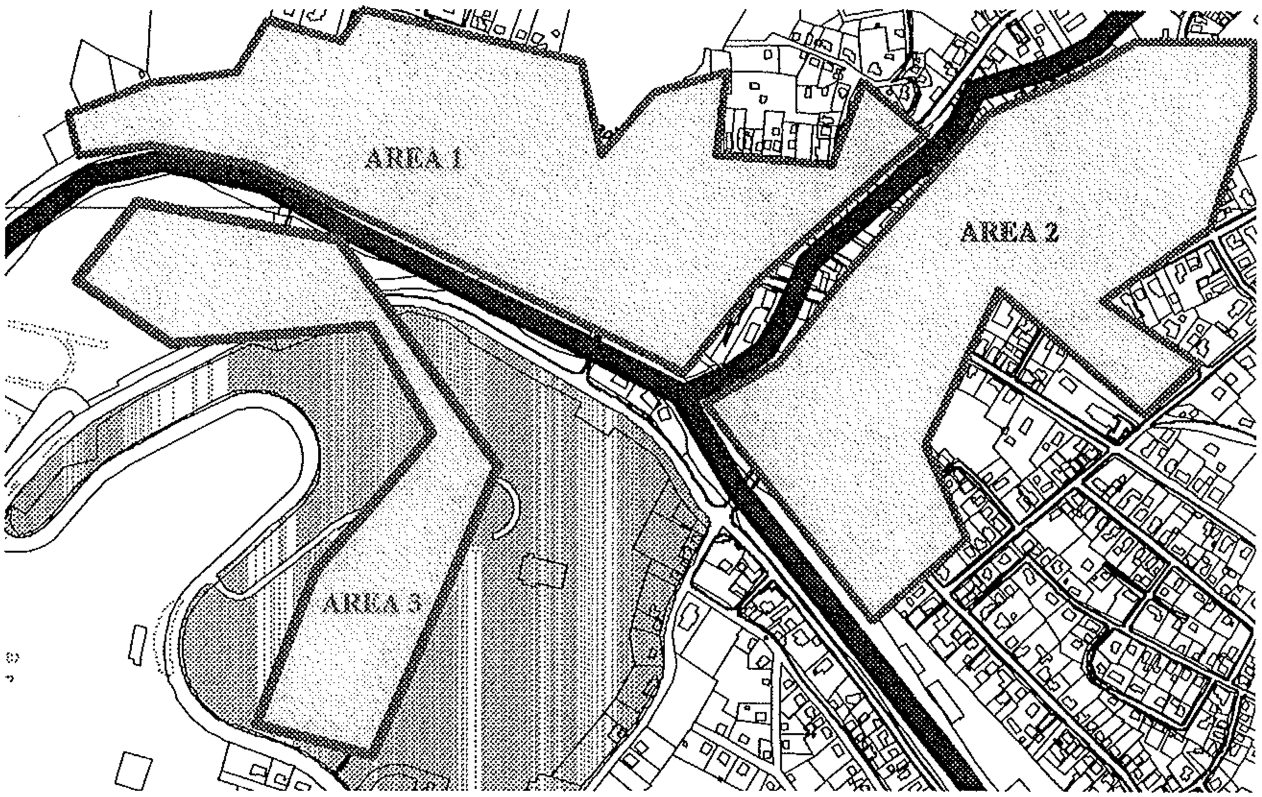


Figure 2: Scope of Study

The three buildings located south of Montpelier High School (Green Mountain Power, Vermont Department of Employment and Training, and the Vermont Department of Liquor Control) were not included in the study. Interconnection could not be justified by their small load and location which is distant from either of the potential plant locations. Although the National Life building appears to be distant from the existing State plant, it's large load and thereby energy consumption justifies its connection.

The three areas demonstrate the potential for a phased project although for the purposes of this study, their loads will be combined in a single system. A phased approach may act to reduce initial capital requirements and may thereby benefit certain options over others; for example, expansion may be possible from the existing state system by connecting properties in Area 1, (i.e., those closest to the plant). As confidence with the system grows, then inclusion of Area 2 might be considered, leading eventually to inclusion of Area 3. In this way, initial capital requirements and risk are reduced through the inclusion of experience gained through operation.

The estimated heating load was determined using a building's usable area and heat loss factor. For the properties in Montpelier, a value of 25.4 BTH/ft^2 (80 watts per square metre) was used and resulted in a peak load of 72.7 MMBTH (21.3 MWt). In multi-use communities such as Areas 1 and 2, a diversification factor of 0.85 reduces this load by allowing for the overlapping demand of customers. Area 3 however, does not exhibit such diversity in its demand profile and could not therefore reduce its estimated peak demand.

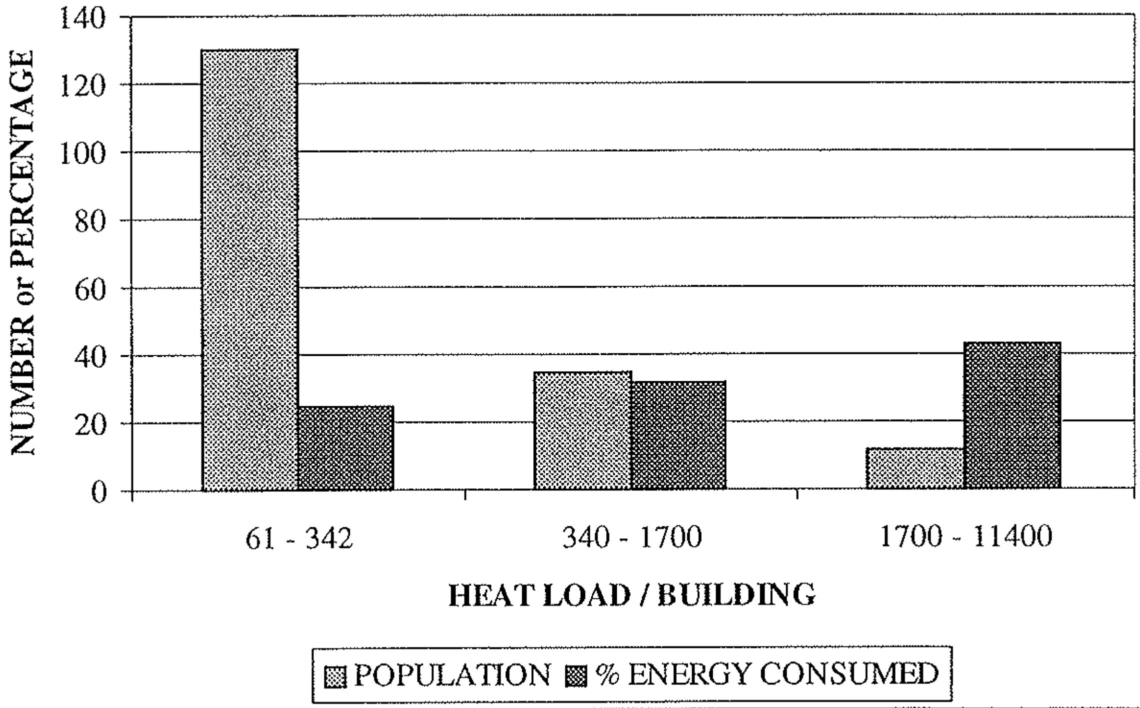


Figure 3: Breakdown of Loads and Energy Consumption

The individual loads ranged from 61 to 11,400 MBTH with a breakdown as shown in Figure 3. The majority of loads (73%) lay between 61 and 342 MBTH (18 kWt to 100 kWt) but accounted for only 25% of the connected load. The next largest group (340 MBTH to 1700 MBTH) comprised 20% of buildings and 32% of the connected load. Large buildings, or those over 1700 MBTH, make up the remaining connections and load.

2.1 FUEL USAGE

Many of the residential buildings (~80%) in Montpelier currently use #2 heating oil and individual furnaces or boilers for heat. Liquefied Propane is used in about 15% of the buildings while the remainder ~~use electricity.~~ Likewise, ~65% of the buildings employ a hot water system and 15% use a forced warm air system[2], both of these methods would readily accept hot water from a district energy system ~~without~~ minimal modification. The remaining 20% of customers use low-pressure steam and electricity and would require more extensive modifications if they

[2] Estimates obtained from a previous survey

were to convert to the district energy system. Unfortunately, these steam-based customers include parts of the Capital Complex and the National Life buildings. A dual-energy system can be designed and built although it should be remembered that a system that is designed for both steam and hot water must inevitably compromise some of the system's inherent advantages.

	Connected Load MMBTH	Diversified Peak MMBTH (85%)	Number of connections	Energy consumed MMBTU
Area 1	29.3	24.9	61	54,630
Area 2	28.7	24.4	113	53,600
Area 3	14.7	14.7	3	27,315
Totals	72.7	64.0	177	135,545

Table 1: Load Distribution

3 HEAT SUPPLY

The use of district energy concepts is not new to Montpelier. The Capital Complex buildings have been using the technology for over 50 years, circulating low-pressure steam from a central heating plant. Most of the sixteen connected buildings in the system convert the steam to hot water at site for use within the buildings themselves. The heating plant is located just north of the Winnooski River and currently uses both oil and wood chips as its source of energy. The plant has two oil (#6) boilers and one biomass boiler with a total installed capacity of near 31 MMBTU (9 MWt). The two oil boilers are dated but are in good condition. Between them they have a capacity of 20 MMBTU (6 MWt). Plant operations have a policy of maintaining an even split in heating duty between oil and woodchip so as to comply with Agency of Natural Resources Permit allowances and control emissions.

With an aging plant comes the discussion of phase-out and replacement. The current plant is ideally located close to the main business district and to the Capital Complex buildings. It is however, on land that the Master Plan envisions as a more people-friendly environment with access to the river. It is also located in the flood plain of the Winooski River. Siting a new plant away from this area would, no doubt, provide the city with recreational space but would likely impact the economics of the district energy system. Locating a new plant at the current site is not ruled out although such a plant would need to integrate with the Capital District Master Plan as well as compensate for possible flooding of the Winooski River.

Realistic alternative locations for a heating plant are limited, the exception being property near to the National Life building on the south side of the river in Area 3. In this location, the plant could integrate the demands of the city with those of the insurance company. The current heating system at National Life consists of four boilers with an installed capacity of 41 MMBTH. They use #4 oil. In addition, two newer boilers have a capacity of 25.3 MMBTH. This location is however, almost 1/3 mile (1675 ft) from the current state plant and the need for steam at both locations would necessitate a steam main of that length linking the two sites with heat

exchangers to convert to hot water for the remainder of the system. Steam mains are traditionally more expensive to install and maintain than transmission lines for hot water. Alternatively, the Capital Complex could complete its conversion from steam to hot water and utilize less expensive distribution piping, fewer heat exchangers and incur lower O&M costs.

3.1 PLANT CAPACITY

Combustion systems for solid fuels are traditionally more capital intensive than those for liquid, or gaseous fuels. With this in mind, there are two schools of thought regarding plant sizing. The first designs a biomass plant to meet the peak demand of the system, while the second designs the biomass plant to provide only the base load, (i.e. ~40% of the estimated peak load). Oil fueled boilers would provide the remaining heat demand. Obviously, a biomass plant sized to meet the peak heating load would satisfy all eventualities of the system but only operate efficiently at full load for a minimal length of time. Conversely, a biomass plant that is sized to meet 40% of the peak demand will not meet all eventualities and only 87% of the system's energy needs. It will however have a lower capital cost. As noted earlier, the remaining heat load would be provided using oil fired units that have a lower capital (but a higher operating) cost. It should not be forgotten here that it is often recommended that an oil-fired unit be installed as back-up/emergency in district energy systems.

Option 1 - Peak load using biomass only:

20,885

Three wood fired units would be required, supplemented by an oil-fired unit for back up. This configuration would consume about 18,100 tons of woodchips per year based on fuel moisture content of 40% and a combustion efficiency of 75%. 65%.

Option 2 – Base load using biomass:

Two wood fired units and three oil fired units would be required. This design would consume about 15,700 tons of wood products annually at a subsequently higher operating efficiency.

18,115

4 OPTIONS FOR ANALYSIS

4.1 HEAT SOURCE DESIGN

Several location options have been proposed along with combinations of biomass and oil as fuels. These, linked with key common elements of the existing distribution piping, heat exchangers, and customer connections provide a number of scenarios that may be considered.

For the analysis, a matrix of options was developed to cover all potential systems. An economic evaluation would then highlight the system most likely to present the community with the greatest economic and environmental benefits. The evaluation considered the operational requirements of each scenario to develop a delivery cost for the heat from each system.

SYSTEM OPTION	PLANT LOCATION	LOAD - BIOMASS	LOAD – OIL
1	NATIONAL LIFE	100%	0%
2	NATIONAL LIFE	40%	60%
3	STATE COMPLEX	100%	0%
4	STATE COMPLEX	40%	60%

Table 2: Concept Options

- **SYSTEM OPTIONS 1 & 2**

A plant near National Life would serve the downtown core as well as the National Life building. The central plant would function best with National Life's involvement as a stakeholder in the project, as a provider of land and as a customer of district energy. Depending upon compatibility and location, the existing equipment at the National Life heating plant might be incorporated in a peaking or back-up capacity. National Life's buildings are currently heated with steam and, while conversion of the building to hot water is possible, the equipment is relatively new (compared to the Capital Complex) and conversion might not be justified on a purely economic basis. A more likely solution is that the boiler system generates steam, which is then condensed either at the National Life plant or at an energy conversion station at the Capital Complex.

To avoid the real estate demands of an energy conversion station, aging steam heaters within the Capital Complex offices could be converted to accept hot water directly. This would enable water transmission lines to be installed in place of the more expensive (to maintain) steam lines. An interim measure would be to utilize the existing State complex system until conversion could be financed and undertaken.

Option 1 would serve a peak load of 64 MMBTH and be required to produce 135,545 MMBTU of energy per year. Three biomass units rated at 21 MMBTH minimum each would be required. For prudence, an oil unit of a similar capacity (21 MMBTH) would be recommended as backup in the event that a wood fired unit failed. The most common reason for failure is feed system malfunction. Although this is often a short-term interruption, a failed feed system may affect more than one boiler.

In Option 2, a biomass system designed to meet 40% of peak load would require two units of 12.8 MMBTH. In addition, three oil-fired units, rated at 12.8 MMBTH would be installed, possibly using existing units from the National Life plant. A similar approach to back-up would be used as in Option 1.

- **SYSTEM OPTIONS 3 & 4**

The second pair of options assumed that the proposed heating plant would be located at, or adjacent to, the current site beside the Winooski River. The plant would serve the same loads as were discussed for Options 1 and 2, those in the downtown core, as well as, the National Life plant. It is still recommended that the Capital complex heating system be converted to hot water although this conversion could be integrated with the development of the system in general. By necessity, the plant would provide steam to the National Life buildings although a smaller line would be required. The required new biomass unit and any new oil units would be of the same capacity as those described for Options 1 & 2 at the National Life plant. Unlike Option 2 that utilized existing boilers, the age and size of the State plant's oil units would preclude their inclusion. The capital cost estimate for this option would therefore assume all new equipment. As a compromise, some savings would be made in the reduced capacity of the steam transmission line to the National Life plant.

4.2 DISTRIBUTION LAYOUT

Hot water piping in a district energy system distribution network is laid in pairs, one supplying hot water, and the other returning cooler water to the plant. Depending on the prevailing weather conditions, the supply temperature for the heating loop could be as high as 230°F (110°C) in winter, or as low as 176°F (80°C) in summer. The determining factor is the need to ensure sufficient thermal differential between the supply and return lines for heat transfer to the building's heating equipment. The cost of the distribution system varies inversely to the temperature differential between the supply and the return lines. The greater the differential, the lower the water flow rate, the smaller the piping, the lower the pumping requirements, and the lower the capital and operating costs. Traditional in-house heating systems are designed with a 20°F differential (180°F – 160°F) 'across the boiler' while district energy uses a higher supply temperature and encourages a differential of up to 104°F (40°C). A system differential temperature of only 36°F was used in this design to accommodate the large number of existing residential systems and thereby minimize any requirement to change.

Piping is buried in road allowances and the routing must be considered carefully in the light of the on-street congestion present in many urban centers. The depth of the piping within the street would normally be 3ft (1m), since modern piping and insulation technology does not require the piping to be installed beneath the frost line. The exact piping location must be coordinated with

the appropriate city authorities so as to enable the coordination of piping and other infrastructure activities and the management of costs. Lines would be fitted with suitable tee-junctions to allow for future connections. Manholes and inspection ports would ensure minimum inconvenience during maintenance periods.

In the Montpelier system, the largest pipe (excluding insulation) would be 12" in diameter. Pipes would be thin wall steel with a high-density polyurethane insulation, surrounded by a thick nylon sheath. The piping system is designed for a pressure of 235 psig (16 bar). Plastic pipes may also be used in district energy systems. These are usually restricted to system peak loads of 6 to 10 MMBTH and a maximum supply temperature of 194°F. A sketch of the piping/trench installation is shown as Figure 4.

The analysis of the piping sizes and requirements for this report assumed a plant location near the State complex. It should be noted that the pipe layout with the plant located at the National Life site was similar. Piping sizes were the same for both with the exception of the line from National Life to the State complex, which increased from 6" diameter (150 mm) in Option 3 to 12" (300 mm) diameter in Option 1.

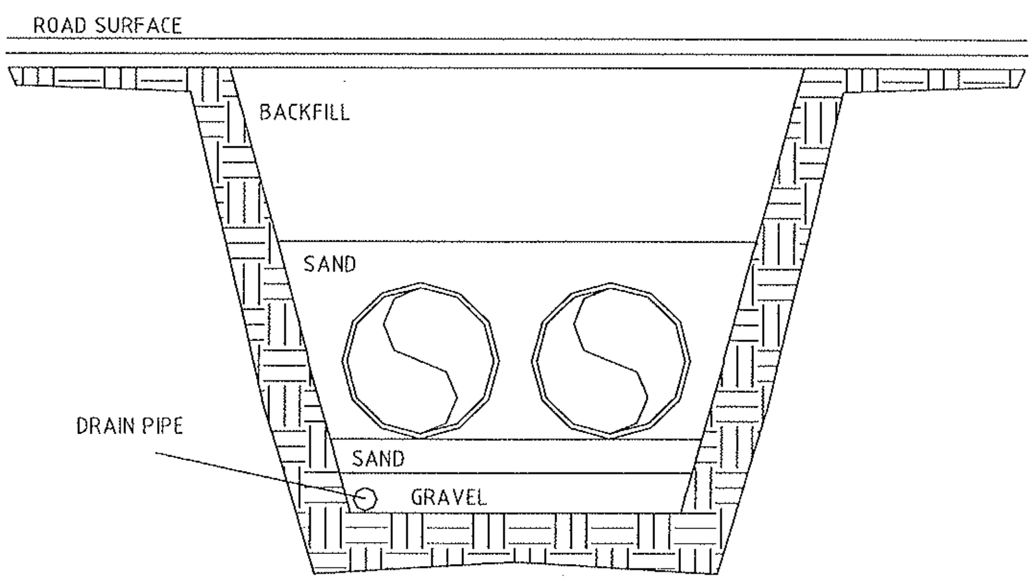


Figure 4: Typical trench/pipe arrangement

A preliminary distribution layout was developed encompassing all 177 buildings. The lines were sized to meet all of the building loads as well as respect pressure drop and maximum water velocity criteria. The total pipe trench using all buildings was calculated at 6.5 miles. The layout in Figure 5 represents only a preliminary route; a final design with input from The City of Montpelier will detail optimum routes.

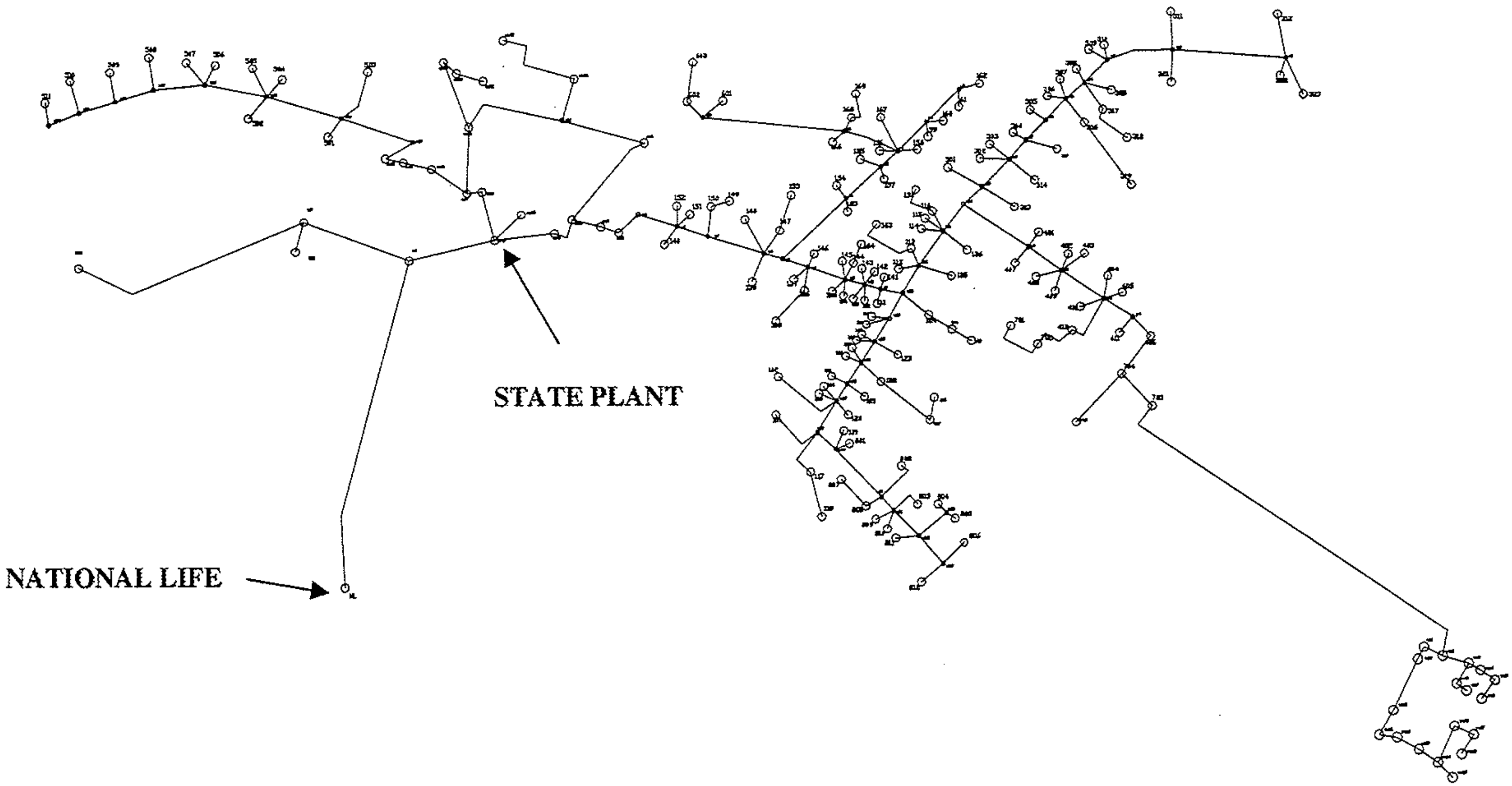


Figure 5: Preliminary Route

Montpelier District Energy
March 2001

4.3 ENERGY TRANSFER STATION

In many district energy systems each building is isolated from the distribution piping by an Energy Transfer Station (ETS). This unit extracts the heat from the supply pipe and distributes this energy to the building. Each station comprises one or two compact, plate type heat exchangers. The principal exchanger would accommodate space heating while the second might provide heating for domestic hot water. Controls and monitoring systems would be incorporated. Energy transfer stations are usually located within each building load and would allow the district energy system to operate at optimal pressures without consideration for operating conditions at each separate building. A typical energy transfer station is seen in Figure 6.

European district energy systems are well established and it is normal practice for customers to own their ETS units. In North America the market is smaller and to assist with project up-take and customer buy-in it has been assumed that the ETS units remain the responsibility of the district energy operator. The cost of the ETS and its installation is therefore included within the overall project estimates. It should be noted that any alterations within the building to accept district energy remains the responsibility of the building owner. ETS costs used in this study assumed connection to forced air duct based systems. Interfacing with hydronic systems is less costly, avoiding the need for coils, and extensive piping.

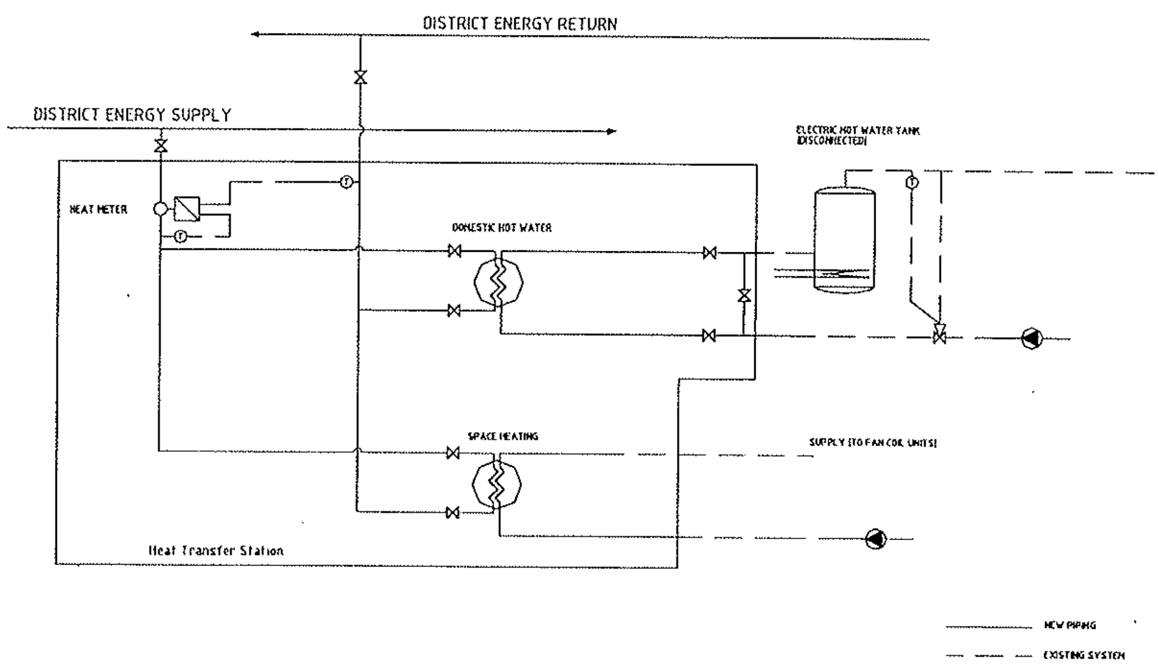


Figure 6: Energy Transfer Flowsheet

- **Alternative Approach**

With the number of smaller loads present in the Montpelier proposal it may prove feasible to reduce installation costs by utilizing a cluster approach to energy transfer stations. A single energy transfer station could be devised to serve a number of smaller loads rather than have an

ETS located in each building. This concept has been used in Europe but is not common in North America due to the preference of district energy companies for large commercial loads. The intimate nature of many of the loads in Montpelier may justify this approach. Data from preliminary work at the Community Energy Systems of Natural Resources Canada suggests that savings of up to 35% may be achieved on the installation costs associated with the building interface using this approach. Convenient building groups would be identified and a single heat exchanger sized for the cluster load (e.g. 10 buildings to each heat exchanger). Each building within the cluster would be connected directly to the heat exchanger and its energy use monitored using an individual energy meter. Safety would be ensured using isolating valves. Cost savings would be achieved from the economy of scale provided by the larger 'regional' heat exchanger. The concept is shown in Figure 7.

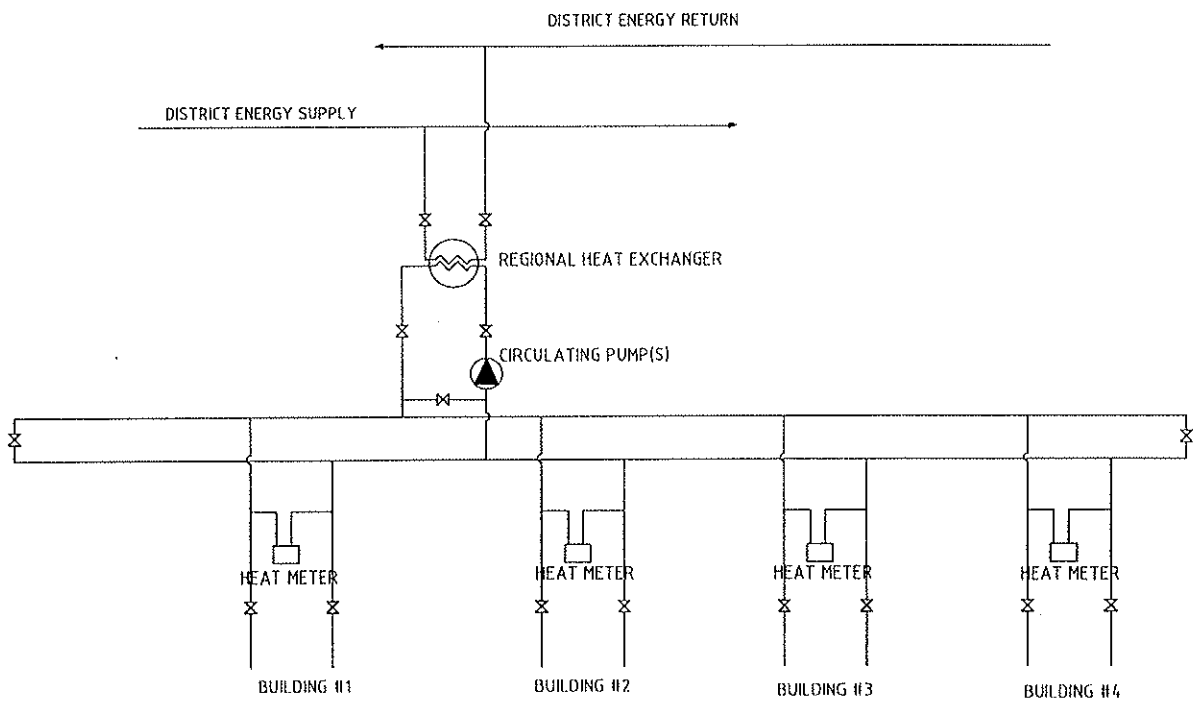


Figure 7: Multi-unit connections

4.4 COMBINED HEAT & POWER

Community interest in biomass fuelled district energy systems invariably leads to interest in biomass fuelled Combined Heat and Power (CHP). CHP can reduce energy costs significantly by creating additional revenue from the sales of electricity to the power grid but it must be remembered that the introduction of electrical generation will introduce into the project a new and greater level of operational and administrative complexity.

Ideally, CHP involves the generation of steam from biomass combustion, electrical generation from that steam, followed by the use of the turbine exhaust (either as steam or condensed to form hot water) for district heating. In this way the maximum energy is extracted from the fuel and the

system operates at peak thermal efficiency. Using high-pressure steam directly from the boiler, without passing it first through the turbine negates the impact of electrical generation and should be avoided.

The requirement for 60 psig steam in the Capital Complex and 15 psig steam in the National Life buildings limits the potential effectiveness of CHP by necessitating a backpressure turbine to be designed and installed for conditions appropriate to the heating systems. Assuming that the turbine exhaust satisfies the system's peak heating load then Figure 8 below, illustrates the power output available from the turbine at various turbine exhaust conditions.

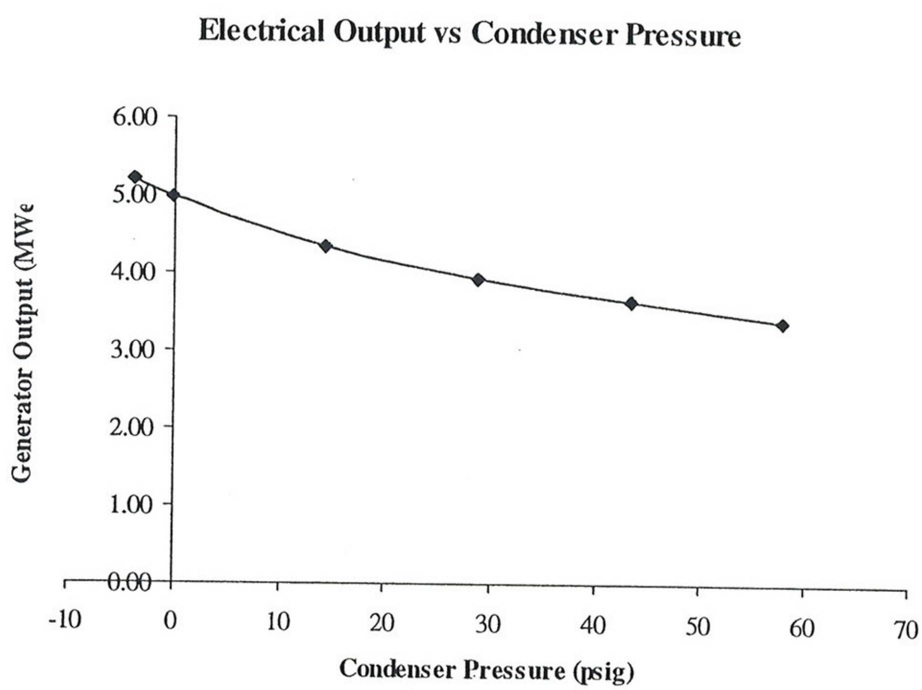


Figure 8: Generator Power vs Condenser Conditions

Electrical output increases significantly with reduced backpressure, providing an incremental addition of 1MWe between 60 psig and 15 psig and a further 1 Mwe, if hot water at 212°F was used instead. Using lower pressure steam may be limited by the swallowing capacity of the Capital Complex's heating network and thus the cost of building conversion must be compared against the incremental power generation benefits. As an example, the use of hot water rather than 60 psig steam would provide an incremental addition of 1.9MWe generation capacity. Operating for 8000 hours each year with electricity valued at \$0.6 /kWh results in an incremental revenue of \$912k. This additional revenue may justify the cost of building conversion.

Capital costs for CHP initiatives are primarily driven by the cost of the steam turbines and are estimated to cost \$1,200 /kWe installed. Thus, a 5 MWe system could be estimated at \$6 million.

4.5 SYSTEM OPERATING CONDITIONS

\$1500/kWe

The system would operate at a peak supply temperature of 230^0F with a design return of 194^0F. As the peak load is reduced the supply temperature will be reduced until it reaches 176^0 F at which point will hold at that temperature. This minimum temperature will serve the domestic hot water loads in the community. This is a common approach in district heating systems and uses a variable flow rate to meet the heating requirements. A typical operating scenario for conditions at Montpelier is shown in Figure 9. Although the graph is in metric the concept remains the same.

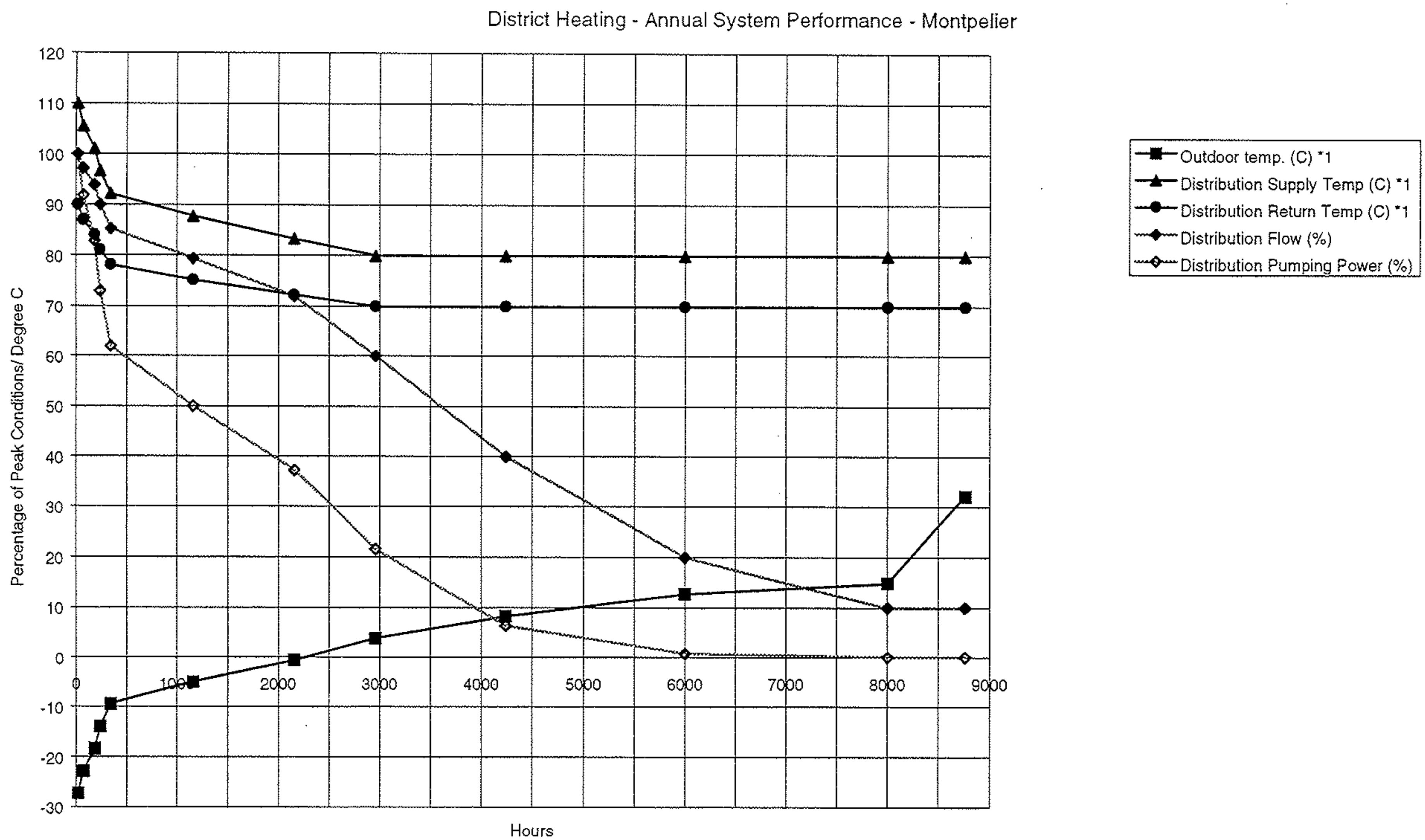


Figure 9: Operating Conditions – Montpelier District Energy

annualized Capital & ont in cost

: \$ 2.1 / MMBTU

add 22.78% for increase in Capital Cost

+ add inflation 3.25% / yr '09

[illegible]

\$ 3.0 / MMBtu

~~MMBtu~~ / ton 8 9

Cost \$ 40 / ton

\$ / MMBtu = 4.49 \$ / MMBtu.

1997 70¢
2000 $1.45
oil 2007 $2.00 triple in 10 years
wood 1997 $28
2000 $36
2007 $40 10 yrs + 43%
increase to now 38%
wood then: $1.45/gal oil

5 ECONOMIC ANALYSIS

5.1 ENERGY COSTS

$2.0/gallon

$2.1

Buildings within the study area consume fuel oil to generate approximately 80% of the 135,545 MMBTU of energy demanded annually. This is equivalent to 1,040,000 gallons of oil, worth $1.5 million to the community. This oil is imported to the City solely for heating purposes. The current cost (December 2000) of oil for small to medium sized consumers in Montpelier is $1.45 per gallon although larger volume consumers pay less and residential consumers pay more. This is approximately twice the cost paid for oil in 1997 in the region and the upward trend can only be assumed to continue. While it is true that the money paid for this fuel does provide some level of benefit to the City in the form of services, delivery charges, local taxes, etc. the bulk leaves the community. Implementing district energy, with the system using lower cost biomass fuel, can reduce this level of 'financial export'. Furthermore, if the system is owned and operated by a Montpelier based organization, then the retention increases with the company providing employment, revenue, salaries and an additional tax base for the community.

~~$1.45 per~~ gallon.
$2.00 per gallon.

5.2 COST OF HEAT

$19.32

The average boiler operates with a seasonal efficiency of 75% and, with the current price of oil translates to $14.6/MMBTU ($50/MWh). This price reflects only the energy component of building heat and does not include costs associated with controlling and maintaining a building's heating system. Equitable comparison of the cost of oil heat and district energy necessitates the inclusion of these capital and operating costs. With a largely residential community this is not always an easy comparison. For this analysis, it was assumed that the multiple heating systems could be equated to a centralized oil boiler. In this way, typical capital and operating costs may be estimated. An estimate of the annualized capital and operating costs increases the cost of heating by oil to $16.7/MMBTU ($57/MWh). In the event that oil prices dropped by 25%, this cost would be reduced to $13/MMBTU. These costs are very conservative but may be used to compare with heat delivered by a biomass based district energy system. In reality, the O&M costs and capital replacement cost would be higher due to the diversity and number of oil fired systems currently in Montpelier when compared to a central oil fired plant. Although the two costs are derived in similar ways, the central oil method will have smaller fixed capital costs and higher variable fuel costs when compared to the biomass central plant which has high fixed capital costs and low fuel costs. This major difference will tend to stabilize delivered fuel costs as the cost of the raw fuel begins to escalate. If the price of woodchips were to increase dramatically or if another fuel were to become available at extremely low cost, the district energy system (upon analyses) could switch fuels and/or combustion systems but leave the high cost infrastructure, distribution piping and heat exchange units, unaffected.

$3.0
$2.1/MMBtu.
annualized capital & O+M cost.

22.32

$27-31/ton 4.5

@$40/ton.

For the State heating plant the current cost (efficiency adjusted) of woodchips is $4.1/MMBTU ($14/MWh). It is estimated that with the larger volume of woodchips that would be required for a district heating system, this cost could be reduced to the range of $3 to $3.5/MMBTU. Records indicate that the cost of wood fuel has been stable for many years in the Montpelier region and has not experienced increases of the sort seen by the fuel oil market. This is due in part to several large consumers of wood energy making the woodchip and wood fuel industry competitive.

4.5

(14.6 - 4.1) (19.32 - 4.5)
diff 12.6 (original) ($17.8/MMBtu)

Another larger consumer such as the district heating system can only add to the competitive process.

Cost estimates are provided in Table 3, along with a comparison of estimates of the current heating methods in Montpelier using the above assumptions with a biomass district energy system using current oil and biomass raw fuel costs in the Montpelier region. For clarification, capital cost items include: distribution piping, energy transfer stations, biomass and oil fired boilers and back up units.

5/27

take a building that now uses 10,000 gallons oil / year

current fuel cost $20,000

assumed seasonal efficiency 70 %

.138 MMBtu / gal before combustion

.097 MMBtu / gal after combustion

10,000 x .097 = 970 MMBtu / yr

energy purchased from DH @ $20.4 / ~~million~~ MMBTU

= $19,788

$\frac{\$19,788}{\$20,000} = 99\% \Rightarrow 1\%$ reduction in fuel cost

Fuel component of DH bill: 15 %

0.67

0.6

56

5.3 SNAPSHOT ANALYSIS

OPTION	LOAD MMBTH	ANNUAL ENERGY MMBTU	HEATING PLANT (million)	Distribution (million)	Connection (million)	Total Project (million)	Annualized[3] capital (million)	O&M[4] and pumping cost (million)	Fuel cost (million)	Total annual cost (million)	UNIT ENERGY COST $/MMBTU	
Status-Quo						2.5-3.7 $2-3[5]					**16.7**	22.3.
1	64	135,545	$3.43	$5.5	$4.4	$13.33 16.37	$1.243 1.526	$0.35 0.424	$0.44 0.84	$2.03 2.79	**15.0**	20.6
2	64	135,545	$1.9	$5.5	$4.4	$11.80 14.49	$1.10 1.351	$0.32 0.388	$0.57 0.99	$1.99 2.73	**14.7**	20.1
3	64	135,545	$3.43	$5.3	$4.4	$13.13 16.12	$1.224 1.503	$0.34 0.412	$0.44 0.84	$2.00 2.76	**14.8**	20.4
4	64	135,545	$2.65	$5.3	$4.4	$12.35 15.16	$1.152 1.415	$0.33 0.400	$0.57 0.99	$2.05 2.81	**15.1**	20.7.

Table 3: Comparison of Costs (all estimates $(US))

add 22.78%

add 22.78%

3.25% general inflation:

1.212 times

location: current
wood : 100% of peak

analysis: see back of p.21

add 21.2% option 3

now (5/07)

ann. capital $1.50 million 54%

O&M
fuel $0.84 million (67%) 30%
non-fuel $0.41 million (33%) 15%
$1.25 million (100%)

100%

grand total $2.76 million

[3] Based on 20 years at 7% interest
[4] PY expenses are not included and are assumed to offset PYs associated with the central oil boiler scenario
[5] Cost to replace boilers at Capital Complex Heating Plant

I — 18,100 Tons × $\frac{\$24.25}{Ton}$ = 0.44.

II — 15700 tons × $\frac{\$24.25}{Ton}$ = 0.38 + 0.196 = 0.57

135,200 gallons oil × 1.45 $/gallon

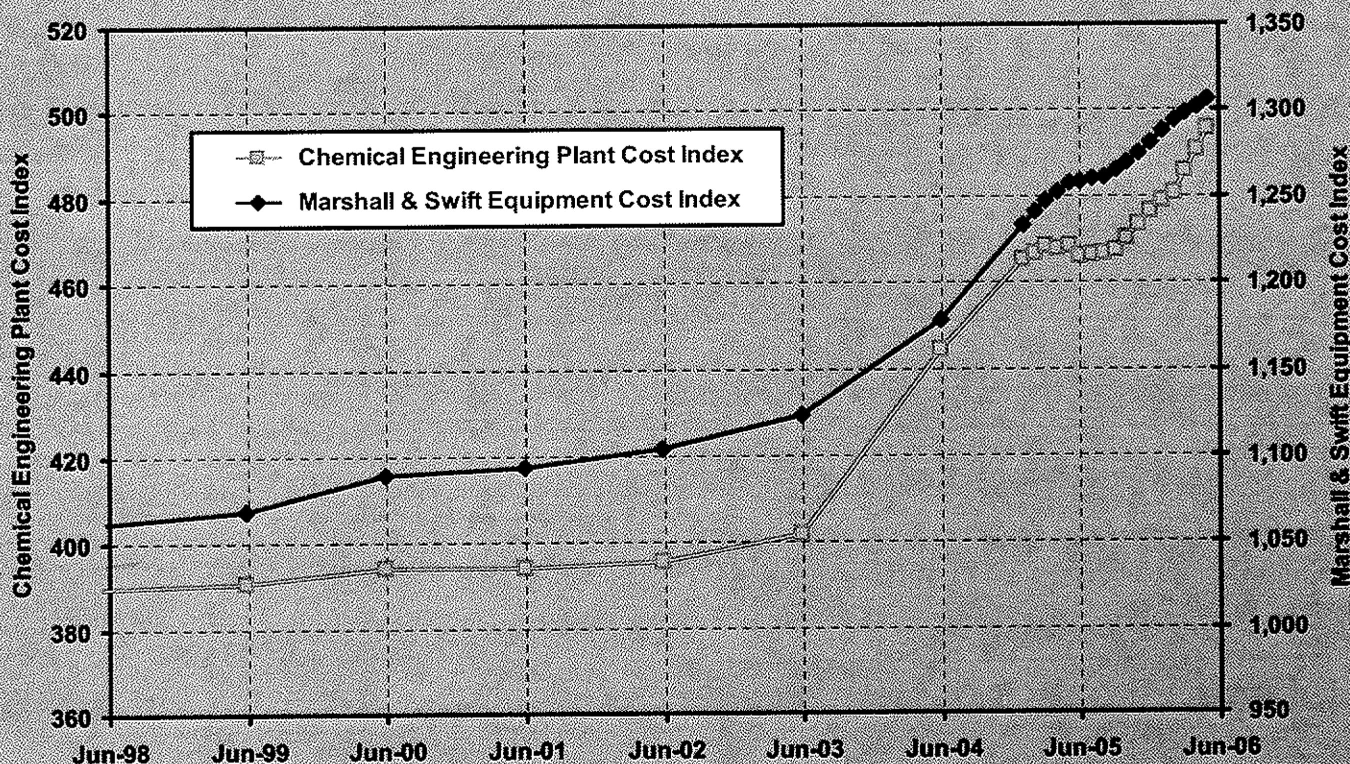
Updated nos:

I 20,885 × \$40 = 0.84

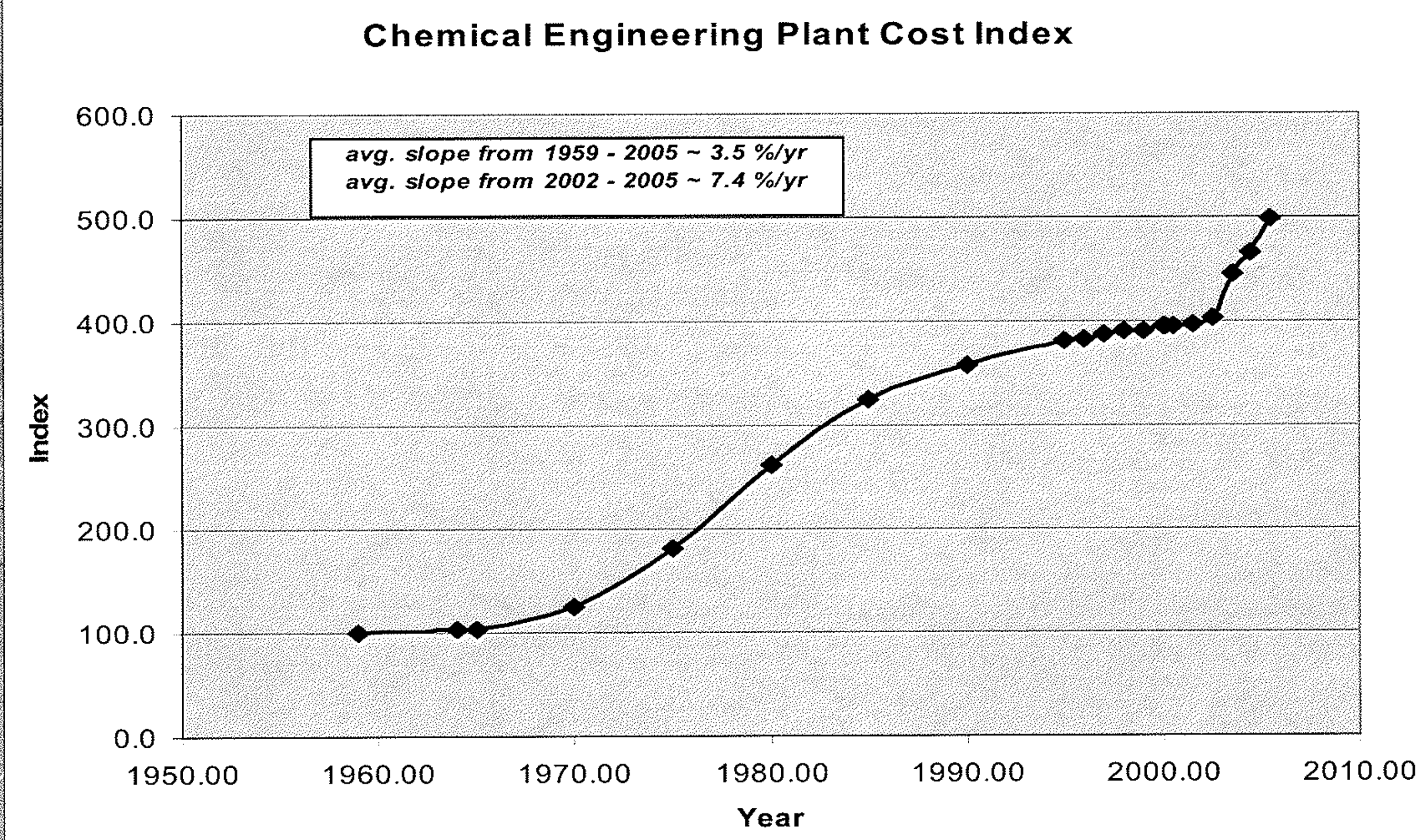
II 18,115 × \$40 + 135,200 × 2.00 =

0.72 + 0.27 = 0.99

That Was Yesterday – This Is Today's Picture



A Steeper Curve Today Than in the Mid 1980s



SNAPSHOT ANALYSIS
(Woodchips at $40/ton)

OPTION	Total Project (million)	Annualized Capital (million)	O&M and Pumping Cost (million)	Fuel Cost (million)	Total Annual Cost (million)	UNIT ENERGY COST $/MMBTU
Status Quo	$2.5 - 3.7					22.3
Option 1	$16.37	$1.526	$0.424	$0.84	$2.79	20.6
Option 2	$14.49	$1.351	$0.388	$0.99	$2.73	20.1
Option 3	$16.12	$1.503	$0.412	$0.84	$2.76	20.4
Option 4	$15.16	$1.415	$0.400	$0.99	$2.81	20.7

*Note: Savings generated by options 1-4 (compared to Status Quo) are roughly the same as the original findings in the 2001 report (9 to 10 percent).

① Construction project cost index.
~~Jan~~ July 1992 = 100.

Dec. 2006 142.2.

March 2001 122.7

Jan 2000 120.1.

increase of 18.4%.

---

② Chemical Engg plant cost index

Jan 2000 → June 06

~~0.8"~~ 395   ~~3.0"~~ 485 ⇒ ~~3.75 times~~ ~~275% increase in 6 yrs.~~ ~~46%/yr~~ 22.78%

---

③ Marshall Equip cost index

Jun 2000 → Jan 06

~~1.25~~ 1040   ~~3.2~~ 1300   ~~2.56 times~~ ~~156% increase~~ ~~26%/yr.~~

25%

* We have used chemical Engg plant cost index for project cost estimates with 22.78% escalation.