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POLICY CONSIDERATIONS INVOLVED IN THE IMPLEMENTATION OF RESIDENTIAL DISTRICT HEATING IN ALBERTA

by

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"POLICY CONSIDERATIONS INVOLVED IN THE IMPLEMENTATION OF RESIDENTIAL DISTRICT HEATING IN ALBERTA"

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ABSTRACT

Policy Considerations Involved in the Implementation
of Residential District Heating in Alberta

by

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19 March 1980

Prepared in partial fulfillment of the requirements for the degree Master of Environmental Design in the Faculty of Environmental Design, The University of Calgary.

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The study was undertaken to evalutate the applicability of district heating/cogeneration schemes to Alberta residential communities. Emphasis was placed on a discussion of the institutional barriers retarding an early introduction of utility-operated district heating schemes.

Energy conservation is seen to play a minor role in federal and provincial energy policies. Reasons for adopting conservation as a major component are presented. Residential district heating is suggested as a way of improving the efficiency of energy use.

The proven Scandinavian experience with district heating/cogeneration systems is examined. Its technology and economics are discussed. District heating/cogeneration schemes are compared to conventional systems of thermal electricity generation and individual building heating. District heating is seen to offer advantages of reduced pollution, reduced energy use and fuel flexibility. However, low energy prices favor conventional systems.

The institutional framework surrounding residential heat and electricity provision in Alberta is examined. The growth and responsibilities of the gas and electric utilities are discussed. The process of energy planning and pricing and the role of energy in the urban development process are described. Provincial government policy and regulation are addressed.

Major barriers to residential district heating in Alberta are identified as inappropriate provincial energy pricing, a lack demonstrated financial viability, a lack of industry expertise, an uncertain regulatory body stance and inadequate consideration of energy use in urban development.

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1.0 INTRODUCTION

As recently as 1970, energy was a commodity that was taken for granted. Low prices for oil and natural gas enabled their extravagant use in all sectors of the economy. Electrical energy suppliers attempted to win customers by persuading the public that it could "live better electrically". An electric future fueled by cheap and abundant nuclear energy was assumed to be in store.

But a series of events in the early 1970's changed this outlook substantially. The "limits to growth" movement offered a reminder that the world in which we live is finite and cannot forever support an exponentially growing population. Then, in late 1973, the so-called energy crisis provided a real-life example of the constraints imposed by a finite globe. Together, these events seem to have fostered an increased awareness of two aspects of energy production and use:

(1) The social and environmental impacts of utilizing non-renewable resources.

(2) The relationship between energy and social organization, technical infrastructure, and the economy.

Non-renewable energy resources are finite both in terms of their supply and in terms of the capacity of the environment to absorb the residual effects of energy production, transportation and use. The present use of limited supplies imposes a social cost on future generations by foreclosing their opportunity to use. Environmental and social impacts are felt in all aspects of the energy process: exploration, development, production, transmission, distribution, and utilization. The residuals of energy production and use - heat, particulates, and gases - cannot be indefinitely absorbed by organisms and ecosystems (Caldwell, 1976).

The interplay between our energy systems and our technical, economic and social systems has become more apparent and better understood (Commoner,1978; Lovins,1977; Caldwell,1976; Georgescu-Roegen,1971). The economic system is oriented to the production process. In order for anything to be produced, work must be done and work requires a flow of energy. The inherent qualities of any energy resource (or any transformed energy resource) determine the ways in which it can be used and thus establish limits on the types of technical processes -- machines, factories, equipment - which can use the resource. This technical infrastructure in turn has a corresponding social organization of workers and administrators "with varying levels of education and professional competence, roles, expectations, and hopes about their own and the organization's future" (Lonnroth et. al., 1977: p.49). As a result, disruptions in the energy systems give rise to disruptions in the technical, economic and social systems.

1.1 Energy and Public Policy

Realizing the intimate relationship between energy and economic, social and environmental policy, it would seem natural for a government to establish a policy regarding the wise use of energy. Indeed, the Canadian federal government has suggested that it recognizes the challenge to formulate an energy policy which ensures "the best management of our resources for the general welfare of Canadians" (EMR, 1973a: 2). At the present time, it is recognized that Canadians are extremely dependent on petroleum fuels -- oil and gas account for about two-thirds of total primary energy consumption (EMR,1976) -- and that these fuels are becoming increasingly expensive (economically and socially) to find and develop or to import. Towards the end of this century, a transition from the dominant use of petroleum fuels to that of other energy resources is anticipated (EMR,1976; WAES,1977; Lovins,1977; Lonnroth et.al.,1977). Future energy scenarios conceivably could range from a high-energy "hard path", utilizing nuclear and coal technologies, to a low-energy "soft path", utilizing solar and other renewable technologies (Lovins, 1977; Lonnroth et. al., 1977). Given the close ties between energy, technical and social systems and the long lead-time required for their planned modification, it would appear worthwhile for the government to analyze the virtues of different energy futures and help steer society in the direction of optimum social welfare.

However, policy decisions can only be made on the basis of existing information. One can only conceptualize about the credits and the drawbacks of alternative energy futures. The most immediate action for government, then, should be one of keeping options open -- ensuring that present actions do not foreclose future electives. And probably the best way of maintaining future energy possibilities is to take steps to conserve energy. Reducing the demand for energy not only keeps options open, it also 'buys' the additional time necessary to more effectively evaluate future energy scenerios.

Energy conservation can be accomplished in two ways -- by "leak-plugging" or by "belt-tightening". Leak-plugging refers to the process of modifying equipment, machines, buildings or management practices so that less energy is used to accomplish the same task. Belt-tightening, on the other hand, involves efforts to reduce energy use by abstaining from energy consumptive types of behavior.

These energy conserving measures can be considered in terms of their impact on lifestyles or behavior. One can envision a spectrum of possible measures ranging from those with little or no impact to those with substantial impact on behavior patterns.

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low impact	high impact
leak-plugging	belt-tightening
fixes	behavioral solutions

Leak-plugging measures, aimed at increasing energy efficiency, generally have no significant impact on lifestyles. For convenience, these low impact measures can be labelled 'fixes'. Belt-tightening programs are often called 'behavioral solutions' as they involve changes in one's "general pattern of behavior or 'individually unique way of goal striving'" (Schooler Jr., 1970: p.277). Clearly, those policy measures which encourage the use of energy-efficient technologies are likely to meet with greater success than those that encourage behavioral changes. However, even relatively low impact measures which yield obvious energy savings are not always accepted without opposition. An example of such is district heating.

For the purposes of this study, it is necessary to establish a working definition of district heating. In this report, the term is used to mean a system in which heat is generated in a centralized source and is transmitted -- as steam or hot water -- to subscribers to satisfy their space and domestic hot water heating requirements. The subscribers of particular concern in the context of this report are residential consumers.

District heating is sometimes employed in conjunction with cogeneration. Cogeneration generally refers to any process which generates electricity and useable heat. In the context of this report, the useable heat from a cogeneration process is utilized in a district heating application. The terms 'cogeneration' and 'combined heat and electricity production' are used interchangably. Again, residential consumers are the subscribers of interest.

District heating systems may refer to either heat-only or combined heat and electricity systems. District heat-only systems, on the other hand, refer to just that -- heat only.

District heating/cogeneration systems are compared to conventional systems of heat and electricity provision. In Alberta, the conventional electricity system is represented by thermal and hydro generating stations feeding a provincial grid. Most of the province's electrical energy is generated thermally. Conventional heating systems in Alberta are individual building heating systems; these are generally fired by natural gas.

In 1977, two district heating studies were completed for the federal Department of Energy, Mines and Resources. These reports -- District Heating for Small Communities and Gas Turbines and District Heating — claimed to have general application across the country. They concluded that district heating systems were not only more economic than conventional systems, but that they also resulted in reduced pollution and reduced energy use (ASL, 1977a; ASL, 1977b). However, there appears to be little concerted effort directed towards the introduction of district heating systems. Perhaps there are other barriers which impede such an introduction. This study uses the Alberta context to investigate the validity of the claim of economic attractiveness, and to probe the existence of other barriers to an early introduction of district heating systems.

1.2 Project Objectives

The purpose of this Master's Degree Project is to examine the policy considerations involved in the implementation of district heating in Alberta residential communities.

District heating and the cogeneration of heat and electricity have received fairly widespread application in numerous northern European cities (Haseler,1976; Muir,1976; Larsson,1977). It is claimed to yield substantial reductions in energy use and pollution, while at the same time offering economic profitability. Yet there seems to be little concerted effort by Canadian suppliers and distributors of heat and electricity to undertake district heating ventures.

Policy considerations regarding the implementation of district heating include assessments of technical and economic feasibility, energy and environmental implications, and institutional practicability. This study attempts to investigate these considerations. The discussion commences by addressing the role of energy conservation within the public policy context (Chapter 2). The general policy-making process is examined and constraints which operate on the formulation of energy policy are mentioned. Mention is also made of the possible relationships between energy and the economy (employment levels, inflation, trade balance), energy and the environment, and energy and the quality of life. The overall appraisal illustrates the importance of energy conservation. District heating is suggested as a way of decreasing residential space-heating demand.

The third chapter looks at the technology of a district heating system through its three components -- the heat source, the distribution network and the consumer's equipment. Consideration is given to both plants which generate heat only and plants which generate heat and electricity.

The fourth chapter discusses the costs and benefits (in a broad sense) associated with district heating/cogeneration ventures. Their direct costs are compared with those of remote thermal generation of electricity and individual-building generation of heat. While an in-depth economic feasibility study is not conducted, the important parameters in determining such feasibility are reviewed. The external benefits of reduced energy-use and environmental pollution are also discussed.

The fifth chapter, the focus of the study, examines the existing institutional framework within which residential heating decisions are explicitly or implicitly made. By analyzing the history behind the institutional framework and the relationship between technology and legislation, an attempt is made to understand the roles played by energy producers and distributors, government planners and regulatory bodies, and residential land developers. Constraints imposed by mandates, legislation and perceived responsibilities are identified. Finally, policy measures and recommendations (Chapter 6) which may mitigate the effects of these institutional barriers are suggested.

Of course, every policy study is subject to limitations. Time and money are the most constraining. As a result, the project must rely upon the available literature for discussions of the technological, economic, energy-use and environmental implications of district heating (Chapters 3 and 4). Further, the discussion of the institutional framework and resulting barriers must be confined largely to the Calgary, Alberta example. Unfortunately, Alberta's unique conditions of relative energy abundance and low energy prices limit the direct application of results to other Canadian provinces.

2. ENERGY CONSERVATION AND PUBLIC POLICY

District heating refers to a system in which heat is generated in a central source and is transmitted to numerous consumers for use. In residential areas, district heating could displace the present system of individually heated dwellings or buildings. The higher energy efficiencies associated with district heating offer a clear potential for energy conservation (see Section 4.3).

Before examining the policy aspects of district heating in particular, it would be worthwhile to first consider the larger role of energy conservation within public policy. District heating decisions will of course be a subset of energy conservation decisions. A better understanding of the present and evolving role of energy conservation would facilitate more operational policy recommendations regarding district heating.

2.1 Public Policy

The public sector has experienced persistant growth since 'laissez-faire' times. While the market system has long been recognized to yield efficient production and allocation of goods, it has become socially desirable for the government to intervene in situations where the 'Invisible Hand' appears inadequate. The market system has been found wanting in terms of its ability to deal with distributional problems and externalities. In these areas, the government is held responsible to "steer and guide the ship of the state" (Friedman, 1977: 162) -- a responsibility legitimated by the popular support of the government

(Schoettle, 1968). The government offers direction through public policy.

Immediately, it becomes obvious that the making of public policy requires value judgments regarding the desired state of affairs -- conceptions of an ideal standard of social welfare or general quality of life. [1] Of course, different individuals conceive of different desired states and thus the perceptions of problem issues and their priority are non-uniform. The way in which policy-makers view problem issues may be influenced through various internal and external forces upon the political system. Internally, problem perceptions are often shaped by advice and opinions of fellow representatives, senior professional civil servants, technical analysts and special advisory staff. External to the political system, input into problem issues may come from the public through direct communication, civil demonstrations, public hearings, court litigation, or consumption of public services. The public may further interact with public organizations and elected representatives through interest group participation, political party involvement and voting. Corporate interests and labour concerns are often voiced through collective groups, issue-oriented conferences or meetings with political authorities. The media groups, although themselves determining the content and emphasis of their presentations,

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[1] The following discussion of the policy-making process is assumed to be applicable to the federal, provincial and municipal levels of government. It is well recognized that the process is not identical at all levels, as each operates under its own jurisdictional and financial constraints and each is composed of different actors. The general process should however be similar.

serve as a tool which can be used by any of the actors within this policy-making framework. It can aid the public in asserting their viewpoints; it can aid the politicians in promoting their policies. By integrating, trading-off and priorizing the numerous concerns and values, the policy-makers formulate strategies for future conduct which are "designed to implement the values, usually of a fairly large group of persons, on a given issue without unduly compromising other values on other issues" (Bauer,1968: 3). Societal response to or unexpected consequences of specific policies may induce policy-makers to modify existing or propose alternative policies. "It is this continuing, never-ending flow of policy, dependent upon feedback, between the authoritative political system and the society which approximates the policy-making process" (Schoettle, 1968: 169). [2]

A 'feel'for the role of energy conservation within this policy-making process can be obtained by reviewing the themes behind existing energy policies and through examining the existing facilities for energy conservation planning, implementation and administration. Energy policy-making has become a function of governments at the federal and provincial levels. Both the federal and the Alberta government energy policies may influence the introduction of district heating to Alberta communities. Municipal governments, while they may influence district heating decision-making, seldom have official energy policies. Instead, attitudes regarding energy use are reflected in transportation and

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[2] This is of course an idealistic assessment, yet it serves as a general description where no universal theory exists.

land-use decisions (see Section 5.3).

Federal energy policy has attempted to ensure that the available energy supply meets the domestic energy demand. Clearly, there are two general ways of obtaining this balance -- by increasing energy supply or by reducing energy demand.

The federal energy policy of the early 1980's is somewhat uncertain. Unhappiness with the Conservative energy policy largely brought about their defeat in late 1979. The majority sentiment in the House of Commons felt that proposed energy price increases created an "unnecessary" burden on the Canadian consumer. It appears likely that federal energy policy will have a similar emphasis to that which it has had since the early 1970's. The federal approach has traditionally emphasized increasing the domestic availability of conventional energy resources -- oil, natural gas, coal, nuclear and hydro (EMR, 1973; EMR, 1976). Supply-augmenting measures have certainly encouraged the development of nonrenewable energy resources. Much less emphasis has been placed on the importance of reducing the overall energy demand. Indeed, prior to 1973, facilities for the detailed planning, implementation and administration, and feedback monitoring of federal energy policy were much better developed for measures aimed at ensuring supply than for those which reduced demand. The federal Office of Energy Conservation was created in late 1973 to fill this obvious void in federal programme delivery. Filling the void has taken time. Federal appreciation for conservation and renewable energy is growing, but concerns about increasing supply still dominate. At the same time as conservation is being promoted, the majority of the federal representatives are reluctant to let energy prices increase. The conservation message has thus become less urgent and confused in the eyes of the public.

If the federal government has not taken great strides in the area of reducing the demand for nonrenewable fuels, the Alberta government in comparison has barely taken a small step. With Alberta's rich endowment of nonrenewable energy resources and its constitutional authority over them, Alberta government energy policy tends to be very supply-oriented. Provincial governments have viewed their control over natural resources as "a most effective weapon for controlling their economic destiny" (La Forest, 1969: 168). The Alberta government's view of their energy resources control is no exception. Provincial energy policy is used to provide an attractive business environment and to encourage economic development in the province (see Section 5.1). Energy conservation has been given only passing attention. A position of Energy Conservation Manager was created within the provincial Department of Energy and Natural Resources in 1977. The conservation programmes are very limited however. The Energy Conservation Manager, Mr. Ian Burn, has had little direct input into provincial energy policy-making, though this is changing. He has had some say on an energy conservation policy being formulated within the provincial energy department (Burn, pers. comm.). Alberta government energy policy stresses resource development and pushes for higher oil and gas prices -- "a fair return for Alberta's resources" (Lougheed, 1973). Within the province, though the government has a very different attitude towards energy pricing. Low energy prices are the rule. The provincial tax on gasoline is zero. Natural gas rates are subsidized by the province (see Section 5.1). Low energy prices do little to discourage energy waste. Instead, they make the urgency of energy conservation to the average consumer somewhat distant.

Clearly, the federal and Alberta energy policies are supply-oriented. Efforts to reduce demand tend to be much less significant. Does this emphasis on increasing the availability of nonrenewable energy constitute a rational approach to energy policy? One must look at the dimensions of the energy problem. The energy problem consists of more than simply balancing supply and demand; "the basic problem of energy policy is the wise use of power" (Caldwell, 1976: 32). As employed here, 'use' includes

> "all aspects of the energy process: exploration, research, development, generation, transmission, distribution, utilization, and the disposition of residuals. It includes the purposes to which energy is put and the effects of energy, in all its aspects, on society and the environment" (Caldwell, 1976: 32).

Examining the role of energy within society and the environment gives a better understanding of the energy problem and its causes. The problem is that energy is critical to the functioning of our society, and that our society is consuming energy which is nonrenewable and polluting at an exponentially increasing rate. The causes of the energy problem seem to have their roots in the limits to growth. Energy growth is a reflection of population growth, industrial growth and the growth of consumption; the ultimate limits to this growth are imposed by finite resources, thermodynamic laws, and a finite capacity to absorb residuals. Any permanent solution to the energy problem must take account of these causes. One may wonder then whether these causal variables are not perceived, or whether they are simply not susceptible to public policy attack. These queries may be partially answered through an investigation of our 'inherited bias'.

2.2 Our Inherited Bias

The deeply-held values and institutions of our society — including private property, individualism, the profit-motive, the market system, democracy, justice, utilitarianism, the Graeco-Christian ethic, voting and social choice — have evolved through a series of historical processes. Together, they shape the way in which society perceives, defines and resolves problem issues; they have given us an 'inherited' intellectual bias (Detomasi, 1976a). Most social issues are viewed in economic terms (Prefontaine, 1973). Further, the government tends "to develop policies which are either designed to achieve growth in one or more of these economic categories or which require (or assume) such growth in order to be successful" (Detomasi, 1976b). Further, energy growth has been assumed necessary to fuel the economic growth (Daly, 1975). As a result, efforts to curb energy consumption are often less than enthusiastically received. Conservation through district heating may be impeded by such a reception. Biases behind energy growth are closely linked to biases towards economic growth.

The conception of economic growth as a cure-all can be traced to a combination of events which occurred around the 15th and 16th Centuries: the great voyages of geographical discovery, the Renaissance, the Reformation, and the population explosion which followed on the heals of the Black Death. [3] Previous to this time, the Catholic church had been instrumental in preserving an organic view of society and in proliferating the values and institutions of the feudal society. The individual was only important insofar as he fulfilled his role within the larger society; social mobility was virtually non-existant and those who attempted to be upwardly mobile (merchants) were at best 'bad'.

The voyages of geographical discovery brought increased wealth to the merchant class. It became politically expedient to form allies with the merchant class. Political power could be augmented by using the merchants' wealth to broaden the domain of political control. Nation-states were formed. Nation-states offered merchants common currency and weights, thereby making trade more efficient. National wealth and power increased.

The Renaissance brought an explosion of contact with other nations. Arabian and Eastern science and technology became available to western Europe. Centuries of ideas which had been confined to the monasteries came into the open. There was a revival of Greek and Roman philosophy — notions of democracy, justice, and individualism.

The Reformation capitalized on the concept of individualism. Luther helped remove the priest as a mediary between the individual and God. The individual become directly responsible for his acts. Calvin's doctrine of predestination condoned individual ambitiousness and thrift. Economic success served as proof that an individual would go to heaven.

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[3] The following analysis is largely adopted from lectures by Dr. D.D. Detomasi and from Detomasi (1976a).

The population growth resulted in an increased demand for goods and services and likely put pressure on national resources. This facilitated the political desire to colonize the world. The national wealth and power could further increase by extending control over other parts of the world. Raw material availability could be assured. Laws regarding imports and exports were passed to maximize the nation's trade surplus. The ability to accompany population growth with an increase in political power and general economic affluence could have reinforced the Graeco-Christian belief in man's role as despot over nature. Natural limits to this increase in prosperity were difficult to see.

Further increases in political power and prosperity were seen in improving the economic efficiency of the production process. It become politically and economically advantageous to create a stable supply of raw materials and labour as inputs into the factory system. The industrial producers became the dominant social class and found themselves limited by mercantile laws. Also unhappy with the mercantile system were David Hume, Adam Smith, and Jeremy Bentham. Their works were becoming recognized and appreciated. Based on the individualist reasoning of the Reformation, they provided powerful intellectual and philosophical reasons for the destruction of the mercantile system. With the institutions of individualism, private property, freedom of contract and the profit-motive, the market system arose. Implicit in Smith's view of the market economy was a minimal role of the political system and a maximum of individual choice and responsibility. The 'Invisible Hand' was seen to bring a 'natural' harmony of interest between the individual and society. The desire to maximize profits brought unprecedented rates of economic and industrial growth.

Economic growth, in turn, generated great advancements in knowledge and technology. The fields of medicine, engineering, transportation and communication flourished. Health standards, life expectancies, education levels, material prosperity and freedom of choice increased substantially. As a result of the evolution of thought over the last 400 years, it has become tacitly assumed that economic growth can resolve social problems; growth has become an end in itself rather than a means to an end. [4]

Throughout this period of economic and social growth, the growth in energy use has also been unprecedented (Starr, 1971: 5; Cook, 1971: 83). There is reason to believe that the availability of relatively abundant and inexpensive energy has facilitated some of the rapid development of learning, technology and the arts (Starr, 1971: 5). It has been suggested that "an industrial society requires .... a high use of energy per capita" (Cook, 1971: 87), given the close correlation between energy use per capita and gross national product per capita. This relationship is shown is Figure 2.1.

Indeed, most arguments for continuing the rapid energy growth of the past [5] assume that such growth is necessary in order to attain a high quality of life and to maintain a satisfactory level of employment (Daly, 1975: 145). These arguments ultimately rely on the presumption

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[4] Now that's history in a nutshell!

[5] The energy growth in the following arguments refers to the use of nonrenewable energy resources -- oil, natural gas, coal or nuclear -- and hydro energy unless otherwise specified.

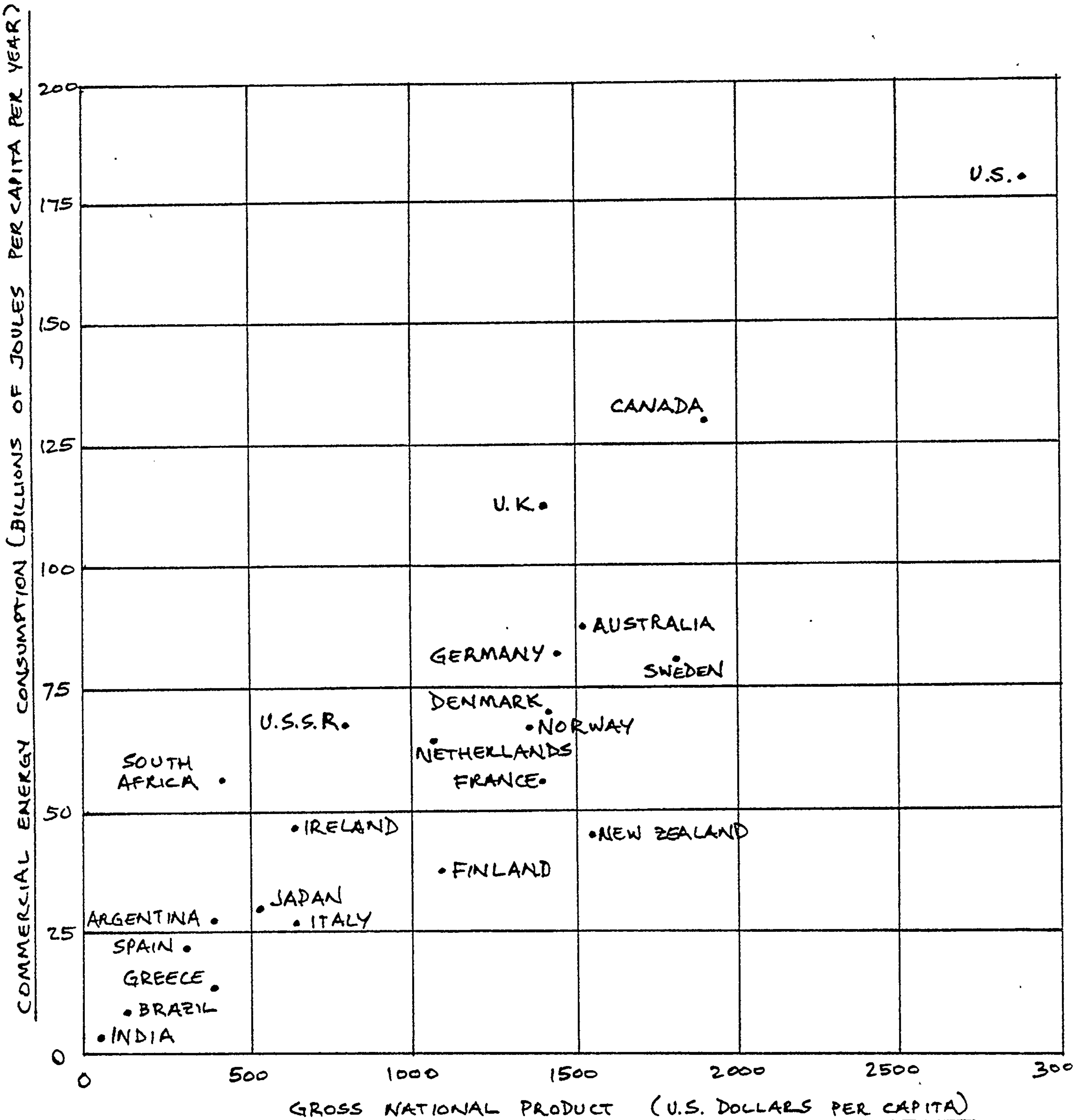

Figure 2.1. Per capita energy consumption and Gross National Product for various nations (Source: Cook, 1971: 90).

that energy growth is a necessary condition for economic growth and that economic growth brings with it desired employment levels and life quality. For example, the federal energy policy of 1973 stated that:

> "The use of energy, in amounts equal to any reasonable demand, is essential to the attainment of a high quality of life in Canada. It is indispensable to generate the wealth that will enable Canadians to improve their social environment, to protect and enhance their natural environment ..." (EMR, 1973a: 29).

The policy seems to assume that 'reasonable' demand includes that which increases at three per cent per year <u>ad infinitum</u>. The use of this energy is assumed to be necessary to augment the stock of all physical and human assets that perform services (wealth). It seems further assumed that such wealth accumulation enhances our social and natural environments -- our quality of life. But it is not clear that the links between energy growth, economic growth and the quality of life are so concise. Nor is it clear that energy growth ensures acceptable employment levels.

The dominant relationship between energy and employment arises from the production process (Daly, 1975; Hannon, 1977; Commoner, 1978). Labour, energy and capital are the basic inputs in the production of goods. The relative contribution of each input is largely determined by the cost and reliability of the inputs. The producer, seeking to minimize costs, employs inexpensive and reliable inputs more liberally and expensive inputs more sparingly. Of course, the costs of inputs may be manipulated by government taxes and incentives. Historically, the cost-minimizing motive has lead to the substitution of energy for labour (Daly, 1975; Hayes, 1976; Hannon, 1977; Commoner, 1978; Henderson, 1978). Fortunately, the loss of jobs arising from increased energy use has been offset by the employment creation effect of overall economic growth. Thus, although there is a positive correlation between the number of men employed and non-human energy use (Daly, 1975), it is important not to assume a causal relationship from the correlation. There can be no guarantee that continuing the energy growth of the past would generate any medium- or long-term employment benefits.

The long-term interrelationships between energy growth, economic growth, and the quality of life are "far from fully understood" (Brooks, 1978: 61). The past has seen energy use stimulate and be stimulated by economic growth. Expansions in energy use and the economy have spurred increases in leisure time, employment possibilities, health and medical care, educational opportunities and material prosperity. But the future relationship between energy and economic growth and social welfare will likely not not be the same. The future cannot neglect the impact of universal constraints which are only now becoming incorporated into conventional wisdom.

2.3 Beyond Conventional Wisdom

The universal constraints imposed by finite availability of resources, the laws of thermodynamics and the finite capacity of the earth to absorb residuals ultimately limit the extent to which energy use [6] and economic activity can grow.

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[6] This again refers to the use of nonrenewable energy resources.

Few would disagree with the statement that the earth is spherical and thus finite. It does not require a great intellectual leap to further deduce that the earth's nonrenewable fund of energy resources is also finite. This constraint has long-run implications for the price of nonrenewable resources. Simple economics dictates that the easiest to produce is produced first — the easiest oil to produce is produced first, the easiest natural gas to produce is produced before other natural gas deposits, and so on. As a result, the cost of production will increase unless technological innovations offset the increased production difficulty. This is the working of the laws of increasing marginal costs and diminishing marginal returns. "Inescapably, whenever the limited supply of a nonrenewable fuel is sufficiently depleted, its price begins to rise exponentially — that is, the higher the price, the faster the price increases" (Commoner, 1978: 10). Increasing prices for energy resources gives rise to a general increase in the general rate of inflation (EMR, 1976: 111). Thus, over the long run, a dependence on nonrenewable resources may complicate inflation problems.

Further limitations on energy use are given by the laws of thermodynamics:

(i) energy of the universe remains constant; and

(ii) entropy of the universe continuously and irrevocably increases with time (Georgescu-Roegen, 1971: 129).

Energy can be classified into two categories:

(i) free energy, which has low entropy and can be transformed into mechanical work, e.g. oil, coal, radiant energy from the sun.

(ii) latent energy, which has higher entropy and cannot do work, e.g. dissipated heat.

The second law implies that free energy always dissipates by itself into latent energy; and that once free energy has been 'used', it cannot be 're-used'. These laws define the maximum efficiencies of energy conversion from source (free energy) to end-use (latent energy). Clearly, the faster that free energy is used, the faster high entropy accumulates within the universe.

The capacity of the environment to absorb the residuals of energy production and use -- heat, particulates, gases, and radioactivity -- is also finite. It is limited primarily by the adaptability of life generally and of ecosystems in particular:

> "No organisms of ecosystems can absorb an indefinite amount of these residuals, and the tolerance of some life forms for them is narrowly limited. Human tolerance is limited directly by the physiological adaptability of the human body and indirectly by human dependence on food chains and the life-supporting interactions of water, air, and living organisms which beyond certain levels of impact would be disrupted by massive or intense outputs of energy residuals" (Caldwell, 1976: 32)

It would seem then that continual increases in the per capita use of energy would not 'enhance the natural environment', and may on the contrary place the quality of human life in jeopardy. Indeed, it is now widely accepted that the residuals of energy production and use -- such as carbon oxides, sulphur oxides, and nitrogen oxides -- represent a dangerous risk to human health (Eckholm, 1977).

Incorporating these constraints into the picture of the future, it becomes apparent that economic growth accompanied by growing nonrenewable fuel consumption may not further improve the quality of life. It is very possible that energy and economic growth may be subject to diminishing marginal returns and increasing marginal costs in terms of providing social welfare. Historical growth futures will require an increasing reliance upon coal and nuclear energy as oil and natural gas reserves near depletion. This future scenario has been termed "the hard path" (Lovins, 1977). It may be characterized by high rates of inflation (from using nonrenewables), high rates of unemployment (from energy substitutions for labour), negative trade balances (from importing nonrenewables), increased environmental sources of disease (from increased pollution), and increased aggrevation between developed and developing countries (over the hoarding of finite resources).

On the other hand, lower rates of economic growth could be accompanied by low or zero energy growth through an active encouragment of energy conservation (Freeman et.al., 1974; Lovins, 1976; Brooks, 1978). Over the long term, a transition could be made to the utilization of renewable energy resources. This transition, "the soft path" (Lovins,1977), would not seem to be plagued with the long-term problems inherent in the hard path. On the contrary, energy conserving and renewable energy technologies tend to be employment-intensive (Hannon, 1975; Hayes, 1976; Grossman and Daneker, 1977; Brooks, 1978) and anti-inflationary (Commoner, 1978; Brooks, 1978). They would tend to lessen national security problems (EMR, 1976) and have low levels of environmental impact (Middleton, 1976; Lovins, 1977; McCallum, 1977; Commoner, 1978).

However, the shift towards a more energy conservative society would not be without its difficulties. In the short and medium term, "factor endowments, the state of the art in technology, individual and social tastes, and the fixed nature of the infrastructure all limit the rate at which a more energy efficient system can be put in place" (Brooks, 1978: 61). Shifts of resources and investment from energy-intensive to energy-efficient sectors of the economy are likely to bring temporary unemployment. Changes in government legislation to encourage energy conservation and discourage energy waste may be met with resistance. The institutional and administrational inertia behind the energy-inefficient ways of the past will be difficult to turnabout.

2.4 Energy Policy

Both the hard path and the soft path scenarios, however, will require government intervention of some sort (Freeman et.al., 1974: 327). The pictures painted above of the hard and soft options are not intended to be rigorous; they are rationalized to suggest that neither one is impossible. The present bias towards growth has evolved over the last four hundred years and is not likely to change overnight. However, "we are living in a world where past behavior.... does not in itself provide sufficient information on which to base future energy policies" (EMR, 1976: 3). There may still be a need for data collection regarding the social consequences of alternative energy futures, but there are long-term limitations to historical energy use. A continuation of high energy growth rates would make time a very pressing constraint in the 'crisis of adjustment'.

It is therefore imperative that energy conservation -- through leak-plugging or belt-tightening (see Section 1.1) -- be adopted as an objective of energy policy. Encouraging the efficient use of energy not only delays somewhat the urgency of energy decision-making, it is also consistant with all energy alternatives. Reducing overall energy demand is one of the least expensive ways of 'increasing supply' (Freeman et.al., 1974; EMR, 1976; Hayes, 1976; Brooks, 1976b; Ross, 1977; Lovins, 1977).

There is enormous potential for energy conservation between the energy sources and end uses. Looking only at the demand for space and hot water heating, fossil fuels could be saved via such practices as increasing building insulation, utilizing active and passive solar energy, employing sound energy management practices, or using district heating. This Master's Degree Project considers only the district heating alternative. It looks in particular at the factors influencing the introduction of district heating/cogeneration systems to Alberta residential communities. A discussion on district heating/cogeneration technology follows.

3.0 THE TECHNOLOGY OF DISTRICT HEATING

The formulation of policy measures aimed at alleviating a specific problem often involves the analysis and evaluation of various technologies. Priorities are established and trade-offs are made. With respect to the problem of exponentially increasing consumption of finite energy resources, one could anticipate the encouraged development or use of technologies which either increase energy supply or reduce energy demand. The selection of appropriate technologies would involve numerous trade-offs. One would think that technologies which had proven capability would be preferred to those which did not. Technlogies which offerred greater flexibility to future energy scenarios should be preferred to those that are less flexible. Technologies which are economically justifiable should be preferred to those which are not. Those which have little negative impact on society and the environment should be selected over those of greater impact. Finally, in order to attain any long-term solution to the energy problem, technologies which reduce the net consumption of nonrenewable energy resources should be preferred to those which do not. [7]

District heating refers to a system in which heat generated in a central source provides consumers with space and hot water heating. The heat is distributed from the central source in pipes, using water or steam as a transfer medium. In residential areas, district heating could displace the present system in which dwellings and buildings have

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[7] These priorities are suggested in Love, 1977.

individual furnaces for the provision of space and hot-water heating. The pipes containing the hot water or steam would simply displace the current pipes containing natural gas.

District heating is often associated with cogeneration -- the combined production of heat and electricity. In this mode, the heat available after electricity generation is used in district heating application. District heating/cogeneration systems could potentially displace the conventional systems of heat and electricity provision (see Section 1.1). A local cogeneration plant could displace some of the capacity of remote thermal generation facilities; local cogeneration and supplementary heating plants could supply the heat otherwise provided by individual building heating systems. Clearly, the combined system would have to fulfil the existing role of meeting the heat and electricity requirements.

3.1 The Demand for Heat and Electricity

At present, the anticipated demands for heat and electricity are forecasted separately by different utlities. The electric utility attempts to ensure that there is sufficient electrical capacity to meet the anticipated maximum electricity demand. The heat utility -- the natural gas distribution company, for example -- attempts to ensure that enough fuel is available to satisfy the anticipated maximum heat demand.

Before a decision is made to undertake a district heating/cogeneration venture, estimates must be made of the potential demands for heat and electricity. For a planned community, this would require forecasts of population, dwelling numbers and types and potential commercial, industrial and service areas (Wahlman, 1976).

Each building type would have a characteristic thermal efficiency and related demand for heat. The maximum anticipated demand (the peak load) would be associated with the coldest expected outside temperature (the design temperature). [8] Adding the peak heating loads for all of the buildings with their hot-water heating requirements and any industrial process heating loads gives the design heating load for the community. In a similar way, the design cooling load (for non-residential buildings generally) and the design electrical load could be estimated.

For areas which may be retrofitted with district heating, inventories must be taken of existing heat loads and heat supply systems, as well as potential subscribers (so that the heat load densities could be estimated). It would be worthwhile to also estimate the heat contribution which could be made by industrial waste heat.

Of course, these demands fluctuate on a diurnal and seasonal basis. Figure 3.1 shows the mean and peak heat demand for a model Canadian community of 70 000 people. The community has residential, commercial, industrial and service components. The mean monthly demand is substantially less than the short duration peak demand. There is also a considerable difference between summer and winter heat demand.

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[8] In Calgary, the design temperature established by the provincial government is -31 C. It represents the coldest temperature which is reached during 1 1/2 per cent of the hours in the coldest month of the year (January).

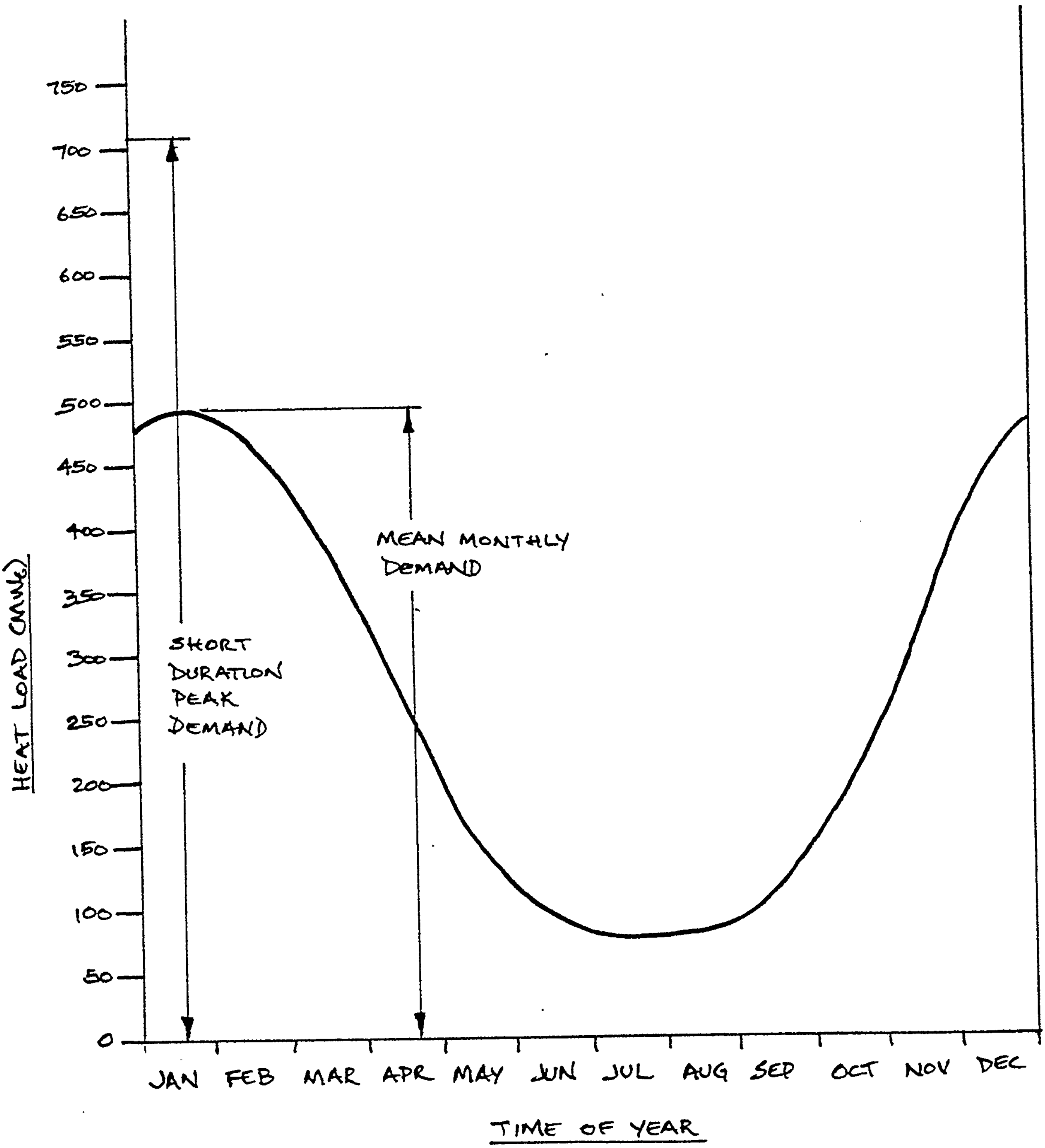

Figure 3.1. Mean and Peak Heat Demand for a Model Community (Source: ASL, 1977b).

Figure 3.2 illustrates the variation in electricity demanded for the same community. While no indication is given of the peak electrical load, it would be greater than the monthly mean demand of December. Again, the summer load is less than the winter load.

Figure 3.3 combines the two previous figures to illustrate the respective variations between the mean heat and electrical power demanded over the period of a year.

The variations in electricity and heat demand have important implications for the design of district heating/cogeneration systems. The heat/electricity production could be arranged such that the electricity demand of a community is met; and the heat demand not satisfied through cogeneration is provided by auxiliary heat-only stations. This would represent a self-sufficient cogeneration system. Alternatively, the yearly base-load heat requirements could be met through cogeneration and surplus electricity could feed a grid system on an "as available" basis. Auxiliary boilers would ensure that peak heat demands were met. Obviously, other combinations of heat and electricity production are possible. In order to deal with the fluctuations in heat and electricity demand, it sometimes becomes advantageous to store heat, or to be able to vary the ratio of heat produced to electricity produced.

District heating and cogeneration are not new technologies. District heating has been used for over half a century in parts of North America and Europe. The scale of development, however, has been substantially greater in Europe than in North America. In particular, the growth of European district heating has been significant since the second world war, whereas North American growth has been relatively idle

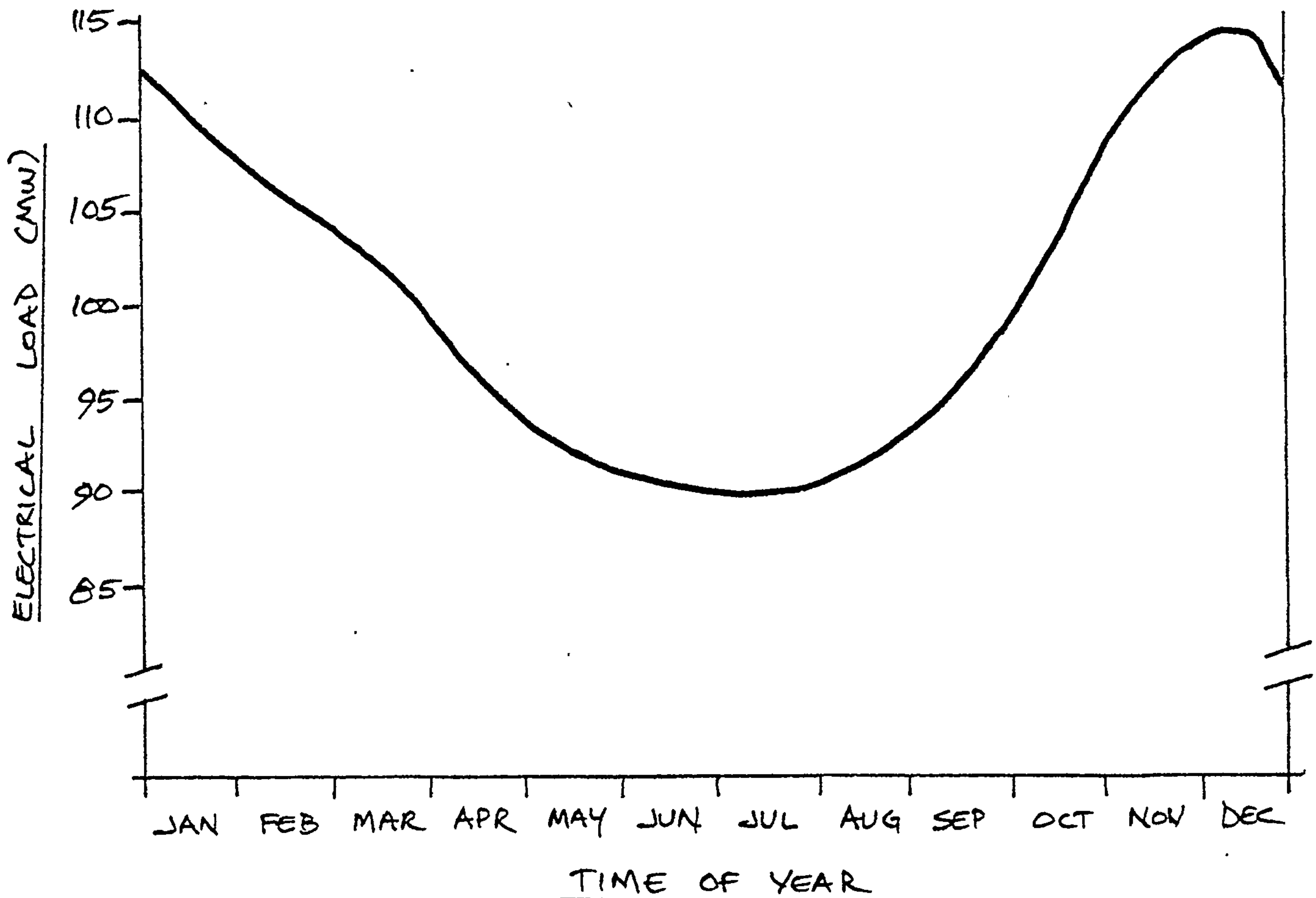

Figure 3.2. Electricity Load Distribution curve for a Model Community (Source: ASL, 1977b).

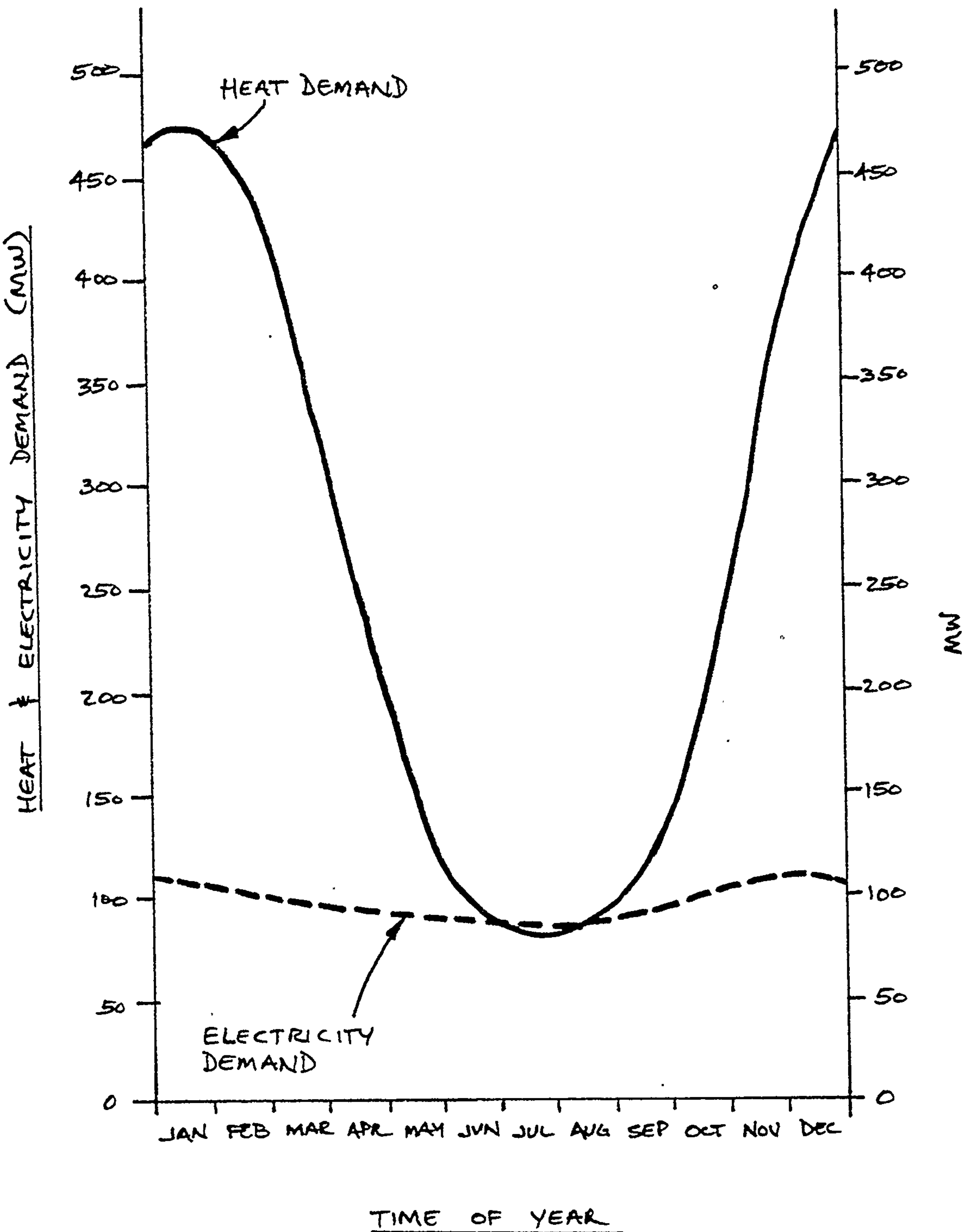

Figure 3.3. Electricity and Heat Load Distribution Curves for a Model Community (Source: ASL, (1977b).

(Brown, 1972; Haseler, 1976; Karkheck et.al., 1977).

A few reasons for this discrepancy may be suggested. Historically, fuels have been relatively less abundant and more expensive in Europe than in North America (ASL, 1976). A reliance on imported oil since the early 1950's gave Europeans an early incentive to search for technologies which offered fuel flexibility and energy efficiency (Erlandsson, 1976; Gahbaurer, 1978). District heating/cogeneration systems can use a variety of fuels (see Section 3.3) and can be 30 to 70 per cent more efficient than conventional systems of heat and electricity provision (see Section 4.3). As well, where fuel oil has been used for heating, district heating systems have resulted in lower levels of air pollution than individual heating systems (Larsson, 1977). Central plants have advantages over individual systems in that pollution abatement equipment can be afforded and maintenance is regular and proper (see Section 4.3). Popular North American use of clean-burning natural gas certainly diminishes the extent of this pollution-reducing advantage. Public concern over air quality has often dictated that thermal plants burning dirty fuels be located in areas remote from the urban population (Brown, 1972).

The North American tendency to use steam (instead of hot water) for district heating made combined heat and electricity production uneconomic (Larsson, 1977). Inexpensive energy fostered the growth of gas and electric utilities and the separate provision of heat and electricity.

Concern in the 1970's over limited fossil fuel supplies has elevated the interest in energy-efficient technologies, including district heating and cogeneration. As district heating developments in Canada have been very few over the last twenty-five years, it would be useful to look at and learn from European experience.

3.2 European Experience

"There are several thousand district heating schemes in Europe, ranging from small ones in villages to those serving whole cities" (Haseler, 1976: 153). District heating is employed in at least twenty-five European countries (Haseler, 1976). It has generally expanded on a cost competitive basis with other heating methods (Karkheck et.al., 1977; Gahbauer, 1978). Denmark, Sweden and Finland provide fine examples of district heating developments.

Denmark's first district heating system was built in Copenhagen in 1900 and utilized steam as a heat transfer medium. Since that time, district heating steadily increased, with the major thrust being in the period between 1950 and 1970 (Gahbauer, 1978). Hot water has become the dominant heating medium. [9] In 1978, Denmark has about 450 district heating plants distributing heat to roughly one-third of the nation's dwelling units -- approximately 350 000 apartments and 320 000 single family homes (Gahbauer, 1978). Some of these residential areas have densities of only five dwellings per acre, typical of low-density sprawl (Haseler, 1976). About forty per cent of the total supply of district heat comes from cogeneration (Gahbauer, 1978); the remainder is provided

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[9] The relative advantages of steam and hot water are discussed in Section 3.4.

by oil- and coal-fired boilers and more recently, refuse incinerators and industrial waste heat.

In Sweden, district heating satisfies twenty per cent of the annual demand for space and hot-water heating (Larsson, 1977). It serves three million people in 30 000 single family dwellings, 680 000 apartments and 340 000 institutional and industrial buildings (Gahbauer, 1978). In one city, Vasteras (population 100 000), ninety-eight per cent of all buildings are served by district heating (Gahbauer, 1978). At present, fifty-seven municipalities in Sweden employ varying degrees of district heating. Of these, fourteen have refuse incineration plants; thirteen have cogeneration plants (Gahbauer, 1978). There is apparently a growing trend towards converting existing steam turbines to combined operation (Gahbauer, 1978). The Swedish district heating systems utilize water as a heat transfer medium.

District heating in Finland began in the 1950's (Kilpinen, 1977). By the end of 1975, there were district heating schemes in forty-three localities; nine of which had cogeneration plants (Kilpinen, 1977). The connected heat load experienced a five-fold increase between 1965 and 1975. By the end of 1976, district heating supplied about seventeen per cent of the country's heat demand (Kilpinen, 1977). It is estimated that district heating will satisfy 45 per cent of the heat demand by 1985 (Smeds, 1977). While over sixty per cent of the consumers are residential, district heating for single family dwellings is only a recent development in Finland (Kilpinen, 1977). [10] At the end of 1976,

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[10] These lower density residential developments tend to be less economic than higher density areas (see Section 4.2).

only 1900 private houses were joined to the district heating networks -- 1250 as single consumers and the balance in groups of eight or ten houses (Kilpinen, 1977). As in Sweden, water is used as a heat transfer medium in Finnish district heating systems.

For economic reasons, the district heating schemes in these countries have developed in stages. As the demand for heat (the heat load) grows, the system is expanded. Initially, hot water is distributed from mobile heating units to satisfy the space and hot-water heat demands of a small group of consumers. The mobile units generally comprise a single hot-water boiler and associated pumps and equipment -- all on a single and unmanned chassis (Smeds, 1977). They have thermal ratings from about one to 7.5 MW (Kilpinen, 1977). When the connected heat load is about to exceed the capacity of the boiler, another temporary heating unit may be joined in parallel.

Once the connected load is sufficiently large, stationary heating plants may be constructed to displace some of the temporary boilers. Other temporary boilers are retained for peak load operation and standby capacity. In Finland, the heat capacity of the stationary boilers generally varies from 28 to 75 MW, with the average being about 50 MW (Smeds, 1977). One may assume that stationary plants begin to appear economically attractive (under Finnish conditions) once the average heat load is within this range.

As the connected heat load continues to grow, the construction of cogeneration plants is undertaken. In Finland, the minimum size of a cogeneration plant which is economically justifiable is "one where the electrical power is about 30 MW and the thermal power is about 60 MW" (Smeds, 1977). In Sweden, all systems with a heat load of 200 MW or more have combined plants (Larsson, 1977). The cogeneration plant is often dimensioned to cover the base-load heat requirements of the system. While the base load may be only about one-half of the peak capacity, it may provide about ninety per cent of the total annual energy consumption (AFC, 1975). To illustrate this, a typical heat duration curve is shown in Figure 3.4. The base load, provided by back pressure turbines and waste heat, accounts for about 45 per cent of the system capacity (measured along the vertical axis). However, these heat sources provide most of the heat energy consumed annually (measured by the area under the curve). Heat-only boiler plants are used to meet the seasonal and diurnal heat load variations and to provide standby capacity.

In all three of these Scandinavian countries, consumer and government attitudes towards district heating are very favorable (Gahbauer, 1978). Although district heating networks have developed and expanded on a cost competitive basis with alternative heating systems, recent government legislation has further favored district heating. In Denmark, a "law of government subsidies" has been passed to encourage the utilization of waste heat from electricity generating stations, incineration plants and industrial plants. In 1977, Swedish legislation made it possible for municipalities to decree that specific areas shall have public district heating (Gahbauer, 1978). Once an area is declared

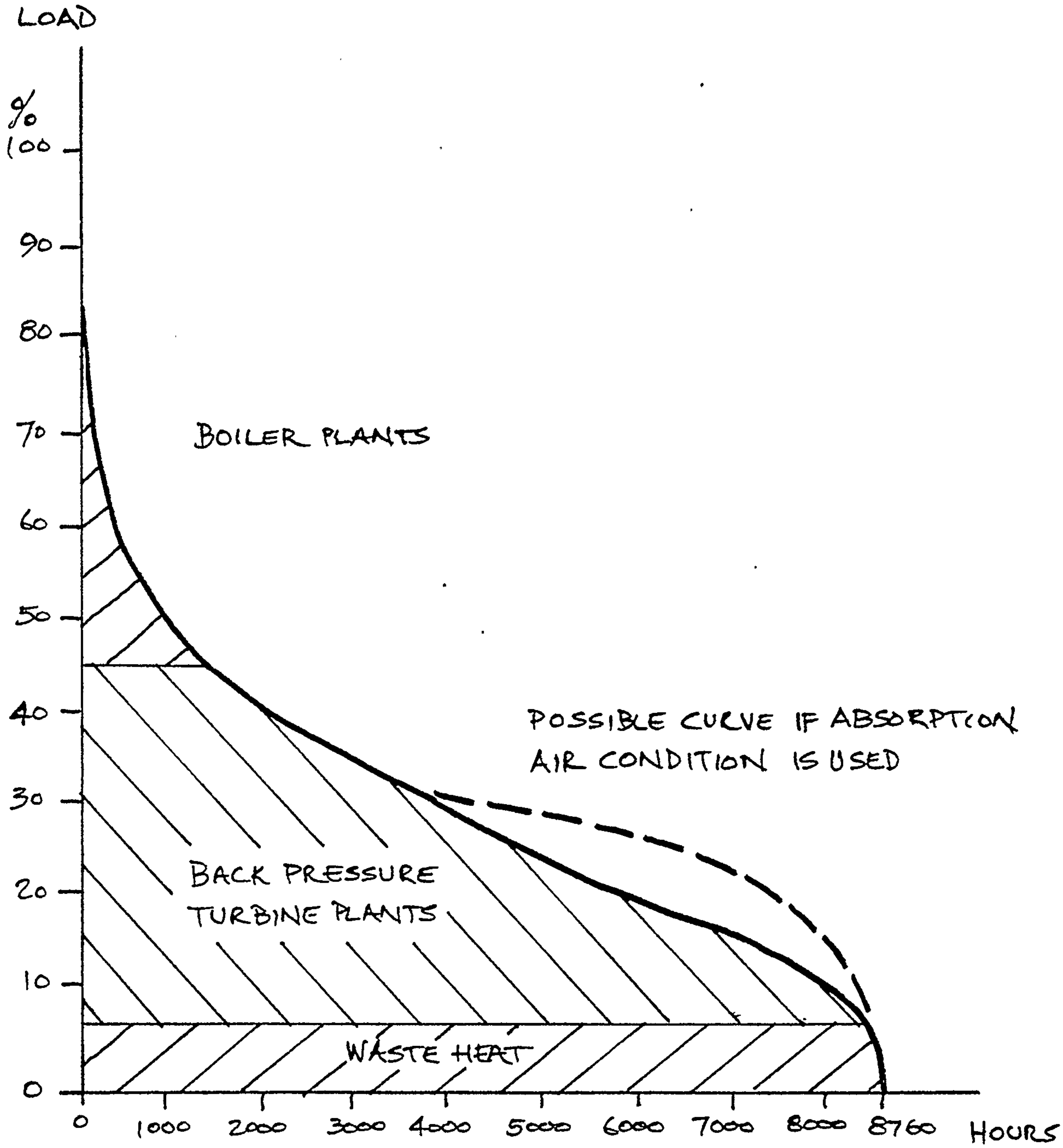

Figure 3.4. Typical Heat Load Duration Curve (Source: Wahlman, 1976).

public, all consumers within the area are obliged to connect to the district heating system (Karlberg, 1976). The main purpose of this law is to give municipalities the opportunity to optimize energy planning, while simultaneously achieving the national objective of reducing the dependence on imported fossil fuels. No district heating legislation has been introduced in Finland; however, a government committee has recommended that priorities be given to district heating and cogeneration over other heat and electricity systems (Gahbauer, 1978). The fuel-saving potential of district heating/cogeneration systems is recognized to be of national significance to all of these oil-importing countries.

On the other hand, consumers appreciate the reliable, cost-competitive and clean aspects of district heating. In fact, the three Scandinavian countries have "a waiting line of consumers who want to be connected to district heating systems in their locality" (Gahbauer, 1978: 24).

The successful Scandinavian experience (and European experience generally (Haseler, 1976)) demonstrates the proven capabilities of district heating and cogeneration schemes. There is no reason to suspect that the technology could not be easily applied to the Alberta environment. Climatic conditions in Alberta are not much more severe than those in Sweden and Finland. There are, however, some important differences between Scandinavian and Albertan conditions which may limit an early introduction of district heating to Alberta. The Scandinavian countries have not had the abundant indigenous fossil fuel supplies Alberta has had. As a result, the Scandinavians have had limited control over fuel availability and cost. Albertans, on the other hand, have enjoyed a selection of indigenous energy resources and low energy prices. The attractiveness of energy systems which offer efficiency and fuel flexibility has thus not been great in Alberta.

Another condition which makes European experience in district heating/cogeneration less directly applicable to Alberta has to do with residential densities. Densities tend to be higher in the Scandinavian countries than they are in Alberta. Higher densities, like higher energy prices, generally improve the economics of district heating (see Section 4.2).

District heating technology can be evaluated more thoroughly by examining the basic elements of the system. There are three major components of any district heating scheme: the central heat source, the distribution network and the consumer's equipment.

3.3 The Central Heat Source

The function of the central heat source is to generate enough heat to satisfy the requirements of the connected load. The consumer is relatively indifferent to the method of heat generation (subject, naturally, to pollution regulations), but is instead primarily concerned with obtaining the quantity of heat he desires when he desires it. Thus, numerous options are open for the heating of the transfer medium (hereafter assumed to be water). [11]

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[11] It is also assumed that the supply water is superheated to a temperature of 100 C to 120 C. The advantages of water over steam as a

A major advantage of district heating/cogeneration systems is that a variety of fuels can be used to provide the district heat. Heat can be furnished directly or indirectly by fossil fuels, nuclear fuel, biomass fuels, solid waste or solar energy. Each type of fuel has its relative advantages and disadvantages. The fuel selection in any particular locality would be dependent on supply availability, fuel cost, social and environmental acceptability and government policy. These conditions will vary geographically, and thus one would expect the selected fuel to vary among localities. This represents an important long-term advantage of district heating/cogeneration systems -- they offer freedom from dependence on any one fuel type and facilitate a transition towards the use of renewable energy resources. While security of supply may not be a pressing concern in Alberta, a responsible government will certainly realize the value of keeping future options open.

Generally, the central heat sources may be considered in two categories: heat-only sources and combined heat and electricity sources.

Heat-only Sources

Heat-only sources basically consist of a boiler (or combination of them), a heat exchanger, a feedwater tank and a pump. [12] Figure 3.5 illustrates schematically the basic process for district heating schemes with heat-only boilers. The type of boiler most commonly used today ap-

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transfer medium are discussed in Section 3.4.

[12] Solar heating systems would have different components of course.

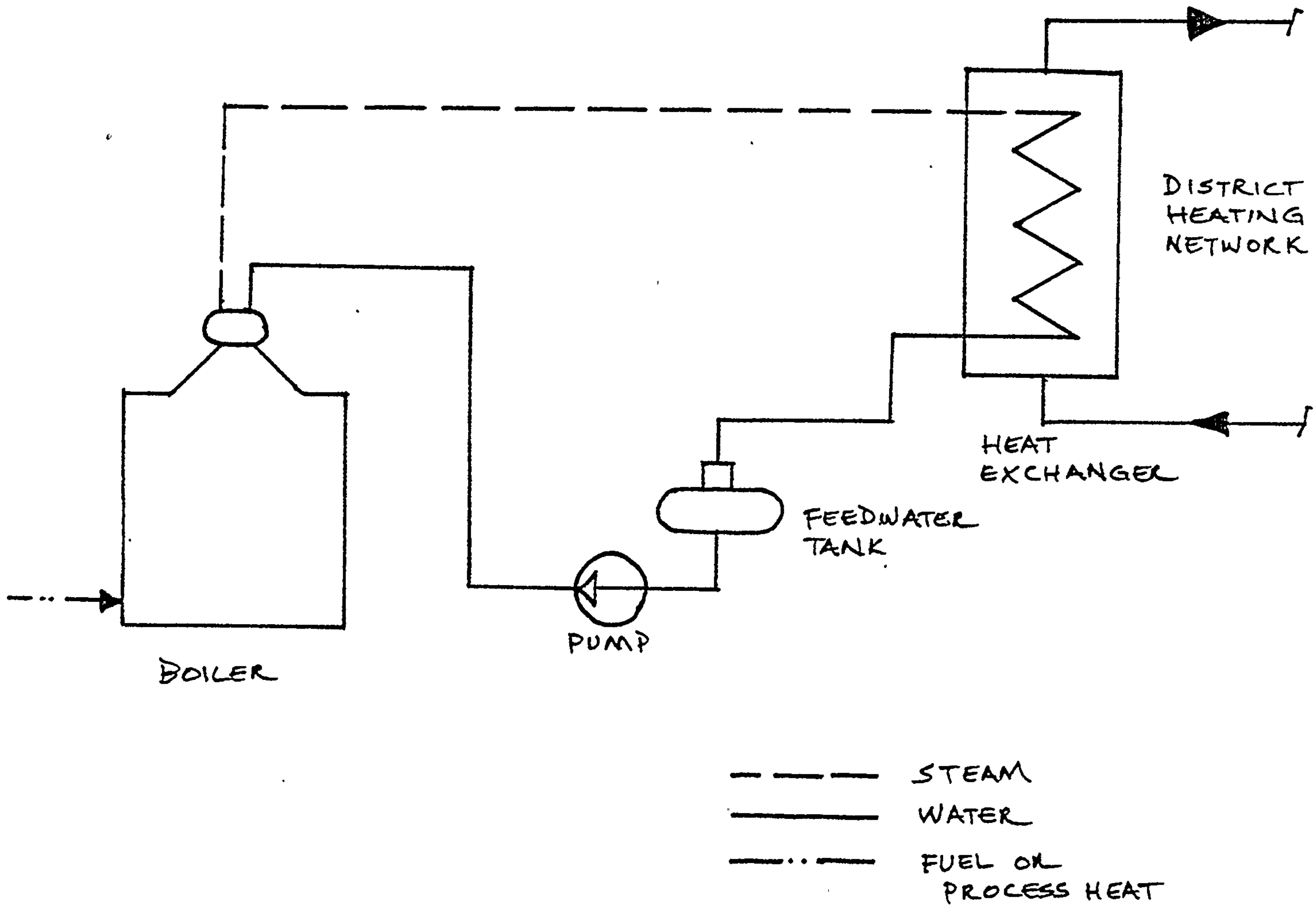

Figure 3.5. Schematic Diagram of a Heat-Only Boiler in District Heating Application.

pears to be the water tube boiler (AFC, 1975).. In these, water circulates through tubes which fill the interior of the boiler.

Heat from industrial process exhaust or fuel combustion is introduced into the boiler. The heat is transmitted through the boiler tubes to the water. As the water is heated, it rises up the boiler tubes and eventually reaches its boiling point. [13] Steam leaves the boiler, goes through a heat exchanger and condenses. The heat lost through condensation is gained by the water that is transmitted through the district heating system. Once through the heat exchanger, the condensate is fed to a feedwater tank and deaerator. In this tank, the condensate is deaerated and make-up water is added. [14] The feedwater is then pumped back to the boiler, where it is heated again. The efficiency can be improved if the feedwater is pre-heated by heat exchangers which take heat from the exhaust gases of combustion (not shown in illustration).

The heat-only station could alternatively heat the district heating water directly, without using heat exhangers. In such case, hot water boilers would be used rather than steam-generating boilers. Though this method is commonly employed in mobile heating units, it tends to be more costly in terms of reliability, maintenance and circuit cleanliness (ASL, 1977b: 8.9).

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[13] Boilers which generate steam (described here) are generally cheaper than hot water boilers at the pressure and temperature range desirable for district heating systems (ASL, 1977b: 8.9).

[14] In steam systems, leaks are common sources of water loss and oxygen gain -- thus the need for deaeration and water addition.

Combined Heat and Electricity Sources

Central heat sources may also produce electric power. Combined heat and electricity stations are basically heat-only stations with the addition of a turbine and a generator. Cogeneration plants generally utilize either steam turbines, gas turbines, or a combination of these two (called combined cycle). [15]

There are three types of steam turbines -- condensing, condensing/extraction and back pressure. To generate electricity, steam of high temperature and pressure is expanded through the turbine. The expanding steam causes the turbine blades to move and thereby rotate the turbine shaft. The work done by the rotating shaft is transformed into electric current in generators.

Of the three steam turbines, only the condensing/extraction and the back pressure types are suitable for district heating. The condensing steam turbine maximizes the amount of electricity which may be generated from the steam. As a result, when the steam is exhausted from the turbine, its temperature and pressure are too low to be useful for district heat. The exhausted steam is condensed by cooling water and its energy is eventually lost into the environment. Condensing steam turbines are commonly used for thermal electric generation in Canada.

In a condensing/extraction turbine, steam is extracted from one or more points in the turbine. Figure 3.6 shows a simplified schematic of such a turbine in a district heating system. Steam is produced in a wa-

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[15] Internal combustion engines with heat recovery equipment are sometimes used to provide heat and electricity for small loads.

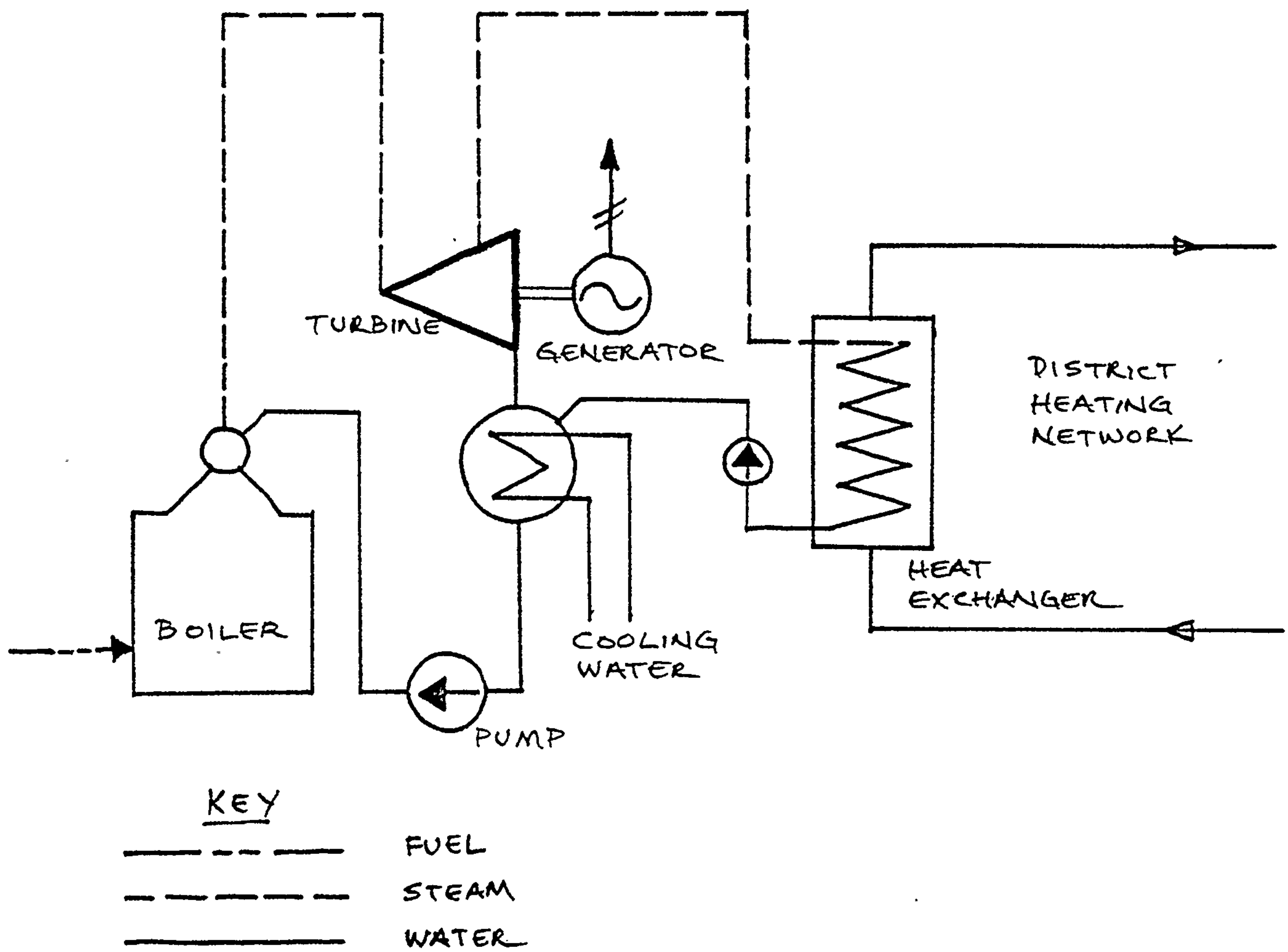

Figure 3.6. Schematic Diagram of a Boiler and Condensing/Extraction Steam Turbine in District Heating Application (Source: ASL, 1977b).

ter tube boiler as it is in a heat-only source. Instead of the steam going directly to a heat exchanger, the high temperature, high pressure steam is expanded through a turbine. Steam is extracted from the turbine to heat the water in the distribution system (by means of a heat exchanger). As the amount of steam extracted is increased, the quantity of electricity generated decreases. The steam exhausted from the turbine is at too low an energy level to be useful in the district heating system and is condensed by cooling water in the condenser. Water from the heat exchanger is also fed to the condenser. The condensate is then pumped to a feedwater tank as in the heat-only system. The feedwater is pumped back to the steam generator.

The condensing/extraction steam turbine can provide a wide variation in the heat to electricity ratio and is therefore good for handling fluctuating loads. When the heat load is substantially greater than the electricity load, it is possible to increase the extraction of steam from the turbine. This would have the effect of supplementing the available heat but reducing the available electricity. Similarily, the cooling water can act as a heat sink when the electricity demand exceeds the heat demand, allowing the electricity production to be maximized. A disadvantage of this turbine, however, is that the overall system efficiency is reduced by the heat lost in the condenser.

Back pressure steam turbines represent another cogeneration option. In a back pressure turbine (by definition), the exhaust steam is employed in a heating process and the turbine work is a by-product. In a district heating/cogeneration system, the exhaust steam would be fed into a steam to water heat exchanger, as illustrated by the simplified schematic in Figure 3.7. The need for cooling water is eliminated. The rest of the system is virtually the same as in the case of a condensing/extraction turbine. The elimination of the cooling water gives the back pressure turbine a high overall efficiency, however the quantity of electricity generated is controlled by the back pressure heat demanded. In other words, there would be a fixed heat to electricity ratio. These turbines are good for base-load operation or relatively constant loads. [16]

A second type of central heat and electricity station would be gas turbines with heat recovery boilers. A simplified schematic of this type of district heating system is illustrated in Figure 3.8. The burners of the gas turbine receive compressed air and use it to ignite fuel (typically oil or natural gas). The hot combustion gases are then expanded through the turbine as steam is in a steam turbine. The exhaust gases, which are still at extremely high temperatures are used to boil water in a heat recovery boiler before being exhausted to the atmosphere. It is often worthwhile to supplement the exhaust gases, which contain a large amount of oxygen, with a combustible fuel (as shown in the illustration). This increases the amount of heat available. By varying the amount of supplementary firing, the heat to electricity ratio can be manipulated. Once heat is supplied to the heat recovery boiler, the rest of the system is comparable to the example of a heat-only source.

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[16] An extraction or by-pass facility could be installed in the back pressure turbine to yield more flexibility in the heat to electricity ratio.

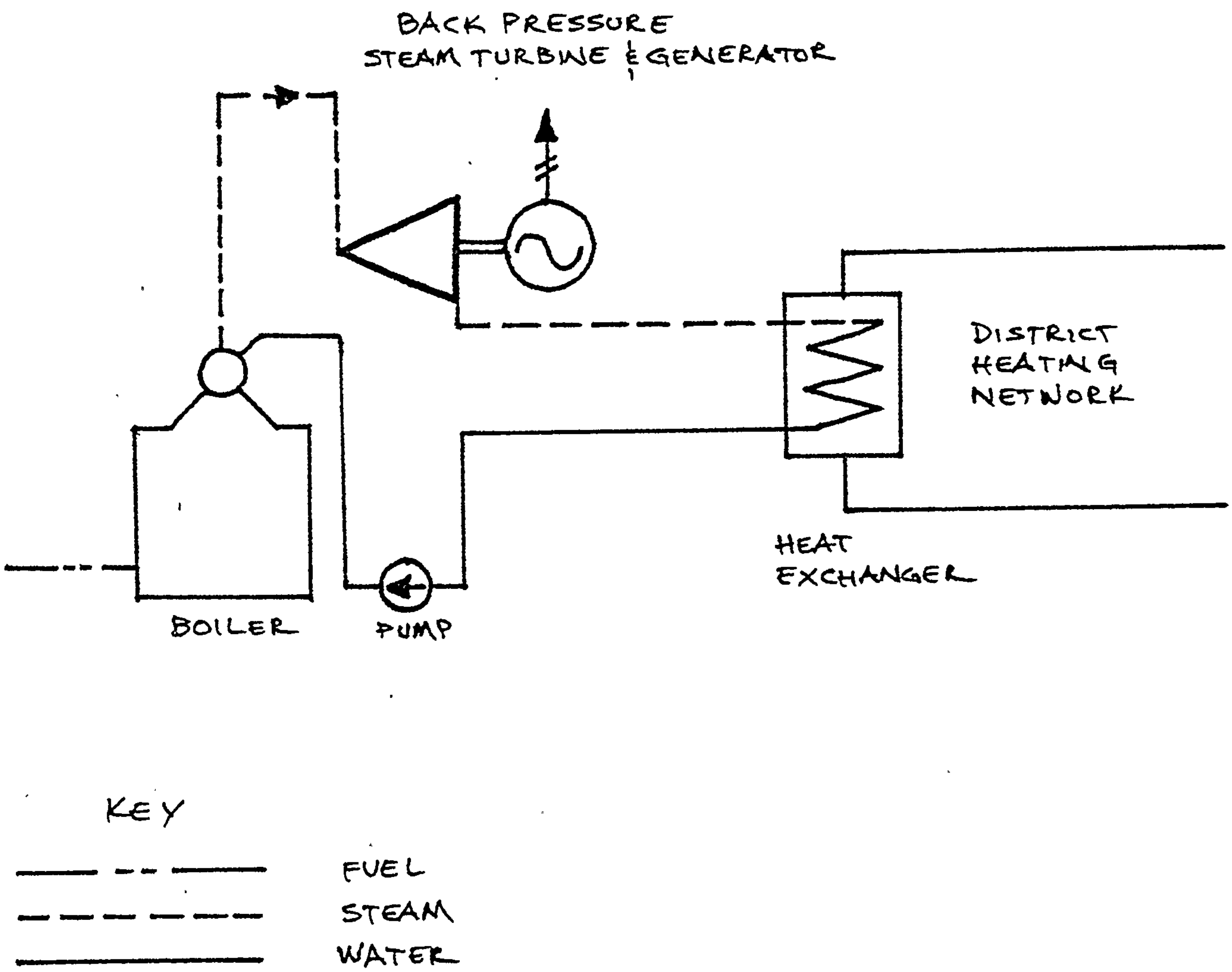

Figure 3.7. Schematic Diagram of a Boiler and Back Pressure Steam Turbine in District Heating Application (Source: ASL, 1977b).

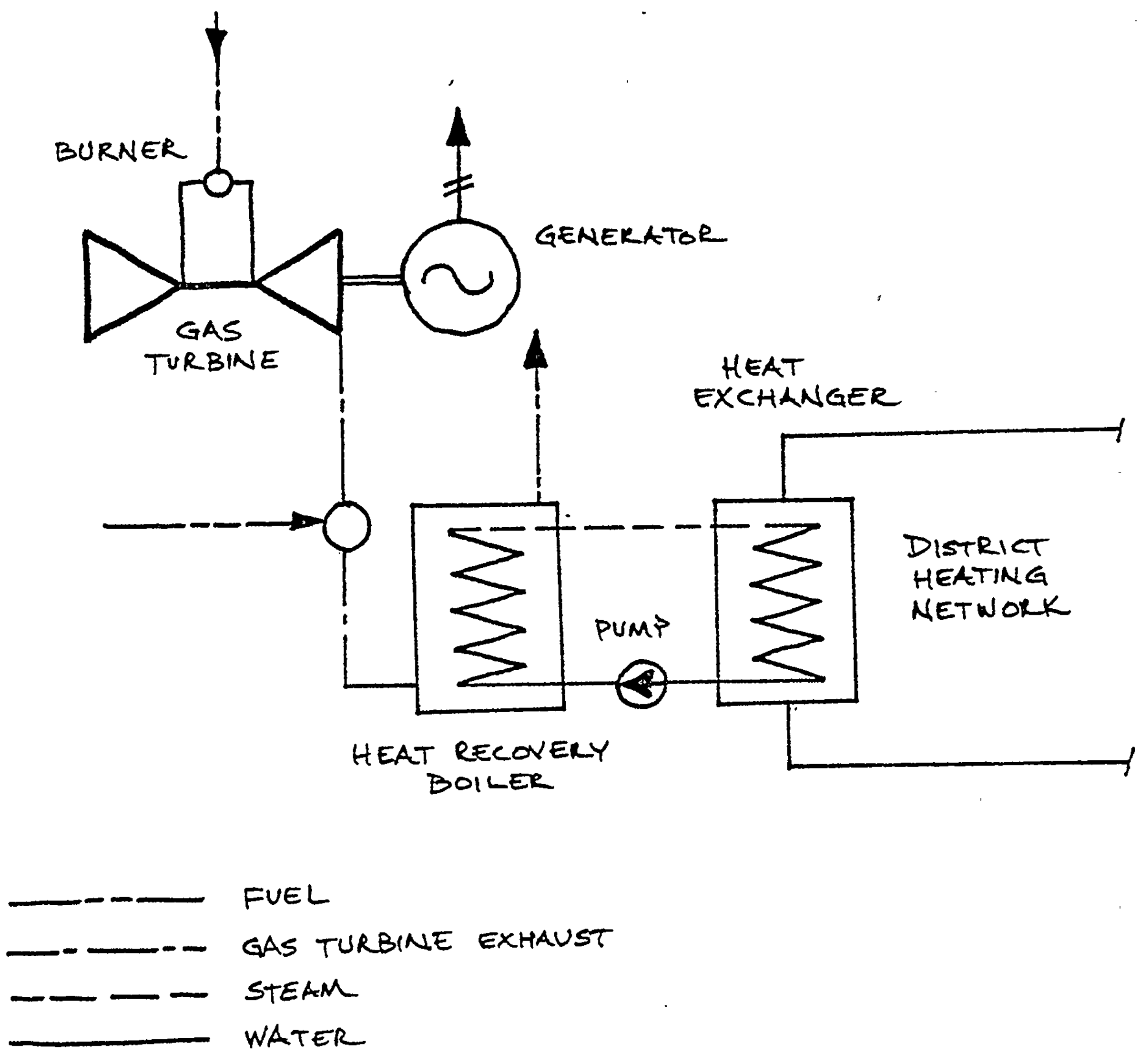

Figure 3.8. Schematic Diagram of a Gas Turbine and Heat Recovery Boiler in District Heating Application (Source: ASL, 1977b).

Combinations of gas and steam turbines, or combined cycles, with heat recovery boilers could provide another surce of heat and power. These schemes are very similar to the gas turbine with a heat recovery boiler scheme, with the exception that a steam turbine is installed between the heat recovery boiler and the heat exchanger. An obvious advantage of this type of system is that the heat to electricity ratio can be manipulated both by supplementary firing and by the extraction of steam from the steam turbine.

Daily fluctuations in heat demand can be met with heat from short-term heat storage facilities. The viability of heat storage facilities is greatest when cogeneration satisfies the base-load heat demand. In such a case, daily heat peaks could be met through stored heat and the peak load boiler capacity requirements would be considerably reduced. If heat-only plants satisfied a large portion of the heat load and could generate heat on an 'as required' basis, then the need for heat storage would be limited (ASL, 1977b). [17]

Standby capacity for central heat sources or combined plants would be in the form of additional boilers and turbines.

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[17] "A detailed analysis of operating conditions and daily/hourly maximum winter, spring, summer and fall heat and electrical power demands would be required to justify the inclusion of a storage scheme with its inherent problems of control, management and operation" (ASL, 1977b: 9.4).

3.4 The Distribution Network

The second component of any district heating system is the distribution network. The distribution system transfers heat from the central source to the consumer. The heat transfer medium may be water or steam, and the network essentially consists of circulating pumps and pipework. A closed-ciruit hot water system is commonplace in Europe (AFC, 1975).

In North America, the choice of heating medium has traditionally been steam (Carpenter, 1952; ASL, 1976; Karkheck et.al., 1977). This may have contributed somewhat to the lack of interest in district heating (Karkheck et.al., 1977; Larsson, 1977). Though steam is well suited for heat transport over short distances and for high density demand, it has numerous problems on larger scales. A steam medium has a limited distribution range; it experiences large heat losses; and it incurs high maintenance costs (Larsson, 1977). Water is predominately used as a heat transfer medium in European district heating systems. The principal advantage of a water medium is that it facilitates efficient operation of the system at much lower temperatures (Anderson, 1977b). Space and hot-water heating requirements can be adequately met with supply temperatures of 100 C and return temperatures of 60 C (Anderson, 1977b). These lower system temperatures yield various benefits. Heat losses will be less than steam for the same heat transmission; and pipe expansion is reduced (Anderson, 1977b). Superheated water of less than 120 C is compatible with combined heat and electricity generation, thermal energy storage, solar heating and heat pump applications (Anderson, 1977; Gahbauer, 1978). Water can also be pumped over any distance and elevation change. Booster pumps can be added as necessary to maintain system pressure. Steam, on the other hand, must have a high enough initial pressure to overcome pressure drops throughout the distribution system (Anderson, 1977a). Thus, for any large-scale district heating network supplying a variety of heat densities, water is a preferred heat transfer medium.

The quantity of heat available to the consumer is a function of the rate of flow of water through the system and the temperature difference between the consumer supply and return flows. Load variations can be met by varying the volumetric flow or by varying the temperature difference. In Sweden and Finland, the temperature of the supply water is usually between 80 C and 120 C depending on the ambient air temperature. Return temperatures generally range from 50 C to 70 C (Larsson, 1977; Smeds, 1977). Figure 3.9 illustrates the relationship between the supply and return temperatures and the ambient temperature. The supply temperature is lowest is the summer, when it is largely determined by the heat required for domestic hot water. To maintain indoor comfort levels with outside temperatures below freezing, the temperature difference between supply and return flows is increased and the rate of flow is held at a constant maximum. Outside temperatures above freezing are handled by varying the volumetric flow while maintaining a constant minimum supply temperature (Wahlman, 1976). Studies of district heating potential in Canada have used constant temperatures of about 95 C supply and 60 C return; load variations are met by varying the volumetric flow (ASL, 1976). [18] The choice between varying the flow and varying the

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[18] These studies are discussed in more detail in Section 4.2.

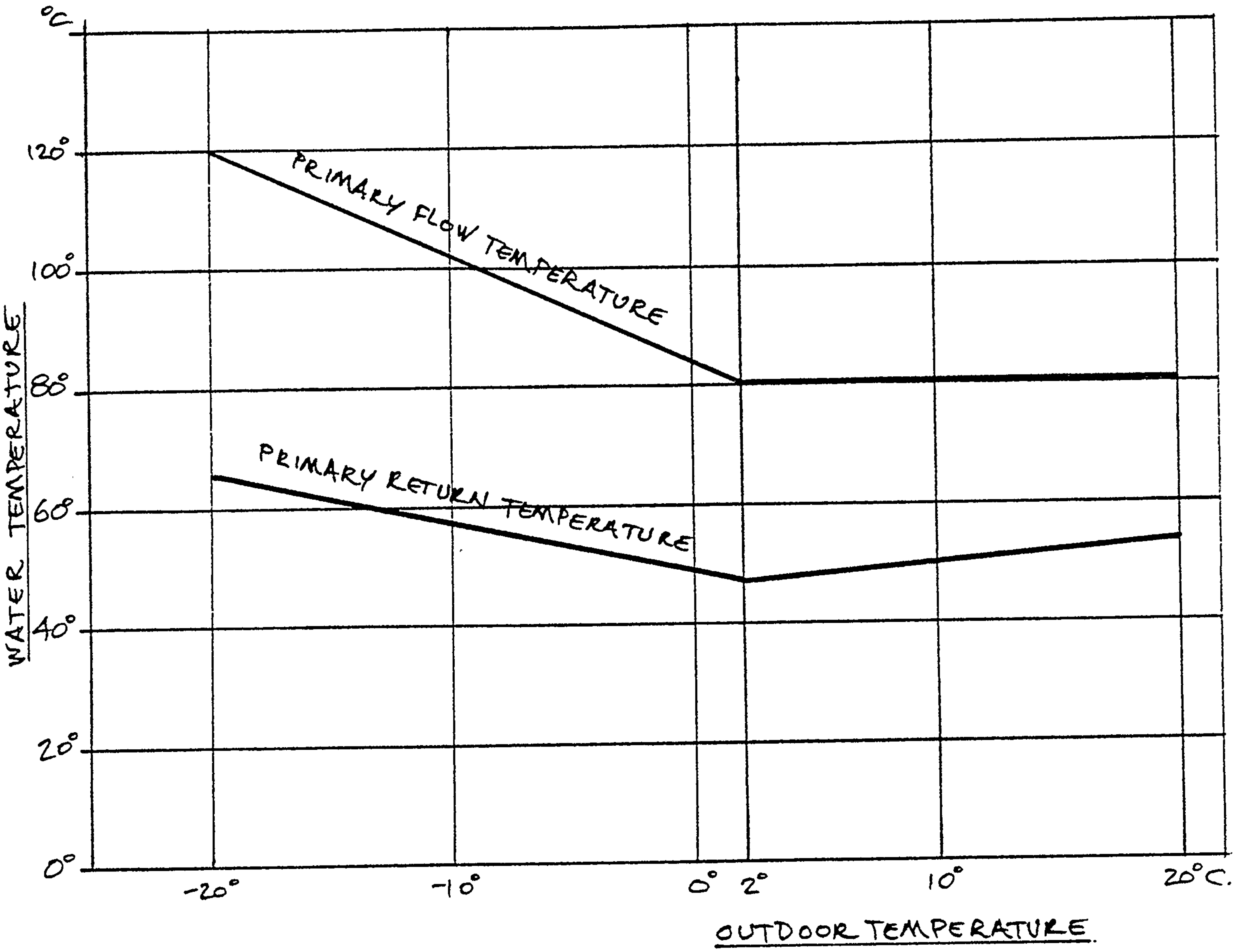

Figure 3.9. District Heating Water Temperature in Relation to Outdoor Temperature (Source: Wahlman, 1976).

temperature difference involves trade-offs between distribution heat losses and pumping costs.

Pipe dimensions are related to the temperature of the heating medium. As the medium's temperature increases, the required dimension of the pipe decreases. The same quantity of heat can be supplied using smaller pipes. Although smaller pipes cost less (and may be attractive for long distance transmission), higher supply temperatures reduce the amount of electricity which may be produced in cogeneration plants. In Sweden, a maximum supply temperature of 120 C has been retained to balance the conflicting incentives to maximize electricity production and minimize distribution costs (Larsson, 1977). Pipe pressure must be great enough to keep the water in liquid state and to overcome pipe friction.

The distribution pipework system is designed with the supply flow and return flow pipes in parallel. The pipe network can be divided into transmission, feed, distribution and service pipework (Wahlman, 1976). Figure 3.10 illustrates the relationship between the types of pipe. In conjunction with the phased development of district heating schemes, distribution and service pipes originally link the consumer to the central heat source. As several schemes become completed and the heat load becomes sufficiently large, transmission and feed pipes connect the schemes to heat-only and combined plants of greater capacity.

In Europe, the larger-diameter (greater than .5 m.) transmission, feed and distribution pipes are generally made of steel. At one time, these pipes were manually insulated with mineral wool and laid in concrete ducts under streets or sidewalks (Larsson, 1977). However, corro-

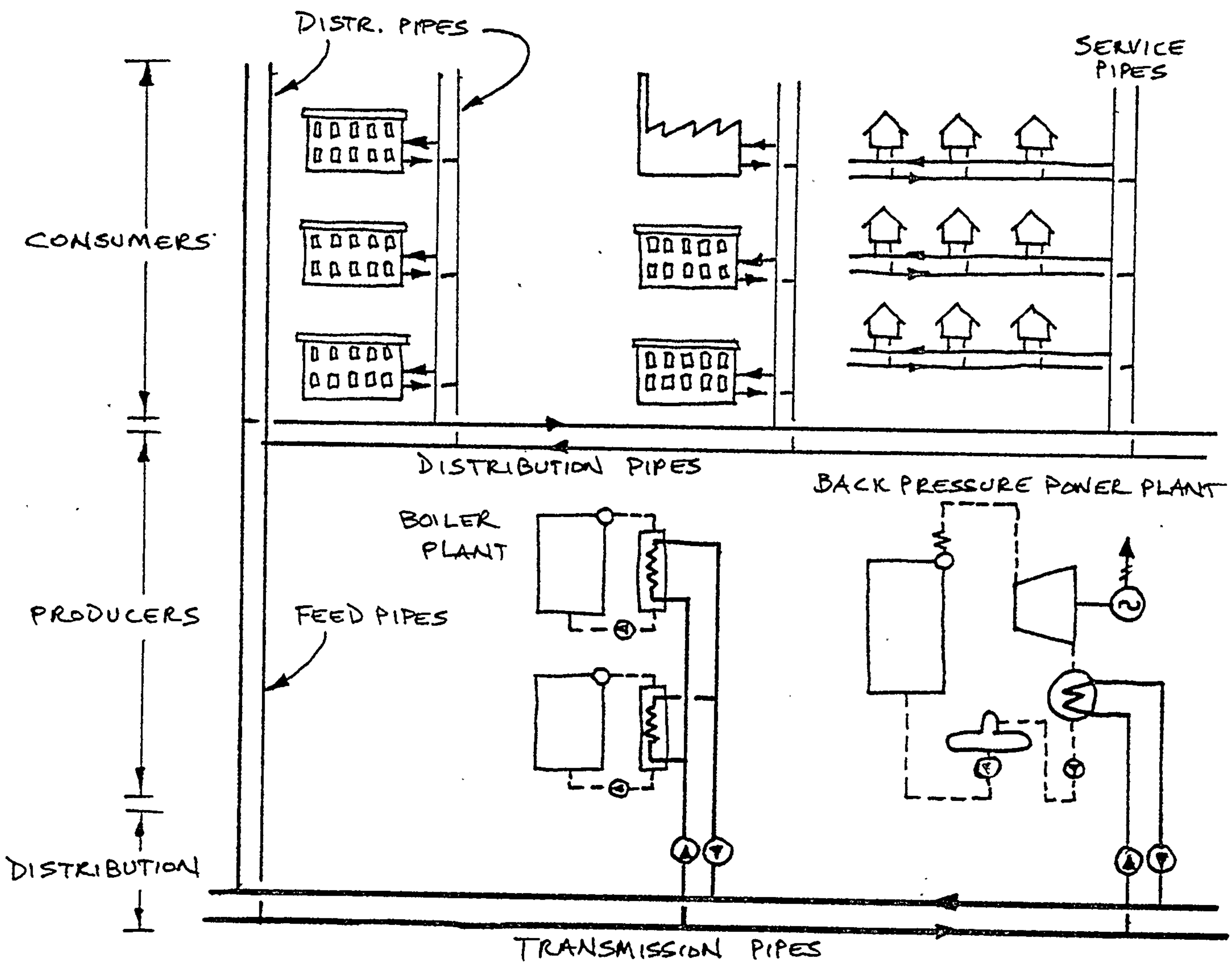

Figure 3.10. Network of Distribution System for District Heating (Source: Wahlman, 1976)

sion and expansion problems associated with these pipes lead to high maintenance costs.

"No district heating system is better than the pipes used to bring hot water from plant to user" (Glassford, 1979a: 9). A reliable system must effectively deal with corrosion and expansion problems. Corrosion often results from poor drainage within the ducts or from high groundwater penetrating the protective pipe covering. Pipe expansion (the lesser problem of the two) is brought about by the temperature difference between the laid pipe and the district heating water. The expense related to these problems has lead to research into new piping techniques (ASL, 1977a).

Today's pipe-in-pipe district heating mains are much less problematical (Haseler, 1976). In Denmark, the most commonly used system consists of polyurethene pre-insulated steel piping with PVC protective covers (Glassford, 1979a). [19] Such pipe has a waterproof exterior, has a low heat loss and is long-lasting (Haseler, 1976; ASL, 1977a; Glassford, 1979a). The waterproof cover virtually eliminates corrosion-related problems. As well, Danish systems are generally equipped with electronic monitoring devices "that instantly sound an alarm when a pipe is damaged, and that pinpoint the exact trouble spot" (Glassford, 1979a: 9). Smaller diameter (.1 m.) distribution and service pipes are laid directly in the ground in asbestos or plastic covered round ducts (Larsson, 1977).

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[19] A similar pipe is manufactured in Edmonton (Winton, pers. comm., 1979)

Corrosion problems may be more significant when pipeline corridors must cross areas with high water table conditions. Corrosion could be reduced in such areas by constructing a concete trench with the piping supported clear of the trench bottom. The trench would be provided with positive drainage and if necessary, pumps could be located in manholes (ASL, 1977a). This would significantly increase the cost of piping, but may be worth the additional cost if it offset maintenance costs.

Thermal expansion and contraction problems can be dealt with by U-bends, loops or bellows expansion joints. Numerous expansion joints are now prefabricated with polyurethene outer casings (Glassford, 1979a). A recently developed expansion-mitigating technique involves preheating the pipe during installation, just before back-filling (ASL, 1977a).

Of course, the type of protection most beneficial for any pipe network will be dependent on the site-specific soil and groundwater conditions. Tests would be required before any firm recommendations regarding pipe protection could be given.

3.5 The Consumer's Equipment

The third major component of a district heating system is the subscriber's equipment. This usually consists of in-coming and outgoing service lines, heat exchangers, pumps, control equipment and radiators or ductwork. The district heating water would satisfy both space heating and domestic hot-water heating requirements.

In residential areas, the hot-water heating requirements are fairly constant throughout the year. The temperature desired for domestic hot water (60 C) dictates the minimum primary flow temperature of 80 C during summer operation. For obvious sanitary reasons, a secondary heat exchanger would be required to isolate the district heating water from the domestically used water.

The demand for space heating varies with the outside temperature (given the building design and use). The winter heat demand can be met either by increasing the water supply temperature or by increasing the rate of water flow. All of the home heating systems must be compatible with the primary supply and return temperatures. Forced-hot-air systems (most common in Canadian single family dwellings) are easily matched with district heating temperature conditions. Figure 3.11 illustrates an example of the consumer's equipment with a forced air system. Water is taken from the primary network at about 100 C (in this case) and is pumped to both the domestic hot-water heat exchanger and the serpentine heating coil. Control valves and monitors ensure that the water from the primary is continually recirculated until its temperature drops to about 55 C. More primary water is added as required, and recorded by the flow meter. When room temperature is below the thermostat setting, the fan is activated and hot air is distributed through ductwork to the various rooms. In this system, no secondary heat exchanger is used in conjunction with space heating. If higher pressures were needed to overcome hilly terrain or long distance distribution, secondary heat exchangers may be desirable for safety reasons (ASL, 1977a).

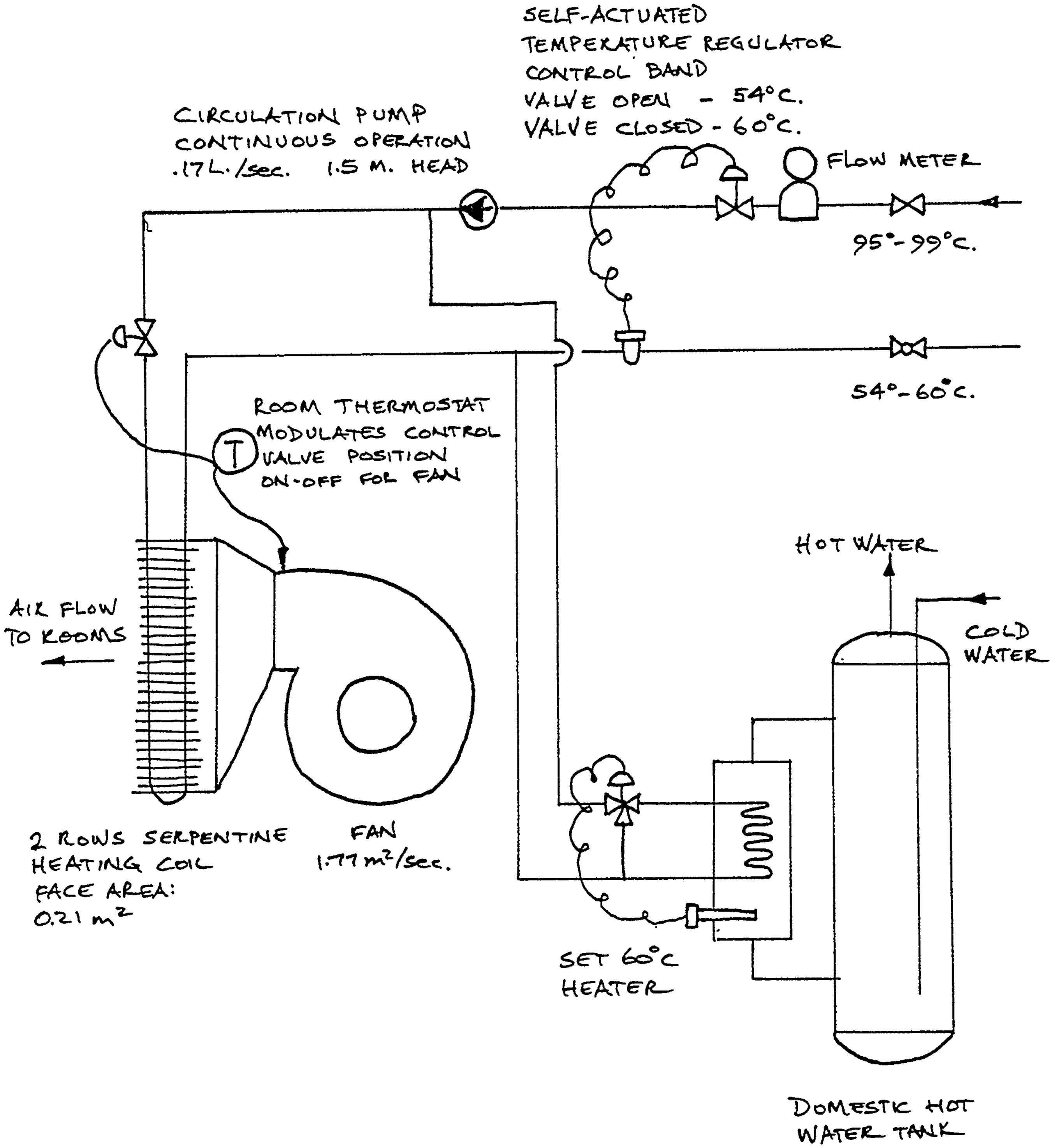

Figure 3.11. Schematic Diagram of a typical Heating system for a Single Family Dwelling (Source: ASL, 1976).

Multiple-unit residential complexes (townhouses, apartments) may use hot water heating systems rather than forced air. In such buildings, secondary heat exchangers would likely be used for both hot-water and space heating needs. This is typical practice in Europe (AFC, 1975; Wahlman, 1976). In some European examples, single family dwellings (all hot water heated) have been connected in groups of eight or ten to a single sub-station (secondary heat exchanger). Pipes from the sub-station distribute heating water and domestic water (Wahlman, 1976; Kilpinen, 1977).

In Europe, measuring of the heat used is done in various ways. In some places, each consumer's heat use is metered. The meter measures units of heat by gauging water flow and temperature difference (Anderson, 1977a). In other places, only the larger consumers are metered in this way. The heat consumption of smaller consumers (house and apartment dwellers) may be estimated on the basis of water flow and the area of space to be heated. Clearly, charges for actual heat consumed would give a greater incentive to conserve energy.

When consideration is given to retrofitting existing residential areas with district heating, a survey must be made of the present heating systems to determine their compatibility with district heating water temperatures. Forced hot air systems are readily convertible to these temperatures (Anderson, 1977a). Electrical resistance and direct fired heating systems would have to be replaced completely if their buildings were to be connected with district heating (Anderson, 1977a). All hot water systems and some steam systems can be satisfied by 120 C supply water, but only at the expense of a higher return temperature of 90 C

(Anderson, 1977a). If a substantial portion of the heat load presently has steam or hot water systems, then it may be more economical to operate at higher temperatures than to convert the existing systems. If such systems represent only a small fraction of the load, conversion may be more economical (Anderson, 1977a). In Alberta, concerns over the compatibility of district heating water temperatures and building heatings systems will be limited. Forced hot air systems are dominant in the province.

3.6 Summary

District heating/cogeneration technology has been proven by decades of experience in northern Europe. District heating systems offer considerable flexibility over the types of equipment required and over the selection of energy resources used to generate heat. They are "compatible with all of the known emerging technologies likely to supply our future energy requirements" (Anderson, 1977a: 6), including solar energy systems. As such, the encouragement of district heating/cogeneration systems should be considered in energy conservation policy decisions.

But while European experience demonstrates that district heating technology is available to be applied to the Alberta example, other European conditions which influence district heating decisions are not as directly applicable. Clearly, the costs and benefits of district heating for Alberta residential communities must be examined within the Alberta context. Some of these costs and benefits are addressed in the following chapter.

4.0 THE COSTS AND BENEFITS

A leading concern of policy-makers regarding the viability of any suggested policy measure is whether or not such a measure is economically justifiable. Before measures are designed to encourage district heating, the economic status of district heating must be understood. Determining the economic viability of a project involves weighing its associated costs and benefits. Indeed, "cost-benefit analysis, or some variant of it, has come to play a major role in decisions respecting the expenditure of public funds" (Detomasi, 1974: 1). While the intent of this chapter is not to perform a cost-benefit analysis of district heating, the more significant costs and benefits are identified. Prior to such identification, though, the notions of 'cost' and 'benefit' should be more clearly defined.

Benefits refer to advantageous or positive effects; costs imply negative effects. For simplicity in evaluation, these can be separated into direct costs and benefits and external costs and benefits. Direct benefits consist of "the gains which accrue to those who make use of the goods and services which can be provided by a given project" (Sewell et. al., 1965: 5). For example, the direct benefits of a power project are given by the market value of the electricity produced by the project.

External benefits include all advantageous effects which are not covered by the direct benefits. Thus, it would include all monetary and non-monetary benefits stemming indirectly from, or induced by the project. For example, if the power plant provided comparatively inexpensive electricity, industries may be induced to locate where such power is available. (This would be a monetary benefit as its dollar value could be measured.) [20]

Direct costs represent the goods and services which must be surrendered in order that the direct benefits of a project can be realized. This includes expenses for design, construction, operation, engineering and supervision, land acquisition, the cost of financing and the opportunity cost of foregoing alternative investments.

External costs comprise all negative effects incurred by society beyond those included as direct costs. External costs can be monetary or non-monetary. Examples would include the effects of pollution, the costs involved in the production of external benefits, and the loss of scenic or aesthetic values. [21]

The viewpoint from which the effects of a project are considered is of importance to the analysis. If the analysis is conducted by an individual profit-maximizing firm, only the direct costs and benefits are likely to be included. And while a public organization is more likely to account for the externalities (external costs and benefits), these will differ with the scope of the organization. At the municipal level, increased commercial activity induced by some public expenditure may be viewed as an external benefit. However, if the increased activity represented no net gain to the province (nation), then it could not be viewed as an external benefit to the province (nation):

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[20] Of course, the scope or viewpoint of the analysis influences the counting of some external benefits. This will be addressed in more detail below.

[21] Payments made on the project, say, to mitigate against the effects of pollution would be included in the direct costs of the project. In effect, this external cost has been internalized.

> "Appropriate allowances must ... be made for all transfers, cancellations and offsetting influences. This warning becomes progressively more important as the viewpoint ... is expanded to cover neighbouring areas and related sectors of the economy" (Sewell et. al., 1965: 10).

Accordingly, some external benefits or costs from a provincial point of view may not be relevant in a national study.

In the final analysis, public policy decisions involve "a complicated set of trade-offs between the positive and negative effects of a series of possible courses of action" (Detomasi, 1974: 8). In order to compare alternatives, the costs and benefits of each must be reduced to a common denominator. The most convenient denominator is of course 'the measuring rod of money'. All direct costs and benefits are expressed in dollar terms. Many externalities may be given a monetary value; yet this value can only be obtained indirectly and is thus less accurate than direct terms. Still other externalities are not capable of quantification in monetary terms. But rather than monetizing or ignoring such elements, they should be considered as preponderantly positive or negative factors and "should be expressed in terms of their simplest units of measurement" (Detomasi, 1974: 11). Obviously, the monetization and quantification of externalities requires the making of value judgements. Thus, when policy-makers are responsible for resolving complex value trade-offs between the positive and negative effects of numerous alternatives, the goals of the particular public entity — whether municipal, provincial or federal -- come into play. [22]

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[22] It is beyond the scope here as to whether or not the parties affected by particular projects should be involved in the quantification and monetization process.

As a result of the inherited societal bias (see Section 2.2), the government often attaches significant emphasis to the monetary costs and benefits. Unless projects are deemed to be clearly in the public interest, there tends to be desire for projects to demonstrate the profitability in the marketplace. The criterion of profitability has been particularily important in the regulated private utility sector. In Alberta, the government attempts to ensure that the provision of gas and electric services by utilities is done in a least-cost manner. Thus, if district heating/cogeneration systems are to make any breakthrough into the existing system of heat and electricity provision, they will have to demonstrate either direct cost competitiveness, or substantial positive externalities, or both.

The most substantial external benefits offered by district heating/cogeneration schemes are associated with reduced fossil fuel consumption and reduced environmental pollution. Considering the direct costs as well as these external benefits, a basis of comparison between district heating/cogeneration systems and conventional systems is suggested below.

4.1 Basis of Comparison

Ideally, district heating/cogeneration schemes would be compared to all alternative systems of heat and electricity provision. Space and hot water heating requirements could conceivably be met through fuel combustion, electrical resistance heating, solar heat collection or waste heat utilization. Typical methods of electrical energy generation include the transformation of the energy of falling water and the conversion of the heat energy from nuclear reactions or from fuel combustion. Unfortunately, the writer's limited resources foreclose the opportunity to examine all of these alternatives.

In Alberta, about 80 per cent of the annual electrical energy consumed is generated through the combustion of fossil fuels. In most cases, this electrical generation takes place in locations remote from the urban load. In 1977, coal fuelled over two-thirds of the electric energy generated in the province (ERCB, 1978). Indeed, coal is viewed as the fuel which will provide the least-cost provision of electricity for the forseeable future (ERCB, 1978). This method of electrical generation will be referred to as the conventional system of generation.

Virtually all of the province's demand for space and hot water heating is satisfied through the burning of natural gas (ERCB, 1978). Detached and semi-detached dwellings have individual furnaces for gas combustion. Row houses often have separate furnaces for each dwelling, though sometimes a central furnace heats more than one dwelling. Heat for apartment dwellings is generally produced in a furnace within the apartment building. Again, this method of heat provision is viewed as least-cost (ERCB, 1978). It will be referred to as individual building heating systems or the conventional heating system.

District heating combined with cogeneration can offer identical end uses of heat and electricity without inconvenience to the consumer. Thus, if cogeneration schemes are cost competitive with the conventional system of heat and electricity provision, the direct benefits of both systems would be equal. The competitiveness of cogeneration schemes from a direct cost standpoint requires examination. The comparison then will be between district heating/cogeneration schemes and individual heating/remote thermal generation schemes which provide equivalent end-use energy.

Within the framework of public policy, it would seem most appropriate to consider the direct costs and externalities over the lifetime of the two alternative systems. An approach which is sometimes used to compare alternative expenditures is the "life cycle costing" methodology. The calculation of the life cycle costs of alternative projects amounts to an application of the usual discounted cash flow or net present value investment criteria.

Typically, investment projects have a distinct profile of benefits and costs. In general, an initial capital outlay is required and the benefits derived from the initial outlays come to fruitation over the future. The discounted cash flow methodology accounts for the value of investments over time. The value of a dollar in the future is less than the value of a dollar today because a dollar today could be invested to yield an additional annual revenue. By discounting the value of the future benefits and costs, a stream of net benefits can be reduced to a single value at a point in time. [23] In this way, the value of alternative investments can be compared.

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[23] Discounting and the selection of an appropriate discount rate are complicated issues which often receive attention in economic literature. The advantages and disadvantages of discounting are beyond the scope of the present discussion.

From an economic standpoint, the case for district heating hinges on its energy-conserving feature (see Section 4.2). Clearly, as energy becomes increasingly expensive, it becomes more and more economically advantageous to use energy efficiently. As district heating/cogeneration systems are more energy efficient than the conventional system, higher initial investment costs may be justified by significantly reduced lifetime operating costs.

In terms of evaluating the attractiveness of alternative investments over time, the discounted cash flow criteria is dependent upon the selected discount rate and project lifetime. The choice of the discount rate influences not only the absolute value of any project, but also can change the relative desirability of alternative projects. In particular, the use of low discount rates may favor projects with large initial investments and large, but delayed benefits. The relative attractiveness of investments can also be influenced by the selected project life (though this tends to be less critical than the selected discount rate). Longer project lives favor investments with delayed benefits.

Cost and price assumptions and projections over the project life can further affect project desirability. In the case of district heating ventures, forecasts of input costs and energy prices may be critical to the comparitive analysis. [24] These limitations must be kept in mind when evaluating the comparative costs of district

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[24] In Alberta, energy prices are established within the arena of government policy and regulation. The Alberta government's energy pricing policy and the present price - replacement price dichotomy is addressed in more detail in Section 5.2.

heating/cogeneration systems versus conventional systems.

4.2 Comparison of Direct Costs

Broad economic feasibility studies of district heating and cogeneration have been performed by the federal government's Office of Energy Conservation. These studies, Gas Turbines and District Heating (1977) and District Heating For Small Communities (1977) claim to be non site-specific in nature and can therefore be used for a preliminary cost comparison with conventional systems of heat and electricity provision. However,

> "it must be appreciated that the availability of heating plant sites, the size and number of buildings to be served, future changes in load on the system, construction, labor and fuel prices and the availability of capital all act in such a way that every proposal for district heating is unique in itself and requires an individual feasibility study" (Brown, 1972: 12, his emphasis).

As a result, in applying a non site-specific study to specific regions, it is important to acknowledge and assess the validity of the assumptions underlying the broad study before any conclusions are reached. A non-specific investigation, however, does serve to identify both the cost components of district heating/cogeneration systems and the factors which influence their economic viability.

Cost Components

Direct costs are typically divided into capital and operating components. Capital costs for district heating/cogeneration systems would be comprised of the installation costs of all:

(i) turbines, boilers and their auxiliary systems;

(ii) transmission, distribution and service piping;

(iii) pumping stations, buildings and land;

(iv) electrical distribution facilities;

(v) subscribers' heat exchangers; and

(vi) fuel storage and handling facilities (if required).

The comparative capital costs for the conventional system of thermal electricity generation and individual building heating systems would incorporate the installation costs of all:

(i) additional generation capacity equivalent to that supplied by cogeneration;

(ii) additional transmission capacity to transport this electricity;

(iii) additional electrical distribution facilities, buildings and land;

(iv) additional fuel transportation or distribution facilities required to satisfy the heat demand; and

(v) individual furnaces, hot water boilers, fuel burners, and fuel storage tanks (if needed).

Other consumer's equipment which is common to both the individual and the district heating schemes can be omitted from the capital costs of both. This would include, for example, the circulation fan and ductwork.

These installation costs include the cost of materials, labor, contractor's overhead and profit, engineering, administration and interest during construction for all equipment. The comparative capital costs as described here are applicable to schemes for new communities. If communities were to be retrofitted with a district heating/cogeneration system, the sunk or historical costs of the existing system would not be included in the analysis. This is one reason why retrofitting ventures tend to be less economic than schemes in new subdivisions (greenfield conditions). [25]

Operating costs for both systems can be grouped into two categories:

(i) fuel costs and

(ii) all other operating and maintenance expenditures.

Fuel costs represent the largest component of operating costs (ASL, 1977b). The other operating and maintenance expenditures are a function of the type of equipment used.

Once the installation schedule for the capital costs is established, the life cycle costs of the alternative systems can be evaluated using the discounted cash flow methodology.

Factors Influencing Economic Attractiveness

The evaluation of the economic attractiveness of a project incorporates the usual notion of opportunity cost. [26] As a result, the economic desirability of district heating/cogeneration systems is influenced by two types of factors:

(i) factors which increase the profitability of district

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[25] If, however, the existing equipment needed replacement, this replacement cost would enter into the analysis.

[26] The opportunity cost is equal to the value of the benefits associated with alternative projects which are foregone as a result of investing in the selected project.

heating on its own, and

(ii) factors which decrease the profitability of other alternatives relative to district heating.

The most significant investments in district heating are first, for the distribution network, and second, for the heat source stations. Minimizing the extent of these investments (while retaining the desired level of reliability) would enhance the profitability of district heating. The total layout for the distribution network and the heat sources is influenced by the characteristics of the heat load, the planning and phasing of the development, and site-specific terrain conditions.

The density, total size and growth of the connected heat load are critical factors in determining the economics of district heating. The heat load density is given by "the maximum amount of heat energy needed to supply a specific region, divided by the surface area of that region", for example, 40 MW per square kilometre (AFC, 1975: 8). For a given residential population, the heat load density influences the cost of the distribution network more than the cost of the heat plants (ASL, 1977a). [27] Generally speaking, as the heat load density increases, the cost of distribution piping decreases. Quite simply, the length of distribution piping necessary to service a given heat load is normally less for higher density areas. An area of multi-storied buildings tends

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[27] Higher net density residential structures (with, say, 40 dwelling units per acre) generally accomodate fewer people per unit than lower net density housing (8 dwelling units per acre). For a given residential population, more dwelling units are required in the case of high density housing. As a result, the design heat load changes little with density changes. Thus, the capacity of the heat source and its associated cost are virtually the same (ASL, 1977a).

to be more economically attractive than an area of single family dwellings. However, if high density housing increases the need for neighbourhood green space, there may be no decrease in the length of distribution piping. This would offset somewhat the savings associated with higher density housing. [28] Under European conditions, the minimum load density considered economic is commonly estimated to be about 35 MW per square kilometre (ASL, 1976). While this figure is determined by higher-cost European alternatives, it is based upon costs for retrofitting a district heating system (ASL, 1976) -- costs which are significantly higher than for the greenfield case. Further, not all customers within areas to be retrofitted with district heating will connect, yet full capacity pipe networks must be installed.

The total size of the connected load also influences the economic viability of district heating. The connected load must be large enough to justify the additional capital expenditure associated with district heating. Oil-fired district heat-only systems appear to require two to three times the capital investment of oil-fired individual heating systems (ASL, 1977a). [29] As the thermal energy transmitted increases,

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[28] This amounts to a discussion of gross versus net densities. Gross densities refer to the number of dwelling units in a total land area including public roadways, parks, etc.; net densities refer to the number of dwellings in a land area which doesn't include public roadways, parks, etc. Two communities could have the same gross density, but different net densities. A district heating system serving areas of the same gross density would not necessarily cost less in the community of highest net density.

[29] Individual systems fired by natural gas are also less capital-intensive. Natural gas pipelines "are very cheap compared to district heating distribution systems" (Gahbauer, 1978: 47).

the investment for heat transmission per unit of thermal energy rapidly decreases. For example, "if the diameter of the district heating pipe is doubled, the thermal energy transmission capacity will increase six times, but the investment per running length of system will increase only about one and a half times" (AFC, 1975: 30). The economic justification of a cogeneration facility requires an even larger connected load. Its capital costs appear to be at least twice that of a heat-only facility (ASL, 1977b). For a heat-only system, the minimum economic load size for a new community under southern Ontario conditions has been estimated to be about 60 MW (ASL, 1977a). This corresponds to a non-industrial community population of about 11,000. [30]

The load growth further affects the economics of district heating. A fast build-up to the capacity of the distribution mains and the heat plants will improve the system profitability. A system operating at capacity has a lower cost per unit of energy generated and delivered. As well, the faster the connected load grows, the faster revenues from heat and electricity sales grow. From an economic standpoint then, fast-growing communities (not uncommon in Alberta) increase the attractiveness of district heating schemes.

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[30] The connected load is a peak design load. The associated estimates represent the point at which the life cycle cost per Joule of connected load for district heating equals that for individual heating. The estimates are very dependent upon energy price assumptions, discount rates and assumed load characteristics. The model community is discussed in more detail in the Cost Comparison that follows.

The planning and phasing of a district heating development would involve matching the system growth with the anticipated growth in heat demand. Information regarding the proposed building types, volumes, quantities and locations would be required. Central sites for heat sources would tend to minimize the length of distribution piping required. Route selection for the distribution network would be planned such that the combined capital and maintenance expenditures would be minimized. A phased development of the district heating system could originally utilize temporary heating plants and eventually use permanent heat-only or combined plants, depending upon the size and extent of the heat load. The possibility of utilizing industrial waste heat or heat form refuse incineration could also be examined. Sources of heat and the size of the heat load will be a function of local circumstances and development plans. Of course, the initial planning and phasing of the development would be included within the preliminary calculation of economic feasibility. On-going plans would ensure that the phasing of the system growth met the actual growth in the heat load.

Another local or site-specific condition which influences the profitability of district heating is the quality of the terrain in the development area. Capital costs will be lowest in a greenfield situation with well-drained soils and flat terrain. Greenfield conditions enable distribution piping to be installed in conjunction with the provision of all other municipal services, before the roads are paved. Capital costs increase if flat, well-drained greenfield conditions are not met. Poorly-drained soils necessitate the provision of concrete-lined trenches. Cutting through rock significantly increases construction costs. [31] Retrofitting a development area with district heating involves breaking up and replacing pavement, and this may add 50 per cent to piping costs (Anderson, 1977a).

The profitability of district heating may also be enhanced by factors which decrease the profitability of alternative methods of heat and electricity provision. Certainly, the most significant of these factors is the cost of fuel. As fuel prices rise, systems which use energy efficiently become increasingly economic. District heating/cogeneration systems can be 30 to 70 per cent more fuel efficient than conventional systems (see Section 4.3). How district heating/cogeneration schemes will compare to alternatives will be dependent upon the types and prices of fuels used by both. In the Alberta example, most future electrical generation will likely utilize coal as a fuel. Residential space and hot water heating will likely be provided through the combustion of natural gas. District heating/cogeneration schemes within residential settings would most likely be fuelled by natural gas. If both natural gas and coal were priced on a competitive basis with oil, then cogeneration systems would become more attractive as oil prices rose. While present policy ties the natural gas price to that of oil, it remains to be seen whether coal prices will be similarily fabricated (with a discount, of course, to reflect the additional capital, operating and environmental costs associated with coal use). However, even if coal prices are decided within the market for coal and are less than an oil

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[31] Of course, these conditions are also dificult for natural gas pipeliness!

equivalent price, district heating/cogeneration schemes utilizing natural gas may still represent an economic venture. One would have to examine the total costs of the cogeneration of heat and electricity using natural gas versus thermal electricity generation using coal and heat provision using natural gas.

Three district heating studies undertaken by Acres Shawinigan Limited -- District Heating Study (1976), District Heating For Small Communities (1977) and Gas Turbines and District Heating (1977) -- have attempted to compare the total direct costs of district heating/cogeneration with conventional systems of heat and electricity provision.

A Cost Comparison

All three studies use the proposed town of North Pickering in Ontario as a model community:

> "The model was specified to contain a typical mixture of residences ranging through single detached dwellings [8 dwellings/acre], medium density housing such as townhouses [15 dwellings/acre], and apartment units up to seven stories high [40 dwellings/acre]. The model contains a town centre, with shopping and office areas, four secondary shopping centres, schools and other facilities and 1000 acres of light to medium industries" (ASL, 1976: 29).

The town of North Pickering was assumed to grow in population from zero to 70 000 over a 14 year period and remain relatively constant thereafter. The growth of the electrical and heating loads was fashioned after the population growth in that both loads reach maturity after 14 years. The design heating load was calculated for each building type using CSA insulation and infiltration values [32] and weather data for the locality. The design electrical load was calculated from information on proposed activity in the area. It was assumed that the proportions of residential, commercial, and industrial facilities would remain constant throughout the load growth.

The first study, the District Heating Study (ASL, 1976), was commissioned by the Ontario Ministry of Energy. It examines the technical and economic feasibility of providing heat from a nuclear generating station. In particular, the study considers the technical feasibility of extracting and storing thermal energy during hours of off-peak electrical generation, thereby not reducing the generating capacity at the electrical system peak. This option is compared to:

(i) conventional, individual building heating systems with 50% using natural gas and 50% using light fuel oil;

(ii) a district heat-only system using fuel oil; and

(iii) a combined district heating and power generating system using fuel oil.

Of course, an Alberta study would use natural gas rather than fuel oil in all three of these options. The study assumes that the district heating authority is a non-taxpaying public utility with its associated objectives and ability to borrow capital. It assumes that the capital funds required can be made available. All potential customers of the district heating system are connected. The electricity from combined generation can be sold to Ontario Hydro for a price not exceeding

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[32] These standards are recommended in CSA C273.1-71. The 1976 standards, CSA C273.1-76, are more appropriate for 1976 energy prices and reduce the overall demand for heat by 40 per cent. It is claimed that this improves the economics of district heating over conventional individual heating systems (Hedlin, Menzies and Assoc., 1976).

Hydro's internal incremental costs. Forecasts are made on fossil fuel and nuclear energy costs.

The District Heating Study concludes that although the capital costs of district heating are higher in the early years, any form of district heating appears less costly in the long run than individual building heating systems. Depending upon the discount rate used, individual heating systems become more expensive than fossil fuelled district heating in 8 to 13 years and more expensive than nuclear based district heating in 14 to 18 years. [33] Another interesting conclusion is that the electricity from oil-fired cogeneration could not compete on a marginal cost basis with forecasts of Ontario Hydro nuclear-based electricity. The same result might occur in Alberta when electricity from gas-fired cogeneration is compared to coal-based electricity. Clearly, this would be very dependent on price forecasts for natural gas and coal, as is the District Heating Study dependent on forecasts of nuclear and oil prices.

The second study, District Heating For Small Communities (ASL, 1977a), was commissioned by the federal Department of Energy, Mines and Resources. It uses the same basic parameters and assumptions as the first Pickering study. However, instead of looking at a community of 70 000 people, the study compares the life cycle costs of district heat-only systems with conventional individual building systems for communi-

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[33] Remember, projects with high capital costs but lower operating costs become less favorable as the discount rate increases. Thus, at higher discount rates, district heating becomes a less attractive alternative. The District Heating Study and District Heating For Small Communties use escalated costs and discount rates of 9%, 15% and 20%.

ties of 2500, 10 000 and 20 000. As well, the costs associated with retrofitting problems -- burying piping systems under existing roads, having less than 100 per cent connection -- are estimated.

District Heating For Small Communities concludes that for new towns with 20 000 people and some industrial component, district heating becomes less expensive than individual heating after 10 to 12 years (depending on the discount rate used). Similar results were found for new towns (or communities) with 10 000 people and some industrial component. New towns of only 2500 people, however, appear to be more economically heated by individual heating systems. For heating loads so small, it appears to take over 30 years for the accumulated costs of individual heating to exceed those of district heating. In fact, the minimum economic connected load is estimated to be between 25 MW and 60 MW, again depending on the discount rate used. These figures would roughly correspond to non-industrial communities of 4500 to 11 700 people.

Retrofitting existing towns or communities of similar populations is not as economically attractive as installing district heating in the greenfield situation. For a town with 20 000 people and an industrial component, the study estimates that 13 to 20 years (depending on the discount rate used) would pass before district heating would become the more economically attractive alternative, even with 100 per cent customer participation. With 70 per cent participation, it would likely be more than 30 years. For communities retrofitted with 100 per cent connection to the district heating system, the minimum economic load is estimated to be between 32 MW (at a 9% discount rate) and 174 MW (at a 20%

discount rate). Such loads could represent non-industrial populations of 5700 and 31 000 respectively. Slightly reduced participation can significantly increase the minimum economic load required. For example, 90 per cent connection would require minimum loads of between 43 MW and 295 MW, or non-industrial populations of 7700 and 53 000 (using 9% and 20% discount rates respectively). This effectively shows the need for 100 per cent connection to the district heating system. [34]

The third study, Gas Turbines and District Heating (ASL, 1977b), was commissioned by the federal Department of Energy, Mines and Resources. It again uses similar basic parameters and assumptions as the District Heating Study. [35] It considers the application of various combinations of turbine generators and boilers to provide the heat and electrical energy requirements of the North Pickering model community. This option is compared to district heat-only systems and to individual heating systems, both purchasing electricity from the regional electric utility. The study further performs an analysis to test the sensitivity of the results to rising capital costs and to rising fuel prices.

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[34] This need for a high connection rate is very similar to problems encountered by the gas and electric utilities during their early expansion. The utilities had to secure franchise agreements from municipalities in order to guarantee markets from which the utilities could recover their large initial investments (see Section 5.1).

[35] Gas Turbines and District Heating, however, uses real, as opposed to escalated capital and operating costs and a cost of capital of 10%.

The study concludes that both pure district heating schemes and gas turbine district heating/electrical generation schemes have lower life cycle costs than systems of individually heated buildings and purchased electricity. Figure 4.1 illustrates the effects of capital and energy cost increases on the different heating schemes. Capital cost increases of 20 per cent augment the cost of heat energy by about 10 per cent for the gas turbine cogeneration schemes, 6 per cent for the district heat-only schemes and less than one per cent for the individual heating scheme. On the other hand, energy price increases result in heat cost increases of about 109 per cent for individually heated units, 40 per cent for pure district heating schemes and 25 per cent for gas turbine cogeneration schemes. [36] Clearly, there is a trade-off between the cost of energy and the cost of capital (see Appendix I -- The Energy-Capital Tradeoff).

The results of the three studies are contingent upon the assumptions made, particularily with respect to the anticipated load characteristics and the projected factor costs. Before applying the studies' results to specific regions, the validity of these assumptions within the specific localities must be assessed. Assumptions respecting the heat load characteristics must be compared to local projections of residential, commercial and industrial facilities, anticipated population growth and local climatic conditions. Broad assumptions respecting

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[36] Energy prices are tied to the price of crude oil. Crude oil prices, in this high price scenario, are assumed to rise at 4.4% per annum in real terms over the life of the project (45 years). This may be a little unrealistic.

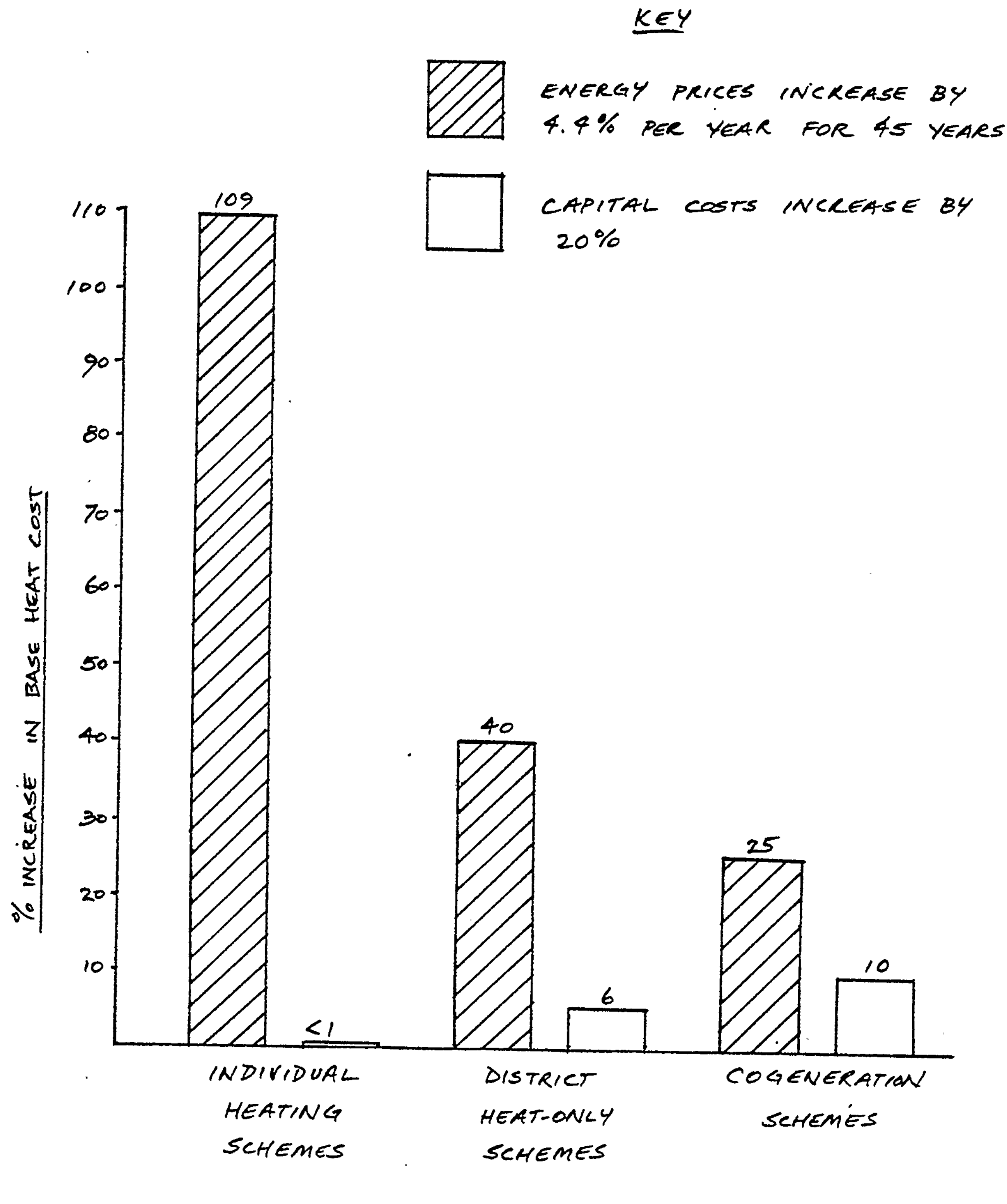

Figure 4.1. The Effects of Capital and Energy Cost Increases on the Three Heating Schemes (Source: ASL, 1977b).

labour, materials and fuel costs are not likely to be consistant for all regions of the country. Fuel costs are well known to be less in Alberta than anywhere else in Canada. [37] This, in turn, limits the direct application of the studies' results to the Alberta example.

On the other hand, the studies vividly demonstrate that rising fuel prices increase the economic attractiveness of district heating and cogeneration. Further, the assumptions which have been made respecting the world oil price (which in effect determines the fuel cost) now appear somewhat conservative. For example, in Gas Turbines and District Heating, the world oil price was assumed to rise in current dollars from $11.51 (1976) to $17.00 in 1982 and $23.50 in 1991. Domestic oil prices were anticipated to meet the world price by 1982 and match it thereafter. However, the February 1980 world oil price has turned out to be about $38.00 per barrel. If domestic prices are to rise to the international level by 1982, then the real price increase will be much more than the 4.4 per cent per annum assumed in the study. Indeed, energy pricing is, in 1980, the subject of considerable political debate. The outcome of such debate will have clear implications on district heating in particular and energy conservation in general.

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[37] Yet the opportunity cost for fuels in Alberta (i.e. their export value) is high.

4.3 Some External Benefits

It has been mentioned that the most substantial external benefits of district heating/cogeneration schemes relate to their associated reduced energy consumption and environmental pollution.

Energy Conservation

The energy saved by district heating/cogeneration systems arises via an increased efficiency of energy use. Figure 4.2 illustrates the fuel use and efficiencies associated with conventional systems, district heat-only systems and cogeneration systems. Conventional systems of individually heated buildings and remote thermal electricity generation do not use energy efficiently. Individual building heating systems are commonly rated to be 60 per cent efficient in burning fuel oil and 70 per cent efficient in burning natural gas. This means that 60 per cent of the original energy content of the fuel oil is used to heat the building; the other 40 per cent goes up the chimney. These were the efficiencies assumed in the studies mentioned above. While higher efficiencies yet may be attainable, the actual operating efficiencies of many domestic furnaces have been assessed at around 45 per cent (Anderson, 1977a; ASL, 1977b). This lower operating efficiency is attributable to an "off/on" mode of operation and typically poor maintenance. [38]

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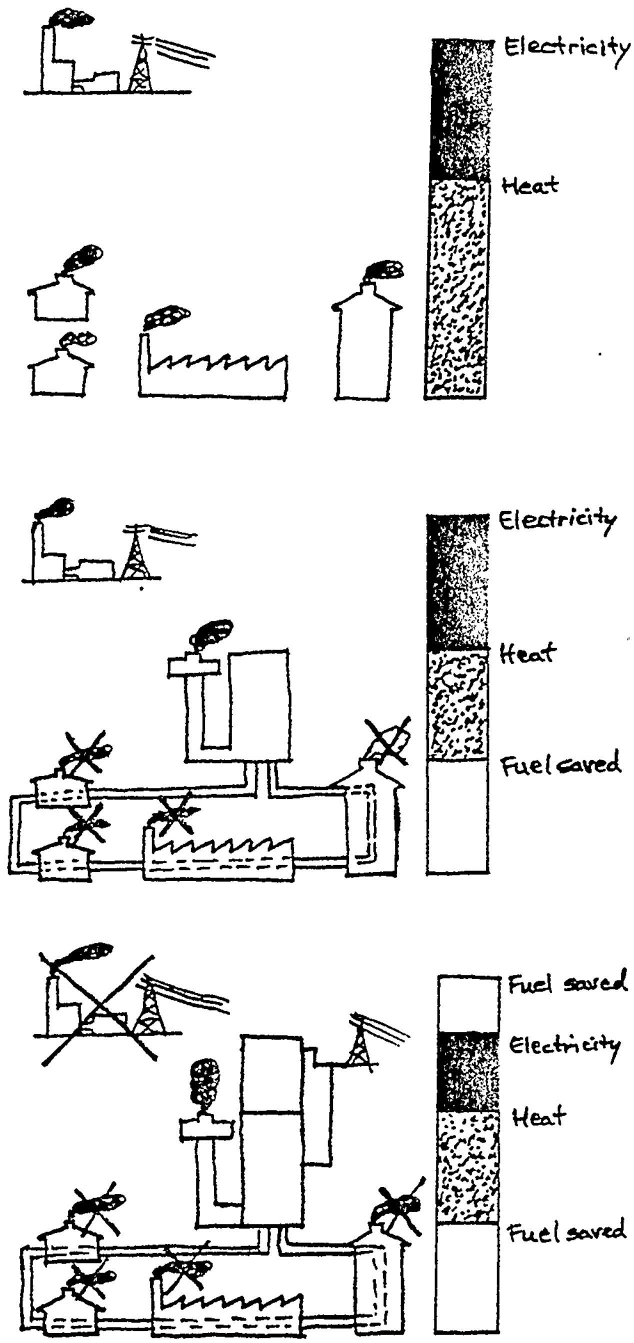
[38] Canadian Gas Research Institute furnaces currently in production claim to attain annual operating efficiencies of about 90 per cent (Ross, pers. comm.). If these claims are true, the advantages of district heating/cogeneratiion become somewhat weaker.



1. INDIVIDUAL HEATING SYSTEMS AND REMOTE ELECTRICITY GENERATION YIELD AN OVERALL ANNUAL EFFICIENCY OF <u>45</u> PER CENT.

2. DISTRICT HEAT-ONLY SYSTEMS AND REMOTE ELECTRICITY GENERATION YIELD AN OVERALL ANNUAL EFFICIENCY OF <u>60</u> PER CENT.

3. COMBINED HEAT AND ELECTRICITY PRODUCTION (COGENERATION) YIELDS AN OVERALL ANNUAL EFFICIENCY OF <u>75</u> PER CENT.

Figure 4.2. Comparison of Producing Heat and Electricity Separately and in Combination (Source: Larsson, 1977).

Thermal generation produces electricity at efficiencies ranging from 25 to 35 per cent, depending upon the primary fuel and process used. In other words, 65 to 75 per cent of the original energy content of the primary fuel is lost as waste heat. With efficiencies of about 60 per cent for heating and 35 per cent for electricity, such conventional systems yield overall annual efficiencies in providing heat and electricity of around 45 per cent (ASL, 1977b).

District heat-only systems represent an improvement in the efficiency associated the individual building heating systems. Large central boilers, equipped with air heaters and economizers, commonly burn fuel at annual efficiencies of about 85 per cent; that is, the boiler plant energy losses amount to about 15 per cent. Heat is also lost in the distribution piping; these losses increase with decreasing pipe diameters and heat load densities (Anderson, 1977b). European experience has shown the total annual heat loss for a normal district heating network to be about 5 per cent (Karlberg, 1976; Kilpinen, 1977). Total energy losses for a district heat-only system, then, amount to about 20 per cent, giving the heating system an annual efficiency of around 80 per cent. Purchasing thermally generated electricity from a local utility would yield an overall efficiency for heat and electricity provision of about 60 per cent (Anderson, 1977a; ASL, 1977b).

Combined district heating and electrical generation further increases the efficiency of energy use. Gas Turbines and District Heating considers the application of different combinations of gas turbines or combined cycles with heat recovery equipment and auxiliary boilers. The schemes have estimated overall annual efficiencies in providing heat and electricity ranging from 71 to 77 per cent (ASL, 1977b). Some European systems utilizing back pressure turbines in conjunction with district heating claim overall efficiencies of about 85 per cent (Larsson, 1977; Smeds, 1977).

Improved energy efficiencies give fuel savings. Gas Turbines and District Heating estimates that over the first 22 years of North Pickering's existence, gas turbine cogeneration schemes would save an average of about 15 million barrels of fuel oil over the individual building heating scheme. District heat-only schemes would yield savings of about 10 million barrels. These fuel savings can be converted into monetary benefits depending on the reader's fuel cost assumptions.

European examples give concrete evidence of the fuel savings attainable. District heating is Finland has been estimated to have saved 2.85 million barrels of oil in the year 1976 alone (Smeds, 1977). For the same year, Swedish district heating systems yielded an estimated savings of about 6.7 million barrels (Larsson, 1977). At $20 per barrel, these fuel savings would have resulted in positive balance-of-payments effects in 1976 of $57 million and $134 million respectively.

Of course, oil is not imported in Alberta and natural gas would likely be used to fuel residential district heating/cogeneration schemes. These examples do, however, illustrate the energy and dollar saving potential of district heating. Since the Alberta government subsidizes the use of natural gas (see Section 5.1), any reduction in gas use saves the government money. Further, fuel savings extend the lifetime of the nonrenewable resource base and enhance the security of these depleting energy supplies.

District heating/cogeneration schemes further mitigate the security-of-supply concern by offering a long-term freedom from dependence on any one fuel type. As fossil fuels become increasingly scarce, renewable energy resources -- biomass, solar -- can be used to fuel district heating schemes. [39]

Environmental Protection

District heating/cogeneration systems may also give rise to lower levels of environmental pollution. The extent of environmental pollution associated with heat and electricity provision is influenced by numerous variables. These include the type of fuel and combustion process used, the amount and type of pollution abatement equipment employed and the ability of the environment to absorb the residuals.

The conventional system of heat and electricity provision causes both thermal and air pollution. The thermal generation of electricity typically involves the use of condensing steam turbines. Condensing turbines require cooling water to condense the steam which leaves the turbine. As a result, thermal generation plants are generally located adjacent to a watercourse of some sort. In condensing the steam, the cooling water absorbs heat energy. It is then returned to the watercourse at a higher temperature. The addition of the hot water to the watercourse constitutes thermal pollution. The extent of damage caused by the thermal pollution is very dependent upon the local ecosystem. In

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[39] This is clearly a long-term consideration in Alberta. 1980 supplies of natural gas are such that concern over their security has been limited.

some cases, the hot water can be beneficial -- perhaps increase the productivity of useful fish. In other cases, it can be detrimental; some animals may be killed outright by hot water (Edmondson, 1971).

Fossil fuel-fired electric power plants also represent a source of air pollution. Emissions of sulphur oxides are particularily concerning. These are of course dependent upon the sulphur content of the fossil fuels. Different fossil fuel reserves have differing sulphur contents. Sour gas, which has a high sulphur content, is processed to remove the sulphur and make the gas a clean-burning fuel. While coal is not similarily processed, Alberta coal fortunately contains low amounts of sulphur. This reduces the immediate harmful effects of sulphur oxides; however it does not diminish the effects of sulphur oxide accumulation over time.

Emissions of sulphur oxides and other pollutants are subject to provincial government standards. Emission standards are typically met through some scrubbing and through increasing stack height (thereby dispersing the pollutants over a broader area). And although power plants are often located remote from the urban population, the pollutants make their presence known in the form of 'acid rain'. Acid rain is claimed by some to be the most serious of Canada's environmental problems (John Fraser, past federal Environment Minister).

Individual building heating systems may add to the air pollution problem, depending upon the fuel combusted in the furnace. Natural gas, the most prevalent heating fuel in Alberta, burns very cleanly.

The pollution from district heat-only plants would again depend upon the fuel used. However, they would have advantages over individual heating systems in that pollution abatement equipment can be afforded and maintenance is consistant and proper. Thus, if the same fuel were used, an area serviced by district heating would likely be less polluting than an individually heated area.

With respect to the provision of heat, cogeneration plants would offer the same advantages as heat-only plants. However, they would have the added advantage over conventional generating stations in that cogeneration plants would cause little or no thermal pollution. The extent of thermal pollution would be dependent upon whether or not any cooling water was used in the generation of electricity, i.e. whether back-pressure or condensing/extraction turbines were used (see Section 3.3). Noise from the turbines, however, would have to be within urban standards.

Swedish experience has indicated a significant reduction in urban air pollution as a result of increased district heating/cogeneration. Figure 4.3 shows sulphur dioxide concentrations in eight Swedish towns with varying degrees of district heating. Generally in Sweden, light fuel oil is used for individual heating systems and heavy fuel oil is used by the district heating plants. If one can assume that these fuels have similar sulphur contents, the figure indicates that even using a less expensive fuel in the district heating systems results in improved air quality.

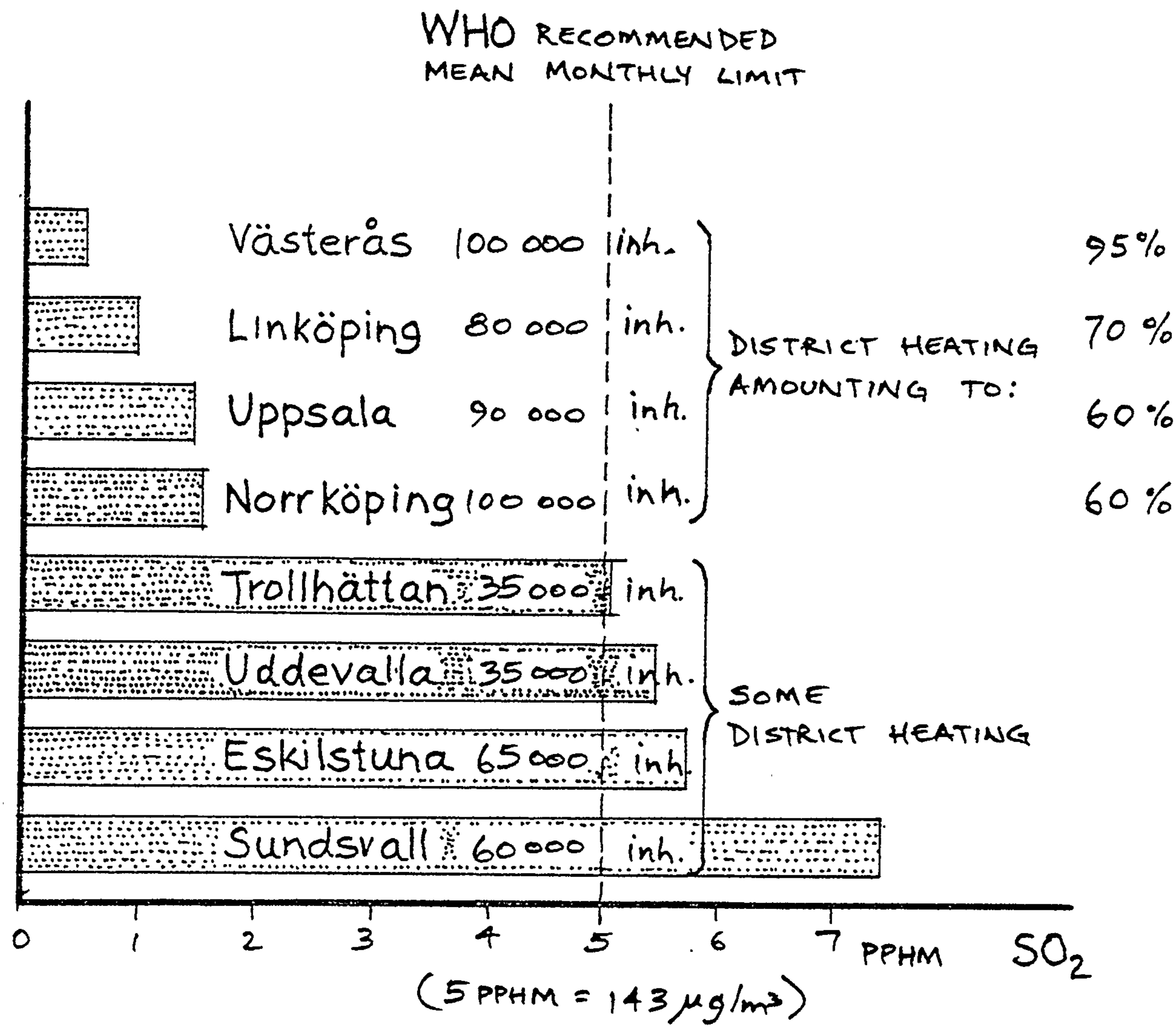

Figure 4.3. Sulphur Dioxide Concentrations For Some Swedish Towns with Varying Degrees of District Heating (Source: Larsson, 1977).

Other Externalities.

There are other benefits which may arise from district heating/cogeneration schemes. First, as any fuel can be used in generating hot water, district heating/cogeneration schemes open a new possibility for municipal solid waste disposal. [40] Incinerating refuse to provide heat and electricity would dispose of the solid waste and at the same time, conserve fossil fuels. As well, a market is created for industrial waste heat. Like refuse, the waste heat could be used to generate electricity and/or provide space heat.

Second, the utilization of district heating/cogeneration schemes would eliminate the household need for volatile combustible fuels for heating. Potential fire hazards are thus reduced (ASL, 1977b).

In addition, to the extent that urban cogeneration systems displace remote thermal generating capacity, the detrimental social and environmental impacts of high voltage transmission are suppressed. These impacts are becoming increasingly expensive to mitigate. Indeed, in Alberta's immediate future, "it is the transmission line hearings rather than generation hearings that will dominate the ERCB's [Energy Resources Conservation Board] regulatory agenda on the electrical side" (Manning, 1979: 3). [41] As well, to the extent that electricity transmission is

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[40] Refuse incineration for district heating application has become increasingly popular in the Scandinavian countries (see Section 3.2). Refuse incineration has associated problems that would require attention -- e.g. problems with air quality control, problems with indirectly encouraging a large throughput of solid waste.

[41] This regulatory process is discussed in more detail in Section 5.2.

reduced, transmission energy losses are eliminated making a more energy-efficient system.

4.4 Summary

District heating/cogeneration systems may not be immediately competitive with conventional systems of heat and electricity provision in all areas of the country. There is clearly a trade-off between capital and energy costs. Low energy costs make conventional systems more attractive. However, studies have shown that on a life cycle cost basis, district heating appears less expensive than individual heating systems.

In the 1960's, fossil fuels were assumed to be cheap and abundant. The social and environmental costs of energy production, transmission and use were assumed to be insignificant. Conditions in the 1970's have brought these assumptions under question. Energy use and social/environmental concerns are becoming increasingly costly. Over the long run, the price of nonrenewable-based energy can only rise. And as fossil fuel prices rise, district heating schemes will certainly become more economically attractive than less efficient individual heating systems.

Policy-makers have access to information on the various systems of heat and electricity provision and methods of energy conservation. The district heating option may be a policy selection if it is perceived to work both within the means and towards the goals of the particular level of government. Indeed, the weight that is attached to any benefits of district heating/cogeneration systems will depend upon the goals, priorities and available resources of the particular government. The federal government may view the energy conserving aspect as desirable to the extent that foreign oil imports are reduced and the national balance of payments is enhanced. Non oil-producing provinces may favor district heating schemes because they lessen the future impact of rising energy prices for their electorate. Oil-producing provinces may realize that by conserving energy, they extend the lifetime of their nonrenewable resource base. Municipal governments, largely limited by available financial resources, would only be likely to participate in district heating/cogeneration schemes if they were obvious revenue-generating ventures.

But before deciding upon any policy measure respecting the provision of heat and electricity, the policy-makers must also consider the probability of its successful implementation. This issue is addressed in the following chapter.

5.0 INSTITUTIONAL BARRIERS

Of course, the policy-maker, hopes that any recommended measure results in a move toward a desired goal. If such a shift occurs, the policy measure will have achieved success. In evaluating possible courses of action, the policy-maker must keep in mind their probabilities of successful implementation. This usually requires an investigation of implementation strategies. The successful delivery of a policy measure may be constrained by the existing social, organizational, administrative or political conditions. These limiting conditions can be referred to as institutional barriers (Lovins, 1977). They may be attitudes or practices which, by their very existence, hamper the adoption of an "improved" practice.

A better understanding of the present practice is essential in enabling the policy-maker to better assess a proposed measure's chances of success. This understanding serves "to indicate realistic limitations on the type of 'improved' behavior to which [one] can aspire [and] to supply that understanding of ongoing practices and existing forms of organization which will facilitate the introduction of better proceedures" (Bauer, 1968: 5).

In looking at the introduction of district heating/cogeneration schemes for residential communities, one must better understand the existing system surrounding residential heat and electricity provision. Such an improved understanding will aid in identifying the organizations and individuals most able to influence decision-making respecting heat and electrictiy provision. These organizations and/or individuals can be termed 'leverage points'. [42]

The European example showed that the most economic way to develop district heating/cogeneration systems was to start with heat-only systems and move into cogeneration once the heat load was large enough to justify it (see Sections 3.2 and 4.2). If district heating/cogeneration systems were to be developed within the Alberta urban context, they would most likely be fueled by natural gas. Natural gas resources within the province are relatively abundant and the use of natural gas would not compromise urban air quality. The special case, where a community happens to be located near a large thermal generating plant, is not examined in any detail here. This case does not apply for most residential communities. Indeed, the provision of heat is only considered incidental to the generation of electricity. Instead, the application of district heating/cogeneration systems to typical residential communities is examined. In this scenario, gas-fired district heating/cogeneration schemes are introduced in a manner similar to the European example -- the provision of heat is intimately tied to the cogeneration of electricity.

The system surrounding the provision of heat and electricity was examined within the Alberta context. The probable leverage points were identified and the district heating/cogeneration scenario above was presented to them. A feeling for their attitudes regarding this scenario and general energy futures was obtained (see Section 5.2). Their attitudes affect the implementation possibilities of district

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[42] In this sense, the notion of leverage point incorporates the usual concepts of power and influence (Gergen, 1968).

heating/cogeneration schemes (see Appendix II — Methodology).

In order to better understand the framework surrounding heat and electricity provision, a brief historical overview is coupled with a description of the present (1980) energy planning, decision-making and regulatory process in Alberta.

5.1 A Brief Historical Overview

In the Alberta context, a discussion of heat and electricity amounts to one of gas and electricity, as the combustion of natural gas satisfies virtually all of the province's demand for space and hot water heating (ERCB, 1978). These low temperature heating requirements need not be satisfied by natural gas combustion. They could be provided by burning any other fuel, by hot water from a district heating plant or by solar energy. Since the 1950's though, natural gas combustion has become tacitly assumed to be <u>the</u> way of providing space and hot water heating requirements in Alberta residential communities. This assumption goes through the ranks from the politicians, to the regulatory bodies, to the planners, to the developers, to the builders (see Sections 5.2 and 5.3). Indeed, it has likely been the least expensive way of providing these low temperature heat requirements.

Electric and gas utilities in the province have experienced similar periods of growth. From isolated systems at the turn of the century, both utilities saw considerable expansion of their service areas until the depression of the 1930's. The post-war boom in Alberta rejuvenated the utility growth. Into the 1980's, this growth is still significant.

Electric Utility Growth

In the late 1800's, electric utilities developed small networks on a scattered basis. Most cities, towns and villages where electric service was available received their service from local plants. In many of the towns and villages, electric energy was provided on a part-time basis, often only from dusk until midnight. The primary function of the utility was to provide current for lighting.

The 1890's were not good years for pioneering in the electric field:

> "Not only was the industry in its infancy, but economic conditions were far from buoyant. Profits appear to have been small or non-existent, while breakdowns or complaints about the quality of service came quite frequently" (White, 1976: 4).

Two trends appear evident in the early growth of the electricity supply industry. First, municipal governments become involved in the production of power, and second, electricity was generated at the load centre.

It is not surprising that the municipal governments of each significant urban centre -- including Calgary, Edmonton, Red Deer, Lethbridge and Medicine Hat -- became involved in electricity production. The rapid settlement of the West began around the turn of the century. And while the province's population was primarily rural, there was a certain influx of urban dwellers. The growth in population increased both the demands for local services and the tax base for municipal revenue. Electrical service was desired and provided.

But while the demand for electricity was growing quickly, it had not yet reached the level that would make it economic to generate electricity at an optimal remote site. Further, electrical transmission was not highly developed at the turn of the century (White, 1976). As a result, electricity tended to be generated within the municipality to satisfy the local load.

These conditions changed somewhat in 1911. Two cement plants were built at Exshaw and represented the first concentrated load in Alberta. The load required by these plants and the City of Calgary economically justified building a hydro-electric plant on the Bow River at Seebe, 60 miles west of Calgary. The Calgary Power and Transmission Company (later Calgary Power Limited) was formed to do just that. The economy of scale attained by the hydro plant enabled Calgary Power to provide lower cost electricity than municipal plants. A contract was obtained from the City of Calgary to supply bulk electrical power at wholesale rates. The City retained the responsibility for electrical distribution within the city limits. This transmission of electricity to Calgary offered reliability and lower cost, and marked the start of the provincial grid.

Calgary Power continued to develop its hydro system for Calgary and surrounding small communities. More dams were built on the Bow River. By the late 1920's, Calgary Power had expanded its transmission facilities north to Edmonton and south to Lethbridge. While the cities of Edmonton, Lethbridge and Medicine Hat retained their generation and distribution facilities, Red Deer decided to purchase its power in bulk from Calgary Power in 1930.

Other electrical utilities operated in the province, yet none expanded their transmission and generating facilities to the extent that Calgary Power did. Edmonton Power, owned by the City of Edmonton, developed significant generating facilities within the city limits. Dominion Electric Power Limited operated small generating stations in the Peace River, Athabaska and Jasper districts. Canadian Utilities Limited (later Alberta Power Limited) generated and provided electricity for the areas of Vegreville and Grande Prairie. [43] The Union Power Company Limited provided power to Drumheller.

Where private utility companies supplied electricity to municipalities, a franchise agreement for a minimum power supply and a minimum service period (in years) was secured from the municipal council. When electricity was first introduced and potential markets were plenty, there was probably little competition amongst the utilities. This was likely followed by a period of competition and then one of competition mixed with agreements not to compete. [44] Strict competition would likely have led to a situation in which the power companies would have experienced lower profit margins and greater excess capacity. The economic inefficiency of having overcapacity may have resulted in higher prices to consumers. At an early stage (1915), the government began to regulate the industry (through the Board of Public Utility Commissioners) to ensure that utility growth proceeded in an economically effi-

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[43] Dominion Electric and Canadian Utilities were both owned by American interests — the former by Dominion Electric Light and Power Company of Delaware, and the latter by International Utilities Corporation of New Jersey.

[44] At least agreements appear to have been worked out during the same era for the same or affiliated companies operating in Saskatchewan (White, 1976). Franchise areas in Alberta are now assigned by the ERCB, recognizing that competition in the regulated utility sector is not necessarily in the public interest.

cient manner (see Subsection Government Policy and Regulation).

The demand for electricity slackened during the Depression years, but started to grow again in the 1940's. Two developments -- rural electrification and the discovery of oil at Leduc in 1947 -- led to a rapid expansion of the electric industry in Alberta. Both continue to be major factors in the province's utility growth. The 1930's, 1940's and 1950's seem to have been characterized by numerous takeovers of smaller private and municipal electric utilities by larger private utilities. The larger utilities could offer improved economies of scale and reliability, both being important concerns in the electric utility industry. By the end of the 1950's, there were only three major private electric utilities operating in the province -- Calgary Power, Canadian Utilities and Northland Utilities.

The 1950's marked the introduction of large coal-fired generating stations and a tremendous expansion of the province's electrical grid. The province's hydro resource potential was becoming more limited and the electrical load was increasing by about 10 per cent annually. The booming oil industry and a rural electrification program resulted in the extension of the main transmission system into isolated areas. [45] The significant and increasing load size made the construction of large

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[45] In the 1950's, the provincial government introduced legislation -- the Rural Electrification Long Term Financing Act (1953) and the Rural Electrification Revolving Fund Act (1956) -- designed to encourage rural electrification by making available long-term, low-cost financing. On a purely economic basis, the scattered load of the rural areas would not have justified the expenditures required to deliver electricity. The government, however, must have deemed the extension of electrical services to remote areas to be in the public interest.

thermal plants economically attractive -- they offered improved economies of scale in providing base load electricity. In the 1950's and 1960's, these thermal plants were either coal-fired or gas-fired. More recently, they have been confined to coal-fired plants (by provincial government policy).

Hydro-power dominated the province's electrical capacity until 1955. Since then, thermal electric generation has become increasingly significant. In 1978, hydro-electric plants represented only about 17 per cent of the province's installed capacity and provided only about 10 per cent of the electrical energy generated. The balance was supplied by thermal generation, with coal-fired thermal plants accounting for about 57 per cent of the province's installed capacity (ERCB, 1979b).

1972 saw the takeover of Northland Utilities by Canadian Utilities, leaving only two investor-owned electric utilities operating within the province. Canadian Utilities became a holding company with Alberta Power as the operator of its electric properties. Calgary Power purchased the City of Lethbridge generating facilities, leaving just two municipalities with ownership of some generating capacity -- Edmonton and Medicine Hat. These municipalities serve only their respective urban areas; the balance of the electricity for the province is provided by the investor-owned utilities. Of the electric energy generated in the province in 1978, Calgary Power supplied 67 per cent, Edmonton Power about 16 per cent, Alberta Power about 15 per cent and the City of Medicine Hat about 2 per cent (ERCB, 1979b). Linked by transmission lines, these electricity suppliers form an interconnected grid.

1972 also saw the creation of the Electric Utilities Planning Council (EUPC), an advisory body with members from all the major electricity producers and distributors. The EUPC coordinates utility plans for generation and transmission additions to ensure that an adequate supply of electricity is available on a provincial basis. One utility's overcapacity, resulting from the addition of a large generating unit, is incorporated into the generation-scheduling plans of the other utilities. This reserve sharing arrangement enhances the reliability and economic efficiency of the interconnected system.

Unlike most other provinces, then, Alberta's electricity supply industry did not evolve into one single government-owned electric utility serving the whole province. Instead, the electricity supply sector represents a mixed economy of:

(i) investor- and municipally-owned utilities involved in both generation and distribution, and

(ii) municipally-owned utilities involved in distribution only.

Any proposal for the combined generation of heat and electricity would certainly require coordination with these generation and distribution utilities (and the EUPC). Residential cogeneration schemes could plausibly be introduced either by existing electric (or gas) utilities or by some innovative independent organization. Of these two, the existing utilities would seem to be the more likely candidates. They are constrained by a lack of some technical expertise (in moving heat) and by the 'blinkers' of present practice (if cogeneration were demonstrated to be economic, these blinkers would be quickly shed). A new organization, on the other hand, would have to acquire the relevant technical expertise, become a public utility (as it would be serving a residential public) and intrude into a marketplace and planning structure dominated by a handful of large firms. These latter hurdles may be insurmountable.

Gas Utility Growth

The use of natural gas was very limited at the turn of the century. Coal was the dominant fuel used for home heating (MacEwan, pers. comm.). Early gas utilities developed on a very localized basis, serving areas adjacent to natural gas fields.

Like privately-owned electric utilities, investor-owned gas utilities made agreements with municipalities to obtain a franchise for the gas supply. [46] In order to justify sinking any investment into gas production and distribution facilities, the early gas utilities had to first secure these markets.

In Alberta, the first major expansion in the gas utility industry came in 1912. Canadian Western Natural Gas, Heat, Light and Power Company had been incorporated a year earlier following the discovery of natural gas in the Bow Island area near Calgary. The company secured market agreements with the Cities of Calgary and Lethbridge, and the Towns of Nanton, Okotoks, Claresholm, Bassano, Gleichen, MacLeod and Strathmore. A transmission line was built linking these communities to the Bow Island field.

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[46] The franchises apply to residential and commercial consumers; industrial consumers negotiate individual contracts with gas suppliers.

Natural gas service appears to have continued to expand on a fairly localized basis until World War II. Canadian Western connected additional communities adjacent to the company's main transmission line and extended the line east of Lethbridge (Richards, 1977). Northwestern Utilities provided natural gas service to Edmonton and some surrounding communities. Coal was still a popular fuel for residential heating before the second World War (MacEwan, pers. comm.).

Like the electric utility industry, gas utilities experienced rapid expansion after the war. Many communities and areas within the province were still not served with natural gas and were requesting that service be extended to them. Northwestern Utilities undertook a large-scale expansion program in 1946, having secured franchise markets in Red Deer, Camrose, Wetaskawin, Viking, Ponoka and Lacombe. Canadian Western connected the gas plant at Jumping Pound to meet the increasing demands on their existing system. The location of this supply made it feasible to extend natural gas service to the markets west of Calgary to Banff. Northland Utilities supplied natural gas to several communities in the Peace River - Grande Prairie region. Plains-Western Gas and Electric Company provided natural gas service to localities scattered throughout the province. Smaller investor-owned and municipally-owned utilities offered gas service to individual communities. The larger gas utilities, Canadian Western and Northwestern Utilities, had a policy of extending service to communities only if the rates commensurate to recover the costs of extension were acceptable to the consumer. In this way, the possibility of uneconomic extensions was avoided (Richards, 1977).

The development of the Alberta Gas Trunk Line system opened the possibility for natural gas service to previously uneconomic areas of the province. The Alberta Gas Trunk Line Company Act of 1954 created the Alberta Gas Truck Line Company Limited (AGTL). AGTL was originally formed to operate a province-wide gathering system to carry natural gas located within Alberta to export markets. This common carrier gathering system enabled natural gas service to be extended to many communities and rural areas. Virtually all areas of the province have been franchised to different suppliers.

The large majority of natural gas service in Alberta is furnished by investor-owned gas utilities. By far the most significant of these are Northwestern Utilities Limited, serving north-central Alberta, including Edmonton, Red Deer, Fort MacMurray and Grande Prairie; and Canadian Western Natural Gas Limited, supplying southern Alberta, including Calgary and Lethbridge. Both utilities are 100 per cent owned by Canadian Utilities Limited (also the parent company of Alberta Power) and their systems are almost completely integrated. [47] The other areas of the province have been franchised to smaller investor-owned utilities, municipally-owned gas utilities or rural gas cooperatives. [48] In 1978, the two majors combined to provide over 75 per cent of all the na-

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[47] Northland Utilities was purchased by Canadian Utilities in 1972 and its gas properties went to Northwestern. Canadian Utilities is 64 per cent owned by IU International, an American firm.

[48] The Rural Gas Cooperatives are established through the provincial government's Rural Gasification Program. The government subsidizes the extension of gas service to remote areas, deeming it to be in the public interest.

tural gas sales in the province (ERCB, 1979a; CUL, 1979).

As in the electric utility sector, then, Alberta's gas utility industry is dominated by private interests. The major gas and electric utilities are listed in Table 5.1.

Table 5.1. The Major Gas and Electric Utilities in Alberta

Major Electric Utilities	Major Gas Utilities
(1) Generation & Distribution:	
.Calgary Power Limited .Edmonton Power .Alberta Power Limited (*) .City of Medicine Hat	.Canadian Western Natural Gas Company Limited (*) .Northwestern Utilities Limited (*) . Plains-Western Gas and Electric Company Limited
(2) Distribution Only:	
.City of Calgary .City of Lethbridge .City of Red Deer	

(*) Alberta Power, Northwestern Utilities and Canadian Western Natural Gas are all 100 per cent owned by Canadian Utilities Limited.

Both the gas and the electric utility development in the province has been primarily determined on an economic basis -- service being extended only when the demand was sufficient enough to justify the expenditures required to provide the supply. [49] Similarily, any development of

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[49] The exceptions to this are the Rural Electrification and Gasification Programs, in which the provincial government apparently deemed subsidization to be in the public interest.

district heating/cogeneration systems would likely be on an economic basis. District heating/cogeneration systems would have to be cost competitive with existing systems of heat and electricity provision. Of course, the competitiveness of district heating/cogeneration schemes could be improved through appropriate incentives or subsidies if government policy-makers felt that such schemes were in the public interest.

Further, given that the responsibilities for urban heat and electricity provision rest in the hands of a few major organizations, it seems most likely that any introduction of district heating/cogeneration systems would be through one or more of the major suppliers. It would likely be very difficult for an independent to acquire the relevant technical expertise and break into an energy market and planning structure dominated by a handful of firms. In fact, one of the major electricity suppliers, Edmonton Power, is studying the potential of a district heating/cogeneration venture (Johnson, pers. comm.). The study is looking into the technical and economic feasibility of using heat from a downtown electric generating plant to satisfy the requirements of a nearby commercial heat load. While this study may prove to be very relevant to an early introduction of district heating/cogeneration schemes in Alberta, the study situation is a variation of the special case in which a large heat load happens to be adjacent to a thermal generating plant. The conclusions of the study, not yet available in February 1980, may not be immediately applicable to the general residential case considered here.

A utility by definition serves the public. Residential district heating/cogeneration schemes would certainly be classified as public utilities. If privately owned, they would be subject to government regulation. While the investor-owned gas and electric utilities have grown and prospered, there has been a framework of government policy and regulation within which the private interests have operated.

Government Policy and Regulation

Table 5.2 provides a brief synopsis of the major regulatory agencies overseeing the gas and electric utility industry since 1915.

Table 5.2. A Brief History of Utility Regulation in Alberta

Date	Electric Utility Regulation	Gas Utility Regulation
1915	.Board of Public Utility Commissioners	.Board of Public Utility Commissioners
1944	.Public Utilities Board .Natural Gas Utilities Board	.Public Utilities Board .Alberta Power Commission
1971	.Public Utilities Board	.Public Utilities Board . Energy Resources Conservation Board

At an early stage, the provincial government recognized the need for intervention in the private utility industry to protect the public interest. In 1915, the provincial Liberal government established an independent tribunal called the Board of Public Utility Commissioners (later Public Utilities Board) to oversee the actions of investor-owned gas and electric utilities. The Board was and has since been responsible for ensuring that the utilities provided a "safe and adequate" supply at "just and reasonable" prices (Public Utilities Board Act). By applying these conditions, the Board made certain that the growth of the regulated private utilities took place in an economically efficient manner. Municipally-owned utilities, Although not subject to Board jurisdiction unless they request it, also have tended to attach importance to an economic development.

It appears that the Public Utilities Board (PUB) alone was able to provide sufficient regulation over utility growth until after World War II when demand rapidly expanded. The Social Credit government introduced legislation in 1944 to create a Power Commission and a Natural Gas Utilities Board. The Power Commission was given the authority to investigate facilities used in the manufacture and distribution of power, to purchase existing power facilities and to manufacture, distribute and sell power itself (Power Commission Act, 1944). It could enforce PUB orders with threat of takeover. Its primary purpose, however, seems to have been to "oversee faster rural electrification" -- not surprising considering the rural backing of the Social Credit government (Barr, 1974: 121). The Commission was involved in forecasting and supervising provincial power development. Unlike the case in most other provinces, it never did become an operator in the electric utility industry.

The Natural Gas Utilities Board was formed from members of the PUB and the Oil and Gas Conservation Board (Natural Gas Utility Act, 1944). It had the power to oversee all stages of gas use -- from production to final sale -- and to fix prices at each stage. Its authority later become vested in the PUB.

It is significant that the Social Credit government was in power during the rapid expansion of the regulated utility sector during the 1940's, 1950's and 1960's. The Social Credit government was well known to have an opposition to socialism (Barr, 1974). It tended to turn to the administrative tribunal to provide regulation as the society in Alberta become increasingly complex. While most other provinces were choosing to nationalize power companies in the 1950's and 1960's, the Social Credit government remained opposed to direct participation in the industry. In fact, Premier Manning fought the issue of power company nationalization in the 1963 provincial election and won.

Shortly before their defeat in 1971, the Social Credit government combined the authority of the Alberta Power Commission and the Oil and Gas Conservation Board under the Energy Resources Conservation Board (ERCB). The ERCB and the PUB, both administrative tribunals, remain important in the process of energy decision making.

The energy supply conditions in Alberta have also had a salient influence on provincial government policy. The discovery of oil at Leduc in 1947 marked the major turning point in Alberta's social and economic history (Barr, 1974). The development of the energy industry was seen to facilitate the economic development of the province. Then Premier Manning was at one time accused of being "too concerned about maintaining the goodwill of the power and oil companies" (Barr, 1974: 123). Under Manning's leadership, Alberta was generally thought to provide an attractive climate for business. Energy-related revenues were poured into an "elaborate structure of 'people programs' in health, education, welfare" (Barr, 1974: 133). Certainly, the services of gas and electricity were also seen to enhance the quality of life for Albertans. The apparent abundance of energy resources ensured their provision at low cost.

Yet the Social Credit encouragement of energy and economic growth eventually brought about their downfall and replacement by the provincial Conservative government. The economic growth of the province was accompanied by increased urbanization and industrialization. The rural backing of the Social Credit party become outweighed by the urban majority. However, the attitudes towards energy and economic growth persisted in the government and amongst the public.

The Conservative government and the regulatory tribunals (ERCB and PUB) still appear to tie energy development with economic development. Industrial growth is believed to be encouraged by a "secure supply of energy, either gas or electricity, combined with stability ... of rates" (PUB, 1979: 14). Accordingly, the provincial Conservative government has adopted a policy of exporting only those natural gas resources which are surplus to the province's forecasted 25 year requirements. Utility rates are among the lowest, if not the lowest, in Canada. The Alberta government further protects Alberta consumers from natural gas price increases through their natural gas rebates scheme. From time to time, a political agreement is made to raise the price of natural gas. Under the rebate scheme, 75 per cent of any such price increase is covered by the government; only 25 per cent of the increase is added to the consumer's bill. Rebates are issued to the utilities and the PUB ensures that the full value of the rebates is passed on to the consumer. By providing an attractive business environment through provincial energy policy, the Alberta government encourages the economic development which brings "prosperity" and an "enhanced" quality of life.

An awareness of the attitudes prevailing in the government, the utility industry and the regulatory tribunals better enables one to predict the likely response towards district heating/cogeneration schemes and thus, their implementation possibilities. The key attitudes to identify, of course, are those held by the individuals or organizations in positions of 'leverage'. To identify such positions, a familiarity with the processes of gas and electric energy planning, decision-making and regulation is required. A description of these processes follows.

5.2 The Energy Planning and Regulation Process

The planning and regulation process respecting the provision of natural gas in urban areas is somewhat different than that for electricity provision. Both processes attempt to work towards the same goal -- the assurance of an adequate supply of the services demanded in the future at a just and reasonable cost. The way in which the services are provided is deemed to be the most economically efficient. There are no significant attempts within these processes to manipulate the future demand for services -- this demand is considered exogenous.

The planning and regulation of electric utilities is, however, more involved than that of gas utilities. Electricity generation facilities require long lead times before they come 'on line'. Thus, electric utilities are subject to both upstream (before generation facilities are built) and downstream regulation (after generation facilities are operating). Gas utilities, on the other hand, are controlled primarily through downstream regulation once a franchise to serve a municipality has been secured.

The Electric Energy Planning and Regulation Process

Figure 5.1 provides an overview of the process of supplying and pricing electricity in Alberta. [50]

As in other jurisdictions, the process in Alberta commences with forecasts of electricity requirements. Each electric utility prepares a demand forecast for its service area. In so doing, the utility planners rely upon community and industrial planners for estimates of population growth and distribution and industrial growth and distribution. The individual utility forecasts are coordinated by the Electric Utility Planning Council (EUPC) and a joint forecast is prepared.

Further to this, the Energy Resources Conservation Board (ERCB) holds formal hearings every three years to review Alberta's supply and demand situation:

"These hearings provide a public forum for testing the assump-

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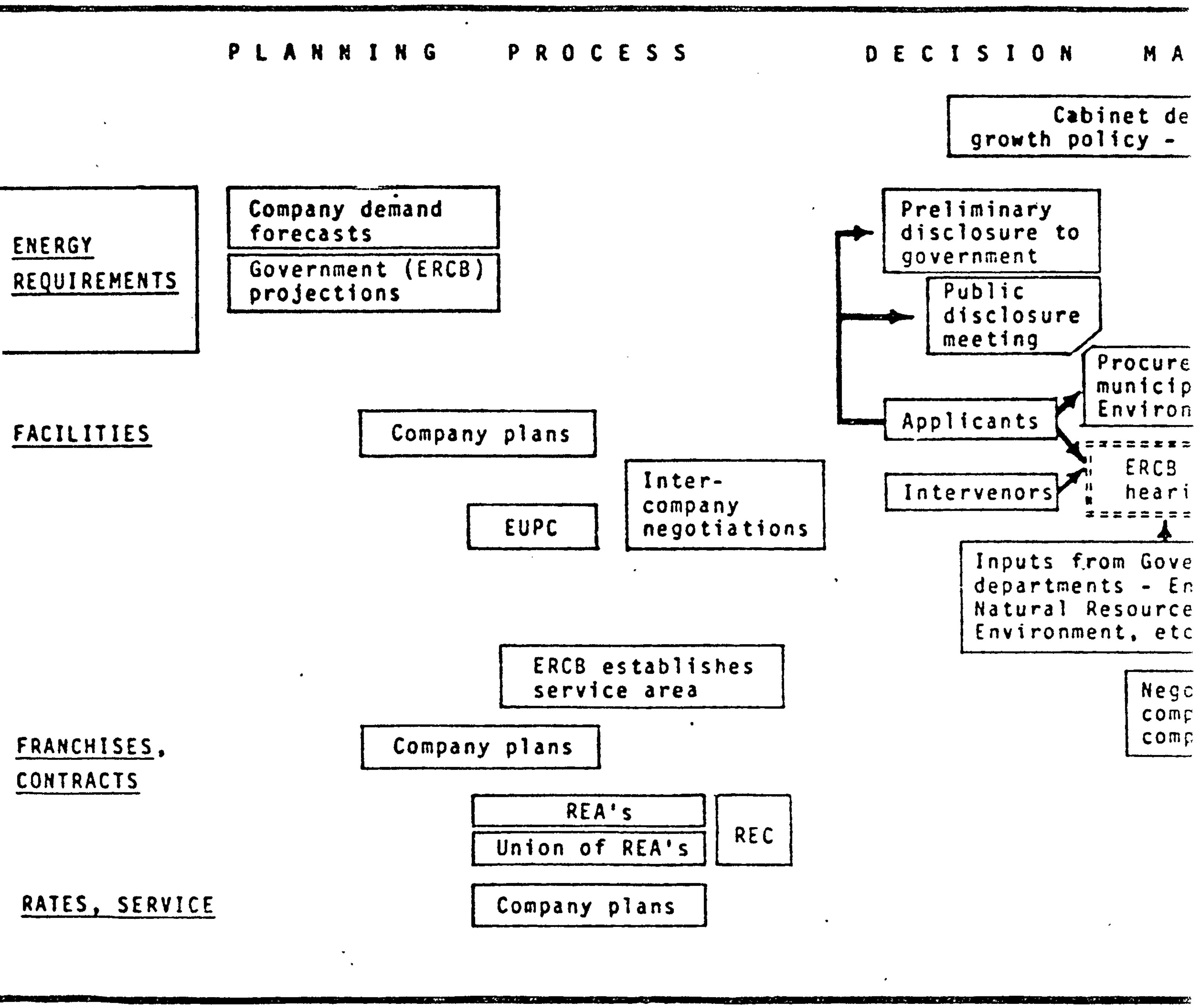
[50] The writer acknowledges Mr. E. Preston Manning, who was involved in preparing the flow chart of Figure 5.1. He also contributed towards an understanding of the process through personal communication and written descriptions [see Manning(1978) and Manning(1979)].



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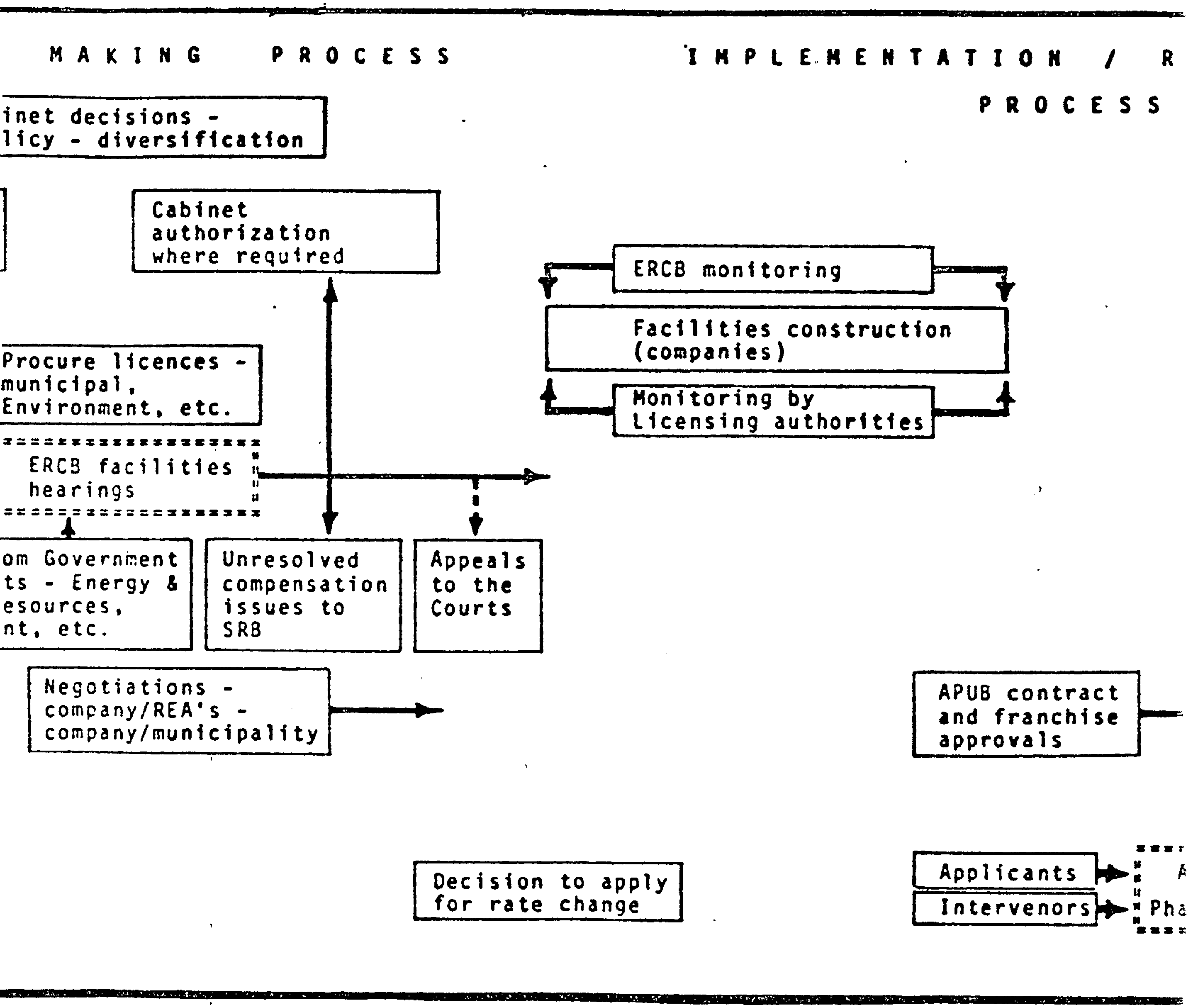

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Courts
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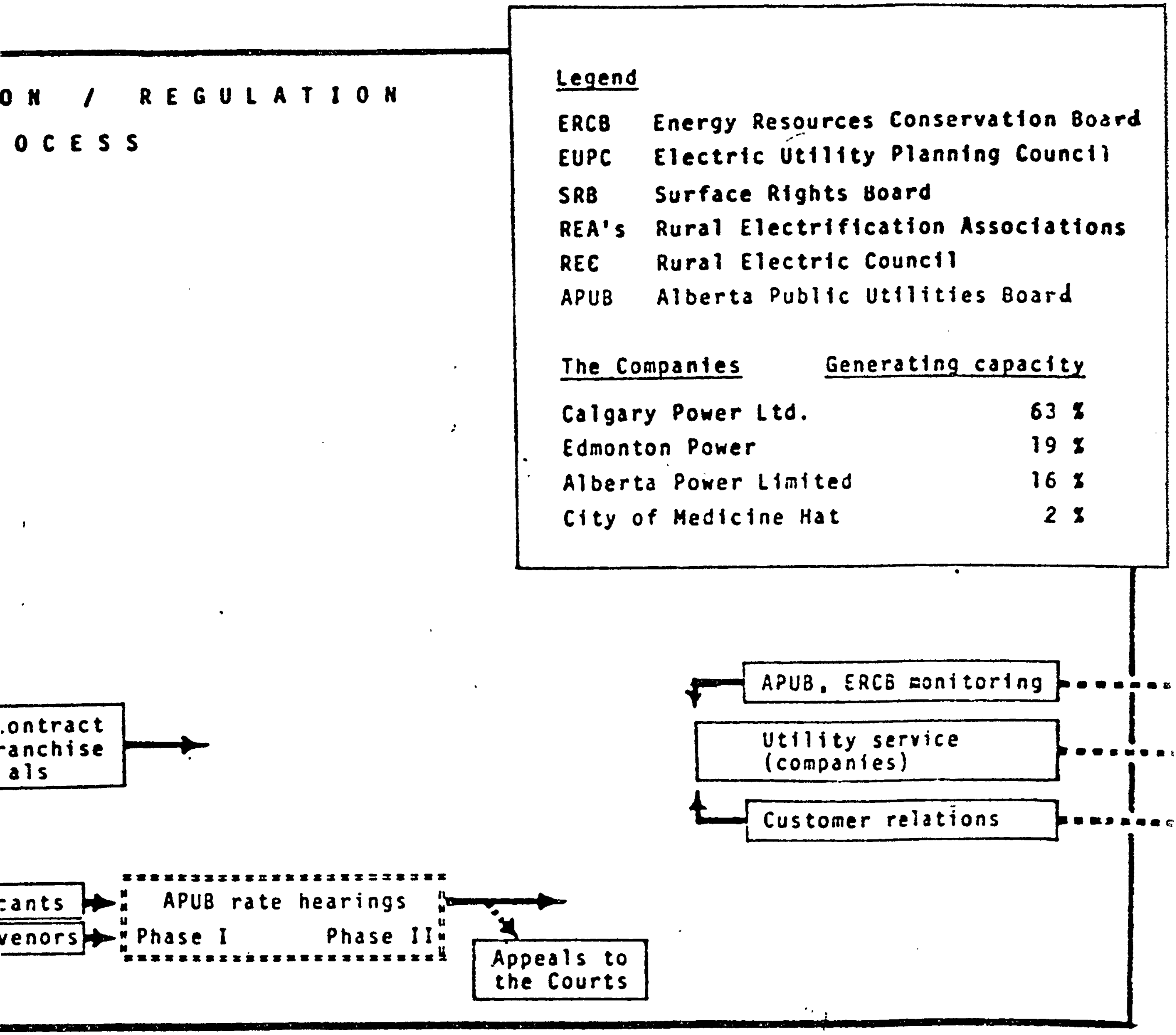

Figure 5.1. The Electric Energy Planning, Decision-Making and Regulation Process in Alberta (Source Manning, 1978)

> tions of industry and government planners with respect to future growth and energy demand ..." (Manning, 1979: 2).

The ERCB synthesizes the EUPC submission with other evidence and its own forecasts to arrive at an "official" forecast of future electricity demand. The need for additional electricity generation facilities (see Figure 5.1) is established on the basis of this forecasted demand.

The planning and construction of major electricity generating facilities requires a lead time of at least ten years (Manning, 1978). Thus, planning in 1980 will focus upon the anticipated demand of 1990 and beyond. Planning for urban cogeneration facilities would likely have to be coordinated with this generation planning.

Once it becomes established that certain generation facilities are required to meet the expected demand, the individual utilities prepare proposals to construct these facilities. As shown in Figure 5.1, the electric utilities involved in generation coordinate their plans for additional capacity. Their generation proposals are disclosed to various provincial government departments as required and, in the case of major facilities, to the public. Eventually, they are submitted to the ERCB and are subjected to public scrutiny through the formal ERCB facilities hearings. While additions to generating facilities have to meet certain technological and environmental standards, the prime concern of the ERCB is whether such additions represent the most economic alternative (Millard, pers. comm.).

Facilities construction may finally proceed once ERCB and, when necessary, cabinet approval is obtained. The government guides the direction of regulatory body decisions through specific policies and legislation (e.g. PUB Act, ERCB Act).

The ERCB also exercizes authority with respect to the establishment of 'service areas'. By defining the regions which may be served by the particular electric utilities, the ERCB determines which company will serve which customers. Within their respective service areas, the electric utilities are involved in ongoing negotiations with municipalities and other power users over franchise agreements and supply contracts (see Figure 5.1). The companies are also continually involved in financial planning to make certain that they have a sufficient cash flow to cover their investment and service commitments.

"Eventually the consequences of both this physical and financial planning are submitted to the scrutiny of the other major regulatory tribunal involved in the process, namely the Alberta Public Utilities Board" (Manning, 1979: 4). The Public Utilities Board (PUB) has the authority to approve or veto any contracts or franchise agreements between investor-owned utility companies and their customers (Public Utilities Board Act). More importantly though, the PUB exercises jurisdiction over the rates (see Figure 5.1) charged for electric power and any changes in those rates. Applications for rate changes, arising out of company financial planning, must be submitted to the PUB for approval.

Like the ERCB, the PUB evaluates rate increase applications on an economic basis -- was the service provided in the most economically efficient way possible, given the desired level of reliability? Rates are established by attaining a balance between the utility company's need to obtain a fair return on their investment and the customer's desire for least-cost electricity.

As shown in Figure 5.1, the ERCB and the PUB monitor utility service on an ongoing basis. The figure also shows that decisions from ERCB facilities hearings and PUB rate hearings may be appealed to the courts on questions of law or jurisdiction (as in any administrative tribunal). Something that is not well illustrated in Figure 5.1 is the role of time in the process of supplying and pricing electricity. Company applications for rate increases are based on facilities which are already in operation. The rates charged, then, are designed to cover the costs associated with developing and operating the physical system which was approved by the upstream regulation of the ERCB. [51]

This is a brief description of the framework within which the supplying and pricing of electrical energy in Alberta works. The electric utilities are primarily responsible for initiating and implementing plans for electricity supply. Coal-fired generation plants are viewed as the most economic units for providing base load electricity. The utilities operate within the 'rules' of government legislation, guided by the regulatory body criteria of economic efficiency. The regulatory bodies, in turn, are guided by government policy. If the electric utilities were to initiate any plans for urban cogeneration schemes, the onus would be on them to demonstrate the economics of cogeneration to the regulatory bodies.

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[51] This amounts to a form of average cost pricing. The present price (average cost) - replacement price (long run marginal cost) dichotomy is addressed in the Subsection Ability of the Process to Respond to Change.

The Natural Gas Provision and Regulation Process

The supply and price of natural gas is regulated by either the ERCB or the PUB at all stages of its use -- from initial extraction to final sale. However, in considering the provision of gas relative to the "most probable" urban district heating/cogeneration application (see Section 5.0), not all stages of natural gas use need be examined. The district heating and individual heating schemes (both using natural gas) will involve the same planning and regulation considerations up to the point at which natural gas enters the district heating/cogeneration plant. Thus, what requires examination is the planning and regulation process surrounding the distribution of natural gas within urban areas.

In Alberta, most of the natural gas made available to urban areas is provided by investor-owned gas utilities. Once such a utility has secured a franchise or supply contract from a municipality, and the franchise is approved by the PUB, the gas utility has the obligation to supply the municipality's requirements for natural gas.

Because the planning for natural gas provision does not require the long lead times associated with electricity provision, the process of supplying and pricing natural gas for urban areas is less complex. There is no upstream regulation over the types of facilities which will be installed to provide heat to the public. The gas utilities feel that because they do not have much excess capacity, they can respond quickly to changing conditions (Richards, pers. comm.). First, a franchise is obtained from the municipality and approved by the PUB. The municipality reveals its plans for the urban development. From these plans, the gas utility forecasts the anticipated natural gas requirements and ensures the municipality that it will meet the anticipated demand. If gas utilities were to initiate district heating ventures, their plans would have to be modified at this stage.

As in the electricity supply sector, the gas utilities are involved in financial as well as physical planning. A cash flow is required to cover the costs of extraction, transmission and distribution facilities and the cost of service. The cash flow is recovered from payments by gas customers. Rate charges and increases in them must again be approved by the PUB. And again, the PUB evaluates rate applications on whether or not the service was provided in the most economically efficient manner. But instead of evaluating alternative methods of heating, this amounts to a consideration of how prudent gas utility investments were. The PUB establishes 'just and reasonable' rates and ensures a fair rate of return for the utilities.

It should be noted that the gas utilities are charged directly with the least-cost provision of natural gas. They are only indirectly responsible for the provision of heat. It seems implicit within PUB ranks .that the exisiting system of heat supply -- that is, individually heated buildings burning natural gas -- represents the most economically attractive mode of supply. If district heating systems were to be introduced, the onus could be on the system owner to demonstrate the economic advantage of his system over individual heating systems (MacDonald, pers. comm.).

Probable Points of Leverage

Within the processes of providing heat and electrical energy, the organizations most likely to influence the energy supply system in urban areas would include:

(i) the electricity generating utilities of Calgary Power, Alberta Power and Edmonton Power;

(ii) the electric utility coordinating body, the EUPC;

(iii) the gas distribution utilities of Northwestern Utilities and Canadian Western Natural Gas;

(iv) the regulatory bodies involved in gas and electricity supply and pricing, being the ERCB and the PUB; and

(v) the provincial government Cabinet and department of Energy and Natural Resources.

Of course, within each organization, there are particular individuals who exert substantial influence and power over organizational policy and direction. On the assumption that these key individuals would be on the top of the organizational heirarchy, an attempt was made to contact and interview such persons. These included E.W. King, President and Chief Executive Officer of Alberta Power, Canadian Western Natural Gas and Northwestern Utilities; M.M. Williams, President of Calgary Power; M. Chorel, Chairman of the EUPC; W. Horton, Chairman of the PUB; V. Millard, Chairman of the ERCB; E.P. Lougheed, Premier of the Province of Alberta; and M. Leitch, provincial Minister of Energy and Natural Resources. Where the individual contacted was unable to comply with the request for an interview, another individual was selected to respond. The views expressed by the persons interviewed appear to be representative of their respective organizations. [52] As Edmonton Power is already involved in assessing the potential of a district heating/cogeneration scheme, the individual in charge of that project, Mr. R. Johnson, was interviewed.

The whole process of providing heat and electricity to urban areas is oriented around the notion of ensuring an adequate supply at a reasonable cost. The electric utilities are concerned with providing electricity in the most economical fashion possible, given a desired level of reliability. Gas utilities view the provision of natural gas in a similar way. The regulatory bodies and the government oversee utlity action in an attempt to ensure that the goals of secure supply and reasonable cost are met.

Fundamental to the notion of a secure supply, however, are views towards anticipated energy demand. And in these processes of heat and electricity provision, the growth of energy demand is largely considered an exogenous variable. Rather than attempt to manage or justify the demand growth, the view within the process appears to be one of meeting the anticipated demand, whatever it may be. Future electricity demand is expected to be handled largely through additions of remote coal-fired thermal plants; projected heat demand is expected to be met through extensions of existing natural gas services (ERCB, 1978). District heating and cogeneration systems are anticipated to play a very minimal role in the future provision of heat and electricity (ERCB, 1978). There appears to be a strong belief within the framework of heat and electricity decision-making that coal-fired thermal plants will provide least-cost

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[52] While the organizations do not have public position papers, organizational views similar to those expressed by the interviewee have been reported by the media.

electricity; and that gas-fired individual building heating systems will continue to provide least-cost heat.

With the exception of Mr. Johnson of Edmonton Power, none of the persons interviewed were extremely familiar with the concepts of district heating and cogeneration. While the meaning of the concepts presented no difficulty, an understanding of the economic way in which district heating/cogeneration systems have developed in northern Europe was generally non-existent. The idea of cogenerating heat and electricity on an economy-of-scale basis dictated by the combined heat and electricity loads appears to be an idea which had not been previously considered within the energy supply framework (Millard, pers. comm.). Electric utility consideration of cogeneration schemes appears to be limited to the special case in which a substantial heat load just happens to be located near a planned thermal generating station. The provision of heat is only considered incidental to the generation of electricity. Still, on an intuitive basis, the gas-fired district heating/cogeneration scheme for urban areas was largely perceived to be uneconomic. It is noteworthy, however, that the individual most familiar with district heating/cogeneration systems, Mr. Johnson, anticipated that they would indeed become economic (Johnson, pers. comm.). This inconsistancy emphasizes the 'blinker' effect of becoming entrenched in existing practices.

Overall, confidence in the existing system of heat and electricity provision and scepticism in the economics of district heating/cogeneration systems serve to give the latter a low priority amongst the energy supply alternatives in Alberta. Low energy prices in

Alberta certainly aid establishing this low priority assessment. A common attitude appears to be that if district heating/cogeneration schemes are to make any breakthrough, it will not be in Alberta (Frazer, pers. comm.). Instead, it will be in provinces not fortunate enough to have Alberta's conditions of energy supply and price. Though pessimistic, this attitude offers a realistic assessment of the likelihood of any early or widespread implementation of district heating/cogeneration schemes in Alberta communities.

Ability of the Process to Respond to Change

While the perceived economics of district heating/cogeneration ventures is likely the most significant factor impeding their introduction, the functioning of the energy supply and pricing process itself may limit the adoption of district heating and cogeneration systems. As described earlier, the process regarding the provision and pricing of utility services is supervised by the ERCB and the PUB.

In Alberta, these regulatory authorities are established as independent quasi-judicial tribunals. Although independent, they are guided by government policy and fixed concepts of regulatory practice as embodied in their enabling statutes. When the tribunals were established, the policy direction and regulatory principles may have been in tune with the times. But with the passage of time, "a gap can easily develop between the policy directives embedded in the regulatory statute, and new lines of policy thinking on the part of society, the industry and the government" (Manning, 1979: 10). Dealing with the changing conditions may be difficult for the regulatory authority unless its enabling statute is altered to reflect such conditions.

The regulatory umbrella which oversees the supply and pricing of utility services in Alberta evolved over a period when fossil fuels were assumed to be cheap and abundant. The social and environmental costs of energy production, transmission and use were assumed to be insignificant. Since the early 1970's, though, both of these assumptions have been questioned. The social/environmental implications of energy use have become increasingly costly. The need to conserve nonrenewable energy resources is becoming fast recognized. The days of cheap and abundant energy have passed (see Section 2.3).

The provincial Cabinet appears to be recognizing these changing conditions. During the 1979 Cold Lake hearings, the Cabinet deemed appropriate an expansion of the ERCB frame of reference to include social factors. This broadened mandate may serve to aid the introduction of district heating/cogeneration ventures. In fact, the ERCB has had the responsibility "to effect the conservation of, and prevent the waste of, the energy resources of Alberta" (Energy Resources Conservation Act, 1971, section 2c). However, the term 'conservation' is interpreted in a very narrow sense. It applies only to the energy industry, not to the end uses of the energy resources.

The PUB is further unable to consider any social factors or specific conservation policy in its approach to rate design (Horton et. al., 1977). The inclusion of social and conservation factors would require provincial government authorization.

Overall though, the Alberta government appears to have a limited concern for energy conservation (see Section 2.1). Of course, Alberta is in the fortunate position of having substantial energy resources within her boundaries. As a result, the provincial government has chosen to protect Alberta consumers from energy price increases rather than use such increases to affect conservation. Yet it is not simply rising energy prices which are burdensome to the consumer, it is the consumer's total energy bill. This is a function of both unit energy prices and units of energy used. As a result, rising energy prices coupled with improvements in efficiency of use could plausibly lead to lower total energy bills.

At some point, the government will have to deal with the present price versus replacement price dichotomy associated with the use of nonrenewable energy resources. These resources can be used over a virtually infinite time horizon, but they can only be used once. Every unit of the resource used leaves one less unit available for future use -- in absolute terms, the supply is depleted. Simple economics dictates that the most easily accessible of the energy reserves is tapped first. They have the lowest production cost. As the resources become less easily accessible, they become more expensive to extract. "Inescapably, whenever the limited supply of a nonrenewable fuel is sufficiently depleted, its price begins to rise exponentially — that is, the higher the price, the faster the price increases" (Commoner, 1978: 10). At least this is what happens if present (historical) prices are used. Replacement prices, on the other hand, would be based on the long run marginal cost of the resource. This is the incremental cost associated with increasing production in the long run (20 to 25 years). For example, the 1980 long run marginal cost of oil would be similar to the present production cost of synthetic oil from the Tar Sands.

If historical prices are used until a resource nears depletion,

> "any increase in price may be too late to evoke any effective conservation measures or any smooth change-over to the use of alternative materials or ways of life" (Helliwell, 1977: 271).

The use of long run marginal costs, on the other hand, may affect strong pressure "to conserve resources and to use them slowly enough for an easy transition to alternative materials or methods to take place" (Helliwell, 1977: 271). A reasonable marginal replacement price has been suggested to be "three times the present market value of the commodity" (Helliwell, 1977: 272). The 1980 long run marginal cost of electricity in Alberta is generally understood to be about three times its present price (Ross, pers. comm.).

As long as the provincial government subsidizes energy consumption, the shift towards the more efficient use of energy will be slow indeed. Provincial government policy, in this way, acts as a clear and substantial barrier in the way of district heating/cogeneration schemes.

5.3 Energy Considerations in the Urban Development Process

Whereas the energy planning and regulation process ensures a supply of utility services, the urban development process, in effect, ensures a demand for heat and electrical services. Urban development is essentially controlled through the land use planning process. Land use planning can be defined as "a rational process of identifying the goals of a community and developing means by which these can be met, through control over the use to which the land is put" (Thomas, 1978: 1).

The Land Development Process

Alberta has had a long tradition of urban planning. Following the rush of settlers at the turn of the century, the Alberta government passed legislation in 1913 enabling municipalities to ensure orderly development of future subdivisions (Town Planning Act, 1913). The concept of zoning was introduced in the Town Planning Act of 1929, allowing municipalities "to prescribe building heights and floor areas, lot size requirements, densities and permissible land uses for different areas within their boundaries" (Thomas, 1978: 2). Urban planning waned during the depression of the 1930's and did not receive critical attention until after the discovery of oil at Leduc in 1947. The subsequent rapid growth of Alberta's major cities "led to the hiring of professional planners, first in Edmonton in 1949, then Calgary in 1951" (Thomas, 1978: 2). Urban planning has remained important since that time.

The Town and Rural Planning Act of 1950 made provision for the formation of District Planning Commissions. These bodies were responsible for preparing general plans and zoning by-laws. The Act also introduced the concept of development control, allowing municipalities to make interim development orders that overrode zoning by-laws while a general plan was being prepared. Zoning and development control are still the principal instruments used by urban planners to control development.

In 1957, the general plan become binding on the municipality. The Planning Act of 1963 vested planning decisions with elected officials, except where they delegated authority elsewhere (Thomas, 1978). Regional Planning Commissions were required and municipal general plans had to conform to regional plans. The latest version of the Planning Act, 1977, represents a culmination of planning themes and ideas as they have evolved in Alberta.

Three of the major concerns expressed in the new Planning Act are that:

(i) land be developed in an orderly fashion,

(ii) local autonomy in shaping land development be maintained, and

(iii) the time required to bring land into use be minimized (Thomas, 1978).

Orderly land development is attained through a system of plans, land-use by-laws, development permits and subdivision controls. [53] The general municipal plan and related land-use by-law designate municipal land uses and development proceedures. Local autonomy is preserved by giving local governments the authority to adopt municipal plans and land-use by-laws. The locally elected officials also have input into the regional plan (to which municipal plans must conform). Minimizing the time required to bring the land onto the market reduces the cost of land development. The Planning Act attempts to reduce the processing time required for subdivision and development permit applications.

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[53] There are four types of plans: Regional, General Municipal, Area Structure and Area Redevelopment. The latter two are more detailed and conform to the General Municipal Plan; and it in turn conforms to the Regional Plan. The land-use by-law incorporates the familiar concepts of zoning and development control.

Energy-use Considerations

What role do energy-use considerations have in this process of urban land development? This question can be answered by a brief look at the process. The general municipal plan is the primary planning document used at the municipal level in Alberta. It is primarily concerned with the physical development of a community; however, social, economic and environmental factors as they relate to the physical development are also considered (Thomas, 1978). The general plan typically identifies "the location of different types of land use, the direction of future growth, the design of the transportation network and the level and location of the utility servicing" (Thomas, 1978: 27). The local council is responsible for the final approval of the general municipal plan and the related land-use by-law. Once adopted by Council, the general municipal plan becomes a guide for the subsequent and more detailed area structure or area redevelopment plans.

During the formulation of the more detailed plans, there is steady interaction (established as a practice) between the planners, the developers and the utility representatives. New subdivisions would come under area structure plans. Gas and electric utilities are informed of the proposed land uses, development sequence and population density by the City Planning Department. They estimate their requirements to ensure a safe and adequate supply of their utility service. The gas and electric utilities also participate in determining the location of distribution mains, substations and other utility facilities. Once Council approves the area structure plan, the developer formulates a more detailed subdivision plan, applies for land use reclassification and, if successful, receives a development permit. The developer then coordinates the installation of services by the various utilities in an attempt to minimize the time required to develop the land into sellable plots.

Area redevelopment plans cover the redevelopment of older neighbourhoods. They are prepared subsequent to the designation of a redevelopment area by the local council. An area may be so designated for numerous reasons, including the improvement of public utilities. Area redevelopment plans could thus include plans to retrofit an area with a district heating system. Again, the utilities would be involved in estimating the demand for the particular service (heat or electricity) and would participate in facility location decisions.

As discussed thus far, the role of energy-use considerations in the urban development process is simply one of ensuring an adequate supply. Forecasts are made of requirements for gas and electricity, and the utilities attempt to meet this forecasted demand. The energy use implications of urban development itself have received limited attention in Alberta. [54] In Calgary, these implications have only recently (1979) been considered (Hayley, pers. comm.).

It does appear, however, that the existing urban development process could technically facilitate planning for district heating/cogeneration schemes. Municipal plans could incorporate district heating/cogeneration networks; the land-use by-law could be used

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[54] Master's Degree Projects by Terry Zdan (1980) and Stephen Tyler (1980) have addressed aspects of this issue.

to ensure 100 per cent connection to the district heating system. The by-law could also be used to ensure densities which improved the economics of district heating. The gas and electric utility involvement in the urban development process could be similarly applied to a district heating/cogeneration scheme.

In practice, though, the introduction of a district heating/cogeneration scheme may not be without difficulty. It may be difficult for the prospective owners of a district heating scheme to become involved in the planning process unless such owners were the gas or the electric utilities already involved (see Section 5.4). The municipal planners and local council would certainly have to appreciate the improved efficiency of energy use associated with district heating. Further, a change in the mode of heat and electricity supply is not likely to be readily accepted by the municipal planners or the local council unless it was proposed by the established utilities. Council's acceptance is certainly needed, given their final authority over planning matters. Yet again, even the utilities may be slow to become involved in district heating/cogeneration schemes, given their scepticism over its economics (see Section 5.2).

Probable Points of Leverage

Within the framework of the urban land development process, the groups which could influence the introduction of district heating/cogeneration systems include the local council, the municipal planners, the local developers and the gas and electric utilities. But while all of these groups may be involved in the introduction of district heating to residential communities, the initiation of such schemes would likely have to come from the latter energy utilities (see Section 5.2). After all, they are the ones who possess the expertise in energy production and distribution. But the doubtful attitude regarding district heating/cogeneration evident in the major gas and electric utilities will certainly limit the early introduction of such schemes. The successful implementation of district heating/cogeneration systems will also be affected by the attitudes and priorities of municipal politicians, planners and developers.

Some of Calgary's local politicians, urban planners and developers were asked about their views on the "most probable" residential district heating/cogeneration scenario discussed earlier (see Section 5.0). Their more general views on the energy-use implications of urban development were also probed (see Appendix II - Methodology). The local politicians' awareness in district heating/cogeneration schemes appears most influenced by whether or not the municipality is involved in electricity generation. Of course, the only two municipalities in Alberta which produce electricity are Edmonton and Medicine Hat. Indeed, both municipalities have examined the potential of utilizing the waste heat of electrical generation. Edmonton has been using their waste heat as an input to the municipal sewage treatment plant; and the City Council has apparently been quite receptive to Edmonton Power's cogeneration study (Johnson, pers. comm.). Medicine Hat expanded their electrical capacity by adding a steam turbine which uses the waste heat of an existing gas turbine; the waste heat is not used in district heating application (Mink, pers. comm.).

Calgary, however, is more representative of most Alberta municipalities in that the City is only involved in electricity distribution, not generation. In Calgary, the City Council seems to have little or no concern for the energy-use implications of urban development. As long as the price of energy remains low, the significance of its use will remain a low priority for most of the local politicians. The City Council tends to approach issues on more of a "crisis planning" basis -- when change is necessary, steps will be taken to implement the change (Husband, pers. comm.). District heating is obviously a low priority issue.

District heating/cogeneration schemes are not high priority concerns of municipal planners either. While the planners may be familiar with the energy-use implications of urban development, energy conservation has not normally received attention in planning matters. In Calgary, 1979 marked the first year that energy conservation became one of the criteria for some future city developments -- opportunities for conserving energy through subdivision design were considered (Hayley, pers. comm.). Most of the measures examined dealt with passive utilization of the sun, but they also looked at increasing efficiency through smaller lots and denser urban form. The Planning Department feels that the onus is on the developer to initiate energy conservation measures in residential areas (Hayley, pers. comm.). Similarly, it feels that the initiative to conserve energy in the provision of heat and electricity should come from the utility companies. Apparently, the City Planning Department would respond "very positively" to utility company proposals for district heating/cogeneration schemes (Steber, pers. comm.).

The attitudes of local developers will further influence the introduction of district heating/cogeneration schemes. The bottom line for developers is marketability. They have to be able to sell what they build. In the residential market, the developer makes a best guess at what the consumer desires. When energy prices are low, the consumer is not deemed to be particularily concerned with energy conservation. Consumers are believed to be unwilling to pay additional capital costs in order to save energy operating costs (Lanni, pers. comm.). With housing prices as high as they are in Calgary, the developer spends more time looking for immediate capital cost savings (Thomas, pers. comm.). The market for energy-conservative housing is felt to be limited in Calgary (Thomas, pers. comm.). The primary concern of developers regarding any proposed energy conservation measure (including district heating) would be what its impact was on the marketability of housing. Any measure which adds to the cost of housing but does not also significantly increase the marketability of the housing will be viewed as undesirable by developers. Utility-proposed district heating/cogeneration schemes should not increase the cost of housing. The costs of the system would likely be recovered through consumer payments, and the time required to install the distribution network should be no longer than that required to install a gas distribution network. Developers, then, are not likely to be opposed to the introduction of district heating/cogeneration systems. And if energy conservation becomes a marketable feature (e.g., through energy price increases), district heating/cogeneration systems may become viewed as attractive.

Overall, the land development process does not offer any insurmountable barriers to the introduction of district heating/cogeneration systems. However, energy conservation has not yet become an issue of importance -- energy prices are too low to cause concern. There is a general contentment with the conventional system of residential gas and electricity provision, and a lack of awareness of alternatives to it. As a result, urban residential areas continue to develop as though energy was no concern, establishing an inefficient infrastructure that will become burdensome in the future.

5.4 Other Institutional Barriers

There are other administrative, organizational and social conditions which act to impede the introduction of district heating/cogeneration schemes in Alberta. Difficulties arise with respect to regulatory aspects of district heating/cogeneration systems, ownership and operation of the systems, capital funding of the systems and public attitudes towards such systems.

Regulatory Aspects

Much of Alberta's existing legislation was drafted prior to a contemplation of district heating/cogeneration schemes. As a result, the regulatory climate surrounding such schemes is uncertain. This uncertainty acts as a disincentive to prospective owners of district heating/cogeneration systems.

In Alberta, residential district heating/cogeneration systems will surely be classified as "public utilities", in that thay provide heat and electricity for use by the public. Investor-owned systems would fall under the purview of the PUB; government-owned systems would not be under PUB jurisdiction unless they elected to have such control. At any rate, system costs would likely be allocated in the usual public utility manner -- on a cost of service basis. And if the district heating/cogeneration systems were under PUB review, they would have to demonstrate that they offered a better cost and reliability combination than existing systems of heat and electricity provision. As the costs are always more certain for the existing systems, there tends to be a bias for the status quo. This exemplifies the need for demonstration projects and, in Alberta, gives importance to the Edmonton Power cogeneration project. The introduction of district heating/cogeneration systems on any scale in Alberta will be very dependent on the success of the Edmonton Power scheme.

Another area of regulatory uncertainty would be over the allocation of costs between the heat and electricity outputs of cogeneration schemes. Obviously, some costs will be attributed solely to electrical output (for example, turbine capital costs) and others solely to heat output (for example, distribution capital costs). But there will also be costs which must be split between heat use and electrical use. The most significant of these common costs is the cost of fuel.

There would be a range within which fuel charges could be allocated. At one end, the cost of electrical output could include fuel costs equivalent to those incurred by conventional generating stations of identical size and age. The balance of the fuel costs could then be charged to heat use. Electrical consumers would thus receive no benefit from cogeneration; the total benefit would go towards the heat users (Outhit, 1978).

At the other end, only the energy content of electricity produced could be charged to the turbine. The remainder could be charged to heat production. In this case, the electricity consumers would receive the whole benefit of the cogeneration venture (Outhit, 1978). A balance would have to be struck within this range that would benefit both the heat and electricity users.

Overall, the uncertainty of rate regulation is not likely to impose a major obstacle to district heating. The more significant regulatory impediment will arise through the need to demonstrate a preferred combination of system economics and reliability. The present modes of heat and electricity provision are well established. Estimates of their costs and reliability levels can be made with more certainty than that of the less familiar district heating/cogeneration systems. An uncertain regulatory body stand on district heating/cogeneration will make potential system owners apprehensive about introducing or building district heating/cogeneration systems. This becomes particularily critical when coupled with the general doubt over district heating/cogeneration systems economics and the lack of some expertise and commitment to them within the utilities.

Ownership and Operation

The ownership and operation of district heating/cogeneration ventures could be in the hands of the private sector, the public sector or both. Certainly, the most likely candidates for ownership and operation are those already involved in the provision of gas and electricity. Not only do they possess some relevant technical and administrative expertise, they also already have a role to play within the energy planning and urban development processes. They would however require additional expertise with respect to moving heat. It would not be impossible for an independent organization to undertake a district heating/cogeneration venture, yet more barriers would certainly be encountered. An independent firm would have to acquire the relevant expertise, become a public utility, compete in a marketplace dominated by a handful of large firms and establish credibility in well established energy planning and land development processes. [55]

In Alberta, the provision of gas and electricity is handled by both public and private interests. There are, however, no blatantly obvious ownership candidates for district heating/cogeneration schemes as the provision of heat has been independent from the provision of electricity. [56] If district heating/cogeneration systems were to develop fol-

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[55] There may be a role for AGTL or the Alberta Energy Company in this position. AGTL has relevant technical expertise, is a public utility and has a credible reputation. The Alberta Energy Company is similarly established.

[56] Even within Canadian Utilities, the gas utilities (Northwestern Utilities and Canadian Western Natural Gas) are run more or less independently from the electric utility (Alberta Power).

lowing the European example -- in stages from temporary boilers to permanent cogeneration plants -- then some coordination would be required between the suppliers of heat and the suppliers of electricity. Given the existing system of heat and electricity provision in Alberta, the most likely modes of district heating/cogeneration ownership would seem to be joint ventures between two private utilities, joint ventures between a private and a public utility, or completely public ventures.

The private-ownership joint venture would of course be between a gas distribution utility and an electricity producing utility. The gas utility may be responsible for the heat output; the electric utility may be responsible for the electrical output and facilities; the responsibility over common facilities and costs would be equitably split. Likely, one or the other of the utilities would be responsible for the overall operation. Both utilities would be under regulatory body jurisdiction, ensuring that a safe and adequate supply was provided at a reasonable price. Clearly, a considerable amount of inter-utility planning would be required to ensure that cogeneration facilities were brought on line at the most economic time. While either utility could conceivably own and operate a district heating/cogeneration system by itself, a joint venture would facilitate the negotiation required to overcome the potential problems associated with the gas utility selling electricity or the electric utility selling heat.

A second type of district heating/cogeneration scheme ownership could be between a privately-owned gas utility and a municipally-owned electric generation or distribution utility. For example, a venture could be pursued by Canadian Western Natural Gas and the City of Calgary

Electric System. Such a joint venture would function just as the private joint venture, except that the municipally-owned utility may not be subject to regulatory body authority. Actually, this type of ownership is probably the least likely of the three suggested. If the heating aspect of the venture was revenue-generating, the municipality may consider owning and operating it as well as the electricity aspect.

In a third mode of scheme ownership, the public sector would handle all aspects of the district heating/cogeneration scheme. The division of responsibilities explicit and implied under the BNA Act would suggest that public ownership and operation would rest with the provinces rather than the federal government. And given the local nature of district heating systems and municipal involvement in the electricity sector, the Alberta government would likely give jurisdiction over such systems to the municipalities. In fact, the Municipal Government Act (1977) formally enables municipalities to own and operate district heating/cogeneration systems (Municipal Government Act, section 273). The municipality may or may not combine heat and electricity responsibilities under one body; but there would be some need for coordination of responsibilities if cogeneration was anticipated. Rate regulation would not necessarily fall under the purview of the PUB. However, plans for electricity generation would be subject to ERCB approval. Generation planning would probably involve coordination with the EUPC. Edmonton Power, if it were to undertake a district heating/cogeneration venture, would provide an example of public sector ownership.

In the case of new towns (not uncommon in Alberta), though, the Alberta government could participate directly in the introduction of district heating/cogeneration systems. The provincial government and local industry are already funding most of the infrastructure costs of new towns. The provision of district heat, rather than natural gas, could be incorporated into the service installation plans of such towns.

Private sector participation in district heating/cogeneration schemes would only occur if the schemes were financially attractive. Both the investors and the regulatory bodies would require financial viability. Governments, on the other hand, are not always expected to show a profit. However, it appears unlikely, given tight municipal budgetary constraints, that any municipality would undertake such schemes unless they were financially viable. Again, then, the economic attractiveness is a major consideration respecting the introduction of district heating/cogeneration schemes.

. Capital Funding

Closely related to the issues of regulation and ownership is the issue of capital funding. The initial capital investment for district heating schemes appears to be 2 to 3 times greater than that for individual heating systems (ASL, 1977a). Rising fuel costs may make district heating a less expensive alternative over the long term, however

> "in times of high costs of money and general financial restraint in both government and the private sector, it is unfortunately difficult to be too concerned about the long term" (Smith, Auld, & Assoc., 1976: 21).

The capital funding of district heating/cogeneration ventures thus becomes an important consideration.

In Alberta, the private sector financing of investor-owned utilities is largely influenced by the PUB regulatory decisions. The financing of investor-owned district heating/cogeneration ventures would be similarily influenced. The PUB recognizes that "regulation must take a realistic view of the cost of risk capital and the investors must be assured that their investments will yield a fair rate of return" (PUB, 1978: 14). As long as utility companies can attain a reasonable rate of return, they should generally be able to attract their required investment capital. But before any investor-owned utility could recover any expenditure on district heating/cogeneration, the utility would have to demonstrate the prudence of such an expenditure to the PUB. Otherwise, rate approval would not be obtained and the utility's financial status would be in jeopardy.

Public sector financing could theoretically come from any level of government. More realistically, though, only the federal and provincial governments could make funds available. Few local governments could afford to designate the funds required towards a district heating/cogeneration scheme. The public sector could help establish the financial viability of district heating/cogeneration ventures through funding of demonstration projects. Once the financial viability becomes established, the private investment community may be more willing to finance district heating/cogeneration ventures.

Public funds could be directly earmarked for district heating/cogeneration projects, or they could be provided indirectly through conditional grants or loans. Indirect funding would specify district heating/cogeneration as a condition of eligibility. Edmonton

Power's cogeneration study has received direct funding from the Energy Resources Research Fund (ERRF) -- a fund jointly administered by the Alberta and federal governments. Appropriate tax write-offs and other government fiscal levers would ease the initial financial burden and attract private funds.

Given the Alberta government policy of subsidizing the use of natural gas within the province (see Section 5.1), an argument for provincial government funding of district heating schemes can be readily suggested. District heating schemes would reduce the amount of natural gas used in providing heat (see Section 4.3). By conserving gas, such schemes would be saving the government money that would otherwise be used in the gas subsidy. Anything which conserves gas saves money for the government!

While the levels of capital investment required for district heating/cogeneration schemes may initially present a substantial hurdle, appropriate government funding and fiscal measures would encourage such ventures. Demonstration projects should be publicly funded to help show the financial viability of such systems. Once their financial viability becomes established, private sector financing of district heating/cogeneration schemes should become attractive.

Public Attitudes

Public attitudes (actual or perceived) towards energy conservation and district heating will further affect the introduction of district heating/cogeneration schemes into residential areas.

As the cost of nonrenewable energy continues to increase, energy conservation may become recognized by the public as a valuable pursuit. Such public recognition would cause various spinoffs. Energy efficiency would become a marketable feature of products or designs. Developers would be able to use the district heating feature to enhance the marketability of a housing area. There would be more public demands on the political machine for greater encouragement of energy conservation. Political bodies would be less apprehensive about enforcing a shift towards increased energy efficiency. Clearly, these sorts of spinoffs would favor the introduction of district heating/cogeneration schemes. However, as long as energy prices remain low compared to their long-run replacement cost, the public will tend to remain apathetic towards energy conservation. Such apathy would present a barrier to the early introduction of district heating/cogeneration schemes.

The terms district heating and cogeneration probably mean nothing to the general public. Specific public attitudes, as they develop, will likely be a reflection of the impact of district heating/cogeneration schemes on consumer housing and energy costs. The impact of district heating on housing costs will be dependent upon the way in which the scheme is paid for, the time required for development approval and the marketability of energy efficiency. If scheme costs are recovered in the same manner as existing natural gas distribution facilities, there would be little impact on the cost of housing. If district heating/cogeneration schemes increase the length of time required for development approval, then the developer may try to recover this lost time through increased housing prices. Ultimately, though, the developer can only recover what the market will bear. If there is a demand for energy efficient housing, then housing in district heated communities may be more expensive than in other communities.

Consumer savings from reduced energy expenditures will again be dependent upon the way in which the system costs are recovered. If the plant and distribution network are paid for over the service life of the facilities, based on some rate formula similar to gas or electricity rates, then savings by the householder could appear soon after connection (provided, of course, that district heating was economic). Early savings would help in gaining public acceptance of district heating/cogeneration schemes. The idea of making higher initial payments in order to obtain future savings is not likely to appeal to any temporary householders (ASL, 1976). If however, energy conservation becomes a marketable housing feature, housing in district heated communities may command a higher resale value and be attractive to both temporary and permanent home-owners.

Public acceptance of district heating/cogeneration schemes would also be influenced by the aesthetics of the local energy plants. If heating plants were considered to be eyesores in the community, public acceptance (and developer acceptance) of district heating systems would be difficult to attain.

Overall, the difficulties with respect to regulation, ownership, capital funding and public acceptance do not impose insurmountable barriers to district heating. In a way, they are all somewhat dependent upon one other variable -- the price of energy. As energy prices rise, public appreciation of energy conservation and efficiency improvements will likely increase. District heating/cogeneration ventures will become more and more financially attractive. And finally, the owners of such schemes will be able to attract investment capital and win regulatory body approval.

5.5 Summary

In Alberta, the framework within which energy supply decisions and urban development decisions are made is capable of accommodating the introduction of district heating/cogeneration systems for residential communities. However, before an introduction of any reasonable scale could occur, the financial viability of district heating/cogeneration ventures would have to be clearly demonstrated. [58] In other words, the direct costs of district heating/cogeneration ventures would have to show a competitive advantage over the conventional systems of heat and electricity provision. District heating/cogeneration systems would have to provide a safe and adequate supply of heat and electricity at a reasonable cost.

If district heating/cogeneration systems in Alberta were to develop on a basis similar to the European example -- initially providing heat only and cogenerating heat and electricity once the heat load was large enough to justify the expenditure -- then gas utilities, as indirect

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[58] Or district heating/cogeneration systems would have to be deemed to be in the public interest, in which case the government may be willing to fund, subsidize or otherwise encourage such systems.

providers of heat, may be the first to be in the position of making a district heating expenditure. However, the gas utilities would have to be sold on the district heating concept. Its financial viability would have to be demonstrated in order that the utility could obtain the required investment capital and downstream approval of the PUB. Uncertain regulatory body views on district heating/cogeneration would tend to delay utility involvement. Further, as long as the PUB is only able to consider the direct costs of district heating/cogeneration schemes, the energy conservation and environmental benefits of such ventures will only receive passing attention. Government, regulatory body and utility scepticism over the economics of district heating/cogeneration systems indicate that the opportunities of such systems will remain limited for some time.

Changes in provincial government policy would significantly alter the outlook for district heating/cogeneration systems. Certainly, the major reason why the economics of district heating systems appear dismal is because conventional heating systems are fueled by artificially inexpensive natural gas. The provincial government has a policy of protecting consumers from gas price increases by subsidization rather than by improvements in efficiency of use. It is very difficult to see what benefits this subsidization will yield in the long run. The provincial government has, as a rule, shown little concern for energy conservation. As long as this lack of concern prevails in provincial government ranks, a shift towards district heating and other more efficient use of energy will be slow indeed.

The economics of district heating/cogeneration systems could also be improved through a more dense urban form. However, the energy-use implications of urban development have traditionally received little attention in the urban planning process. No doubt, this is a reflection of the 1950's and 1960's assumption of energy abundance. Artificially low energy prices cause such assumptions to persist.

There is certainly a need for demonstration projects in Alberta and the rest of Canada to reveal the financial prospects of district heating/cogeneration systems. The financial viability of these and conventional systems should be examined under true economic conditions. The use of subsidized energy costs and the neglect of social and environmental costs results in an imperfect account of the status of district heating schemes.

With respect to the introduction of district heating/cogeneration schemes to residential communities, it appears that Alberta will be following examples that will be set by other provinces in the country.

6.0 POLICY RECOMMENDATIONS

Decisions on energy policy must be approached from a holistic perspective. They must take into account the implications of energy use on the economy, the environment and society in both the short and the long term. Unfortunately, the exact nature of the relationship between energy and other aspects of society is not fully understood.

One can only speculate about the credits and the drawbacks of alternative energy futures. There are, however, long-term limitations to historical trends in energy use. The days of cheap and abundant fossil fuels have passed. A transition away from the dominant use of petroleum fuels will occur. Policy-makers must analyze the virtues of different energy scenarios and help steer society in the direction of optimum social welfare (see Chapter 2).

There is certainly a need for data collection regarding the social consequences of alternative energy futures. As information is gathered, the uncertainty will be reduced. Given the present uncertainly, though, the most immediate action for energy policy-makers should be one of keeping options open -- ensuring that present actions do not foreclose future electives. The best way to maintain future energy possibilities is to take steps to conserve energy. Reducing the demand for energy not only keeps options open, it also 'buys' the additional time required to more effectively evaluate future energy scenarios.

Increasing the efficiency of energy use is one way of reducing energy demand. District heating/cogeneration systems can be 30 to 70 per cent more efficient than existing systems in providing heat and electricity to residential communities (see Section 4.3). District heating systems also offer the long-term advantage of being free from dependence on any one fuel type (see Section 3.3). However, there are some impediments to the early implementation of district heating/cogeneration schemes (see Chapter 5). If such schemes were deemed to be in the public interest, these barriers could be overcome through appropriate government policy.

6.1 Encouraging District Heating

While energy conservation does not appear to be a serious objective of federal energy policy, the federal government has taken some steps in that direction. The Alberta government has been somewhat less active in encouraging energy conservation (see Section 2.1). The combination of substantial provincial energy resources and passive government interest in conservation does not serve to aid the cause of district heating/cogeneration in Alberta. Accordingly, the chances of an early implementation of residential district heating schemes in Alberta are remote.

All three levels of government -- federal, provincial and municipal -- could be involved in encouraging district heating in Alberta. Several steps towards facilitating an introduction of district heating/cogeneration schemes could be taken. These would include:

(i) raising energy prices,

(ii) increasing awareness of district heating,

(iii) funding demonstration projects,

(iv) offerring financial incentives,

(v) commencing upstream regulation of heat provision

(vi) overcoming administrative difficulties, and

(vii) designing appropriate land use controls.

Increasing Energy Prices

Surely the most significant barriers to an early introduction of district heating/cogeneration schemes are the low prices paid for natural gas and electricity. Increasing energy prices is an Alberta government concern.

In Alberta, the price of natural gas is somewhat tied to the world price of oil. However, whenever there is an agreement to raise the price of natural gas, the Alberta consumer is charged for only 25 per cent of that price hike. The Alberta government carries the other 75 per cent of the price increase through its natural gas rebates scheme. For the 1979-80 fiscal year, the budget for this subsidy is $140 million (Ross, 1980). This policy amounts to a subsidy in favor of individual building heating systems and energy inefficiency.

Electricity prices are related to the cost of coal and are not likely to be tied to the world oil price. Electricity costs in Alberta are far lower than rates in Europe and are likely to stay that way for some time. Combined electricity and heat production, while certainly energy efficient, does not yet appear to be competitive with large scale electrical generation.

Neither gas nor electricity rates bear any resemblence to their long-term replacement costs. They are much lower. The current long run marginal cost of electricity is about three times the current average price; current natural gas prices are likely a similar proportion of their long run replacement cost (see Section 5.2).

Regulations governing utility rates are not broad enough to include any social costs or specific conservation policy. The Alberta government should take steps in this area to expand the mandate given to the PUB. In the interests of future generations, the rates charged should be high enough to slow down resource consumption to a level which facilitates a smooth transition to alternative materials or methods. Such a price level would certainly encourage district heating/cogeneration and other energy efficient technologies.

The burden of increasing energy prices on the consumer can be offset. The Alberta government has and will continue to recover a large part of the private sector windfalls associated with higher energy prices. The government could use these funds to reward or subsidize Albertans through enhanced service provision or energy-efficient technology promotion. There is no need to provide the subsidy in such a way "that only those who waste our nonrenewable resources benefit significantly from the subsidy" (Ross, 1980: 5).

Further, it is not simply rising energy prices that are a burden to the consumer; it is his total energy bill. This is a function of both unit energy prices and units of energy used. Reducing the energy used (through improvements in efficiency) while paying higher unit prices could, in fact, result in a lower total energy bill. Thus, rising energy prices <u>do</u> <u>not</u> necessitate an extra burden on the consumer. Rising energy prices do, however, make energy conservation a more pressing concern.

Increasing Awareness of District Heating

Within the energy supply and urban development processes, knowledge of district heating/cogeneration systems is limited. There is a general contentment both on the supply and on the demand side with the existing system of gas and electricity provision. Alternatives to the system, like district heating/cogeneration, are largely not considered within either the energy supply process or the urban development process.

Increasing the awareness of district heating would be an appropriate role for either the federal of the provincial government. The federal government has already undertaken and made available several preliminary feasibility studies on district heating. Inviting Scandinavian experts to government-sponsered energy conferences would further spread the awareness of the technology and its potential.

It is most important that the awareness is acquired at the various leverage points in the energy supply and urban development processes. To some extent, people involved in these processes became informed on district heating/cogeneration systems when they were interviewed. The European mode of district heating development -- providing heat and power based on the economics of the combined heat and electricity loads -- was largely unfamiliar. The ERCB has indicated a willingness to undertake a study of district heating/cogeneration looking at these economies under Alberta conditions (Millard, pers. comm.).

Developers and entrepreneurs should also recognize the advantages of district heating/cogeneration schemes. Innovative entrepreneurs could certainly help encourage the introduction of such schemes. They would, however, encounter barriers to direct ownership and operation --

acquiring the relevant technical expertise, having to become a public utility, entering a well-established energy marketplace.

Funding Demonstration Projects

Funds for demonstration projects could come from either the federal or the provincial government. Municipal governments tend to be under tighter budgetary constraints.

Indeed, the Edmonton Power cogeneration study is being jointly funded by the federal and provincial governments through the Energy Resources Research Fund. Funding for the project, if it was to be undertaken, has not been confirmed.

The Edmonton Power study looks at a fairly high density commercial load. The potential of district heating/cogeneration systems for a lower density residential load needs examination. Likewise, the application of other Canadian demonstration projects (as they are undertaken) to Alberta conditions should be examined.

The provincial government is in a particularily favorable position to fund district heating demonstration projects for new towns. The Alberta government and local industry are already funding most of the infrastructure costs of new towns. Investments in an energy-efficient infrastructure would save the government money (see Section 5.4).

As long as the financial viability of district heating/cogeneration ventures is uncertain, government willingness to fund demonstration projects will be important. Without initial government funding, district heating/cogeneration ventures are less likely to be seriously examined.

Offering Financial Incentives

District heating/cogeneration ventures could be encouraged through federal or provincial financial incentives. Appropriate depreciation allowances, direct funding, mortgage subsidies, tax incentives or rate subsidies could increase the economic attractiveness of district heating/cogeneration schemes.

Commencing Upstream Regulation of Heat Provision

As district heating becomes a more economic alternative, it may be wise for the provincial government to initiate some regulation over the provision of heat before natural gas distribution facilities are installed. The process respecting the provision of heat (gas) assumes that gas distribution to individually heated buildings is the most economically efficient method of provision. The only regulatory check on the prudence of expenditures is the downstream -- after facilities are installed -- purview of the PUB. And at that, the PUB can only evaluate gas utility expenditures within the arena of gas provision. At a minimum, the PUB mandate should be sufficiently broadened so that these expenditures can be evaluated within the arena of *heat* provision. This would at least open the door to the district heating alternative (see Section 5.2).

Upstream regulation of heat provision (in addition to electricity provision) would result in a more serious examination of the potential of district heating/cogeneration systems by the regulatory bodies. The ERCB should be involved in this upstream regulation. After all, the ERCB has the responsibility "to effect the conservation of, and prevent the waste of, the energy resources of Alberta" (see Section 5.2). While the term 'conservation' has been interpreted in a very narrow sense, the provincial government should ensourage the ERCB to broaden their interpretation to include the end uses of energy. In this way, the ERCB could ensure that heat and electricity are provided in a more economically and energy efficient manner.

Upstream regulation of heat provision would also lessen the extent of regulatory uncertainty surrounding district heating/cogeneration ventures. This may give the established utilities more incentive to become involved in such ventures.

Overcoming Administrational Difficulties

The Alberta government should take steps to overcome the administrational problems related to the ownership and operation of district heating/cogeneration schemes. Administrational difficulties arise because the processes respecting residential gas and electricity distribution are virtually independent. Further, for the most part, residential gas provision is privately-owned whereas residential electricity distribution is within the public domain.

The provincial government should give appropriate direction to the regulatory bodies so that the magnitude of these administrative hurdles can be minimized.

One private firm, Canadian Utilities Limited (CUL), is involved in both gas and electricity distribution. While a venture in combined heat and electricity production for CUL would certainly encounter fewer administrative problems, the Company does not have franchises for electricity distribution in areas with substantial heat loads (e.g. Calgary, Edmonton). However, CUL should keep an eye on the fast-growing centres in the Peace River and Fort McMurray areas where its franchises for gas and electricity provision overlap.

Designing Appropriate Land Use Controls

Urban planning, while it may be influenced by the provincial government, is a responsibility primarily given to the municipal governments. The energy-use implications of urban development have not traditionally received attention. Much can be done to conserve energy through appropriate land-use controls.

The economics of district heating/cogeneration schemes can be improved through higher density heat loads (than those of most Alberta residential communities) and 100 per cent consumer connection to the district heating system. Urban planning, with district heating in mind, could take these factors into account. Land-use by-laws could ensure that both conditions pervailed.

All of these measures will require trade-offs with other government goals or ideals. Certainly, they all require a government commitment towards the conservation of energy. Only with such a commitment will the transition to a more energy efficient future be attained.

6.2 Suggestions For Further Study

Since time and budgetary constraints precluded work on all aspects of district heating policy, further study is suggested:

(i) a more detailed economic analysis should be performed, applying the European mode of district heating development to Alberta energy, residential and climatic conditions. An attempt could be made to estimate the price levels at which district heat-only and district heating/cogeneration schemes become economic.

(ii) the cost- and energy-effectiveness of district heating investments should be compared to other investments in energy efficiency.

(iii) a more detailed study should be made on the energy-use implications of urban development.

(iv) data should be collected on the social, economic and environmental consequences of alternative energy futures.

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APPENDIX I -- THE ENERGY-CAPITAL TRADEOFF

The average residential consumer in Alberta uses 227 GJ of natural gas and 26.6 GJ of electricity per year (PUB, 1979). If residential furnaces burn natural gas with an efficiency of 60 per cent (some studies have shown this to be 40 per cent), then the heat requirement amounts to 137 GJ.

Typical gas-fired cogeneration facilities attain efficiencies of about 75 per cent (25 % electricity, 50 % heat, 25 % waste). 106.4 GJ of natural gas would thus produce 26.6 GJ of electricity, 53.2 GJ of heat and 26.6 GJ of wasted energy (this includes distribution losses). This satisfies the electricity requirement and part of the heat requirement.

The additional heat requirement of 84 GJ (137 - 52) would be generated in gas-fired boilers, operating at 80 per cent efficiency. 105 GJ of natural gas would provide this heat. The total energy used by the district heating/cogeneration scheme to satisfy the requirements of one residential consumer would thus amount to 211.4 GJ (106.4 + 105) of natural gas.

The conventional scheme would use 227 GJ of natural gas and about 76 GJ of coal. Less energy is used in providing both heat and electricity under the cogeneration scheme than in providing heat only under the conventional scheme.

However, the cogeneration schemes are probably more capital-intensive. (The uncertainty here arises over the capital costs associated with electricity transmission which would not be required under the cogeneration schemes.) As a result, an economic comparison of the schemes rests on the tradoff between the cost of capital and the cost of energy.

District heat-only systems can be similarly compared to conventional natural gas distribution systems. They are more capital-intensive but less energy-intensive. Higher energy prices favor the more energy efficient district heat-only or cogeneration systems.

APPENDIX II -- METHODOLOGY

The focus of this Master's Degree Project examines the institutional barriers which impede the early introduction of residential district heating/cogeneration schemes. Prior to identifying such barriers though, one must acquire a sense for what avenue or implementation route would encounter the least resistance. Clearly, there could be several possible ways of introducing district heating/cogeneration systems to residential areas. However, one would think that the chances for a successful implementation could be greatest along the avenue of least resistance.

In order to identify such a path, I felt it was important first, to gain a sound understanding of district heating technology and economics and second, to become familiar with the Alberta framework within which decisions regarding residential energy provision are made. I acquired an understanding of district heating technology, economics and success in Europe through a literature review.

The process surrounding the provision of heat and electricity to Alberta residential communities is not well documented in the literature. I obtained information about this process through communication with people in provincial government departments (Energy and Natural Resources, Utilities and Telephones, Municipal Affairs); in provincial regulatory bodies (Energy Resources Conservation Board, Public Utilities Board); in municipal government departments (City of Calgary Engineering Department, City of Calgary Electric System, City of Calgary Planning Department); in the energy supply industry (Calgary Power Limited, Alberta Power Limited, Edmonton Power, Electric Utilities Planning Council, Canadian Western Natural Gas, Alberta Gas Trunk Line); in the energy consulting business (Manning Consultants, Stanley Associates Engineering); and in the land development industry (Nu-West Development Corporation, Genstar Development Corporation). I also communicated with one municipal politician (Greg Husband), one MLA (Mervin Leitch) and several university professors (James McKellar, Phil Elder, Dr. Grant MacEwan).

Information on the early growth (1890-1945) of the electric and gas utilities in the province was fairly scant, but I felt that it was sufficient for my purpose of establishing trends. Some early conditions were extrapolated from Saskatchewan's experience in the utility industry documented by White (1976). Dr. Grant MacEwan and Marcel Chorel provided me with other relevant information. Back issues of The Financial Post, early government statutes and early private acts were searched as well.

A very good overview of the electric energy planning and pricing process was documented in Manning (1978) and Manning (1979). This information helped me in further identifying leverage points within the process and was an aid in subsequent interviews with these people.

I learned of the role that gas and electricity provision played in the urban development process through discussions with people in the energy supply industry, in municipal planning and engineering and in the land development industry. On the urban development side, the provision of energy seemed to be taken forgranted -- questions of energy supply seemed beyond their control or interest. As a result, I figured that initiation of district heating schemes would likely have to come from the energy supply industry.

Knowledge of provincial government energy policy and regulation was acquired through communication with the Provincial Minister of Energy and Natural Resources (Mervin Leitch) and individuals in Alberta Energy and Natural Resources (Ian Burn, John Wood), the Energy Resources Conservation Board (notably Vernon Millard) and the Public Utilities Board (Neil MacDonald).

The synthesis of this information and its implications on the early introduction of residential district heating in Alberta remain my responsibility and reflect 'what I think I see'.