combining thermal spring water with wind-generated electricity for greenhouse operations. For example, greenhouses above the Arctic Circle near Nome could supply year-round green vegetables to Seward Peninsula consumers, and export products to other Alaskan communities.

Refrigeration

Another important Alaskan windmill application could be wind-powered refrigeration units. The preservation of meat and other foods is a major problem in many communities where harvesting occurs during warm weather. The Alaskan summers are long and warm, and sometimes hot, even above the Arctic Circle. Adequately-insulated wind-powered refrigerators would not require much, if any, electrical energy storage if frozen brine cold storage techniques were used.

ALASKAN AGRICULTURE AND THE ENERGY PROBLEM

Logistics

The primary energy source for modern agricultural food production remains the sun; however, man has learned that he can increase productivity of his food crops by modifying the plants' environment for maximum capture of sunlight. This environment modification is largely dependent upon the use of fossil fuels to supply the required technological materials such as machinery, plastics, pesticides and petroleum for heating, farming, drying, processing and transportation.

Work specialization, decrease of the agrarian society, better balanced nutrition, movement to northern climates and an increased consumption of products contributing to a quality of living all play a significant role in an increasing energy intensive food and fibre production, processing and distribution system.

Alaska, one-fifth the size of the 48 conterminous states, produces a relatively small amount of the agricultural products consumed by its own population. Alaska has large acreages of land suitable for potential agricultural production (cropland, rangeland and forest) (A.P.C., 1974). Many plants are well-adapted to Alaska's climates. During the Alaskan growing season, there are more hours of sunshine than during a comparable calendar period in the more southern latitudes (Dinkel, et al., 1976). The long summer days contribute to larger, tastier and more tender vegetables. Grains are often higher in protein content. In some cases, yields are even greater than in the best agricultural areas of the United States.

Increasing Alaskan and world population will inevitably require utilization of northern areas and development of new methods for food production in these northern areas. Development of various natural resources (particularly in the petroleum indu..ry) indicate future social and economic development of Alaska. A , the Native Land Claims Settlement, the Rural Development Act of 1972, and the continuing industrialization of Alaska's cities will stimulate development of the State. The world situation that puts agricultural products on the world market will certainly create expanding demand for United States agricultural products and inhibit the development of a United States surplus.

Alaska is at the end of the nation's food system and would suffer the most direct and immediate impact from natural disasters such as prolonged droughts, floods, virulent disease among plants and animals, extreme climatic change and unpredictable weather in the continental United States.

Fuel price increases will undoubtedly have a great effect on the cost of foods shipped to Alaska and on the cost of producing these foods in the more southern latitudes. It is not a wise use of the nation's Alaska produced petroleum to ship it to southern latitudes to produce foods that will later be shipped back to Alaska if we can produce the foods here for a nearly similar energy use on the farm. Alaskan food production will save the 9-15% energy consumption required to transport the oil to the southern agricultural areas and also save the energy now required to ship the foods to Alaska.

Much of the energy required to produce the intensively cultured crops in Alaska is in the form of heat requirements. This energy is used to heat greenhouses and animal shelters, to warm soils, and to dry livestock feed. The wise use of Alaska's wind, geothermal, hydroelectric and waste heat energy sources for agricultural production in Alaska will reduce the nation's use of fossil fuels. This Alaska production will also increase the nation's agricultural land base which is rapidly dwindling in the southern states.

Controlled Environment Systems

Although vegetables are grown during the relatively short summer growing season in many rural areas and communities, only a very small portion of the summer crop can be preserved for consumption during the other months of the year. The high cost of fuel and electricity has prohibited large-scale greenhouse operations, and hydroponic gardening has not yet been attempted in the rural areas for the same reasons.

Controlled environment experiments at the University of Arizona's Environmental Research Laboratory, and the Phyto-Engineering Laboratory of the Agricultural Research Service at Beltsville, Maryland, have demonstrated that certain plants are capable of growing up to 10 to 50 times faster under controlled environments than by conventional growing means, and that the yields in tons per acre can be greatly increased.

Accelerated growth rates and vastly increased yields per unit acre are being developed through the use of higher CO_2 levels, controlled humidity and temperature, artificial lighting and the supply of the proper nutrients through automatic systems.

Hydroponically-grown and sub-irrigation grown lettuce, tomatoes and cucumbers already bring premium prices because of their quality and year-round availability. The yields of such premium produce would be greater under ideal controlled environment conditions. Premium hydroponically-grown tomatoes are now being grown and marketed in Anchorage, with considerable success, by Mosesian Farms.

Recent experiments conducted by Donald H. Dinkel of the Institute of Agricultural Science, University of Alaska, on the Fairbanks campus, have shown that controlled environment facilities have excellent potential for producing year-round salad vegetable crops in northern Alaska (Dinkel, 1974).

Thermal springs are uniquely valuable energy sources for controlled environment experiments, as they can provide hot water, warm and permafrost-free ground, and small amounts of electricity from a common energy source, at very little expense.

Open Plot and Controlled Environment Gardening on Geothermally-Heated Ground

Some Alaskan thermal springs are surrounded by rather large areas of warm ground, which remain frost-free throughout the year. Perennially warm ground around Manley, Chena and Pilgrim Springs has been used for vegetable crop gardening since the arrival of the first white settlers. The Pilgrim garden plots produced vegetables in commercial quantities for miners during the Nome gold rush period; and the Manley Hot Springs commercial vegetable crops have continued from the early 1900's to the present day ... as exemplified by Mr. Charles Dart's presently successful greenhouse operation (to be described in more detail in the next section).

Warm frost-free soil is of great potential value in the arctic environment and should be utilized in a total energy applications system. A soil temperature survey, similar to that conducted by N. Biggar (1973) at Chena Hot Springs (Figure 20), can determine those areas which are optimum for vegetable crops.

Controlled environment enclosures could be located on selected plots of hot ground, adjacent to thermal springs, and require no other source of heat to maintain adequate soil and ambient air temperatures.

Growing seasons could be lengthened and plant maturation time could be accelerated through the use of garden plots which are heated by hot springs water circulated through networks of plastic pipe, buried at shallow depths in the soil.

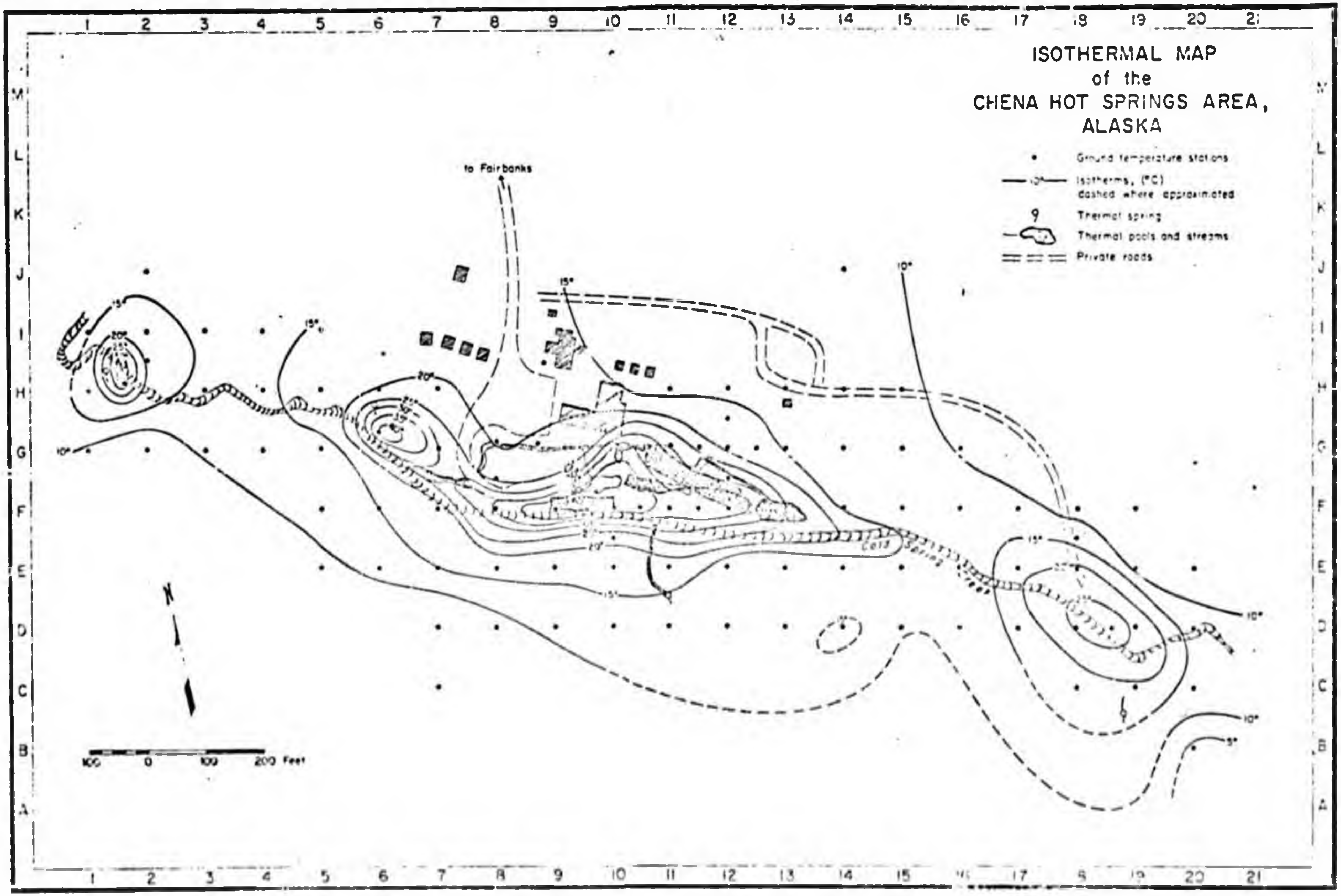

Figure 20: Isothermal map of s il temperatures in the Chena Hot Springs area (Biggar, 1973).

FISHERIES AND AQUACULTURE

Opportunities for Aquaculture

Salmonid fishes offer the greatest promise for tangible benefits from aquaculture in Alaska when biological, technological, economic, and institutional problems are taken into account. The list of salmonids suited for aquaculture includes salmon, trout, char and grayling. However, ocean ranching of Pacific sal-on will most likely afford the greatest potential for an economically-viable aquaculture industry.

Catch records reveal that Pacific salmon have declined precipitously in Alaska. For many years Alaska contributed about two-thirds of the total harvest of North American salmon, but Alaska's contribution is now less than one-half of the total (Figure 21). Catches in the Pacific Northwest and Canada have not declined even though environmental changes wrought by man have had adverse effects on natural stocks. These adverse effects have been compensated to a large extent by hatcheries, spawning channels and other aquaculture systems which today produce 450 million or more juvenile salmon for release into marine nursery waters.

Salmon Ocean Ranching

The potential gain in efficiency of ocean ranching over natural reproduction can be illustrated by a hypothetical example where chum salmon are released into the ocean as unfed fry. The probable fates of progeny from a pair of chum adults spawning naturally and spawned artificially in a hatchery are compared below:

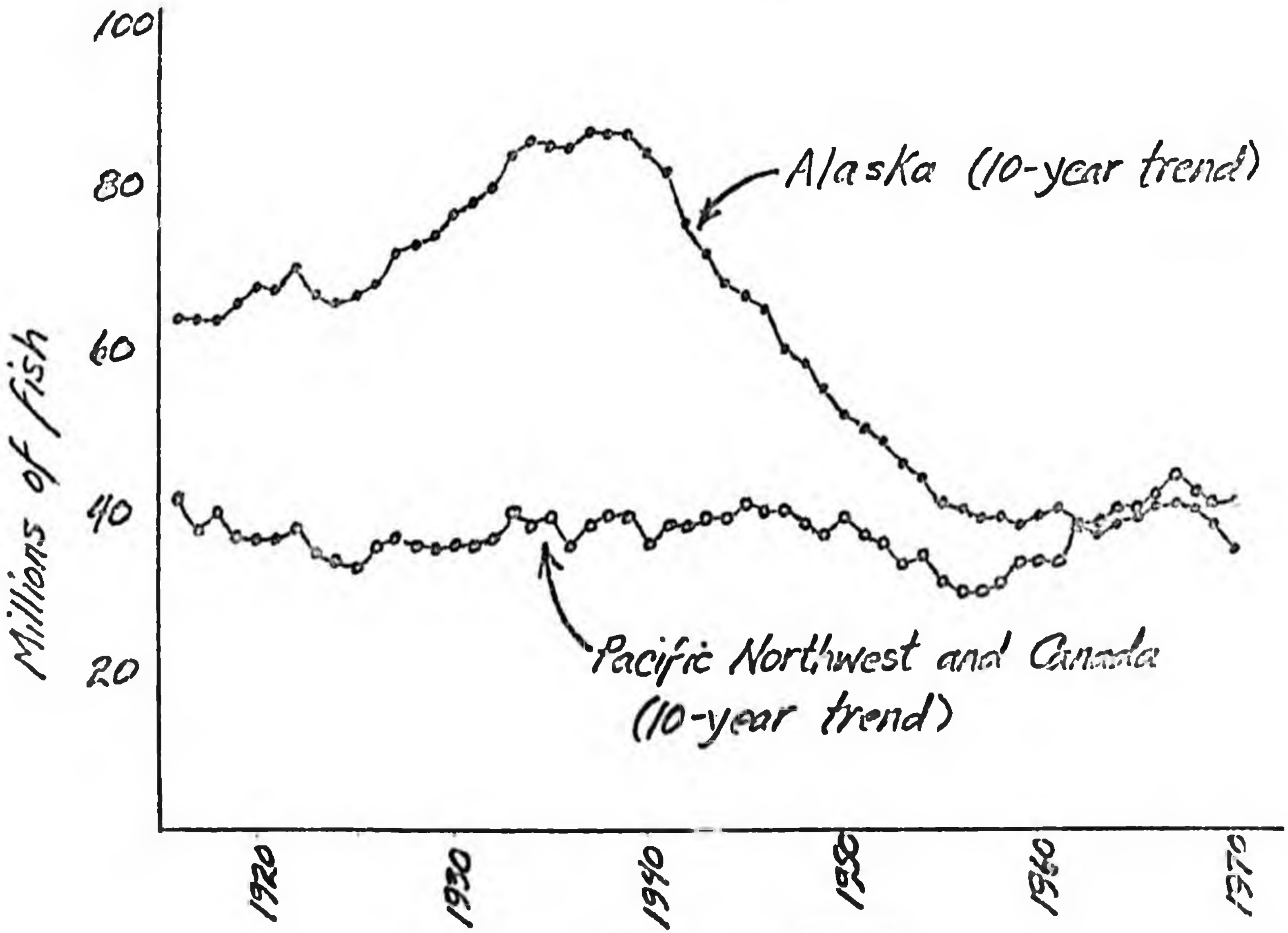

Figure 21: Trends of harvest of Pacific salmon on the Pacific Coast of North America.

Natural spawning	Hatchery
2 spawners	2 spawners
↓	↓
3,000 eggs	3,000 eggs
↓ (10% survival) ↓	↓ (80% survival) ↓
300 fry	2,400 fry
↓ (2% survival) ↓	↓ (2% survival) ↓
6 adults	48 adults
(2 spawners)	(2 spawners)
(4 harvested)	(46 harvested)

Recent experience with ocean ranching confirms that artificial propagation greatly increases the efficiency of production of salmon. The increase is not always 11-fold, as the example suggests, but it is substantial.

Perhaps the most successful ocean ranching program today is with chum salmon in Japan, where more than 500 million juvenile salmon are released annually and contribute about 10 million adult salmon to the harvest. Efforts are being made in Japan to double this production on Hokkaido Island, and the annual harvest of hatchery chum on Hokkaido has surpassed the harvest of wild chum in Alaska (Figure 22). Ocean ranching of chum and other salmon species is also undergoing rapid growth in the USSR and Canada.

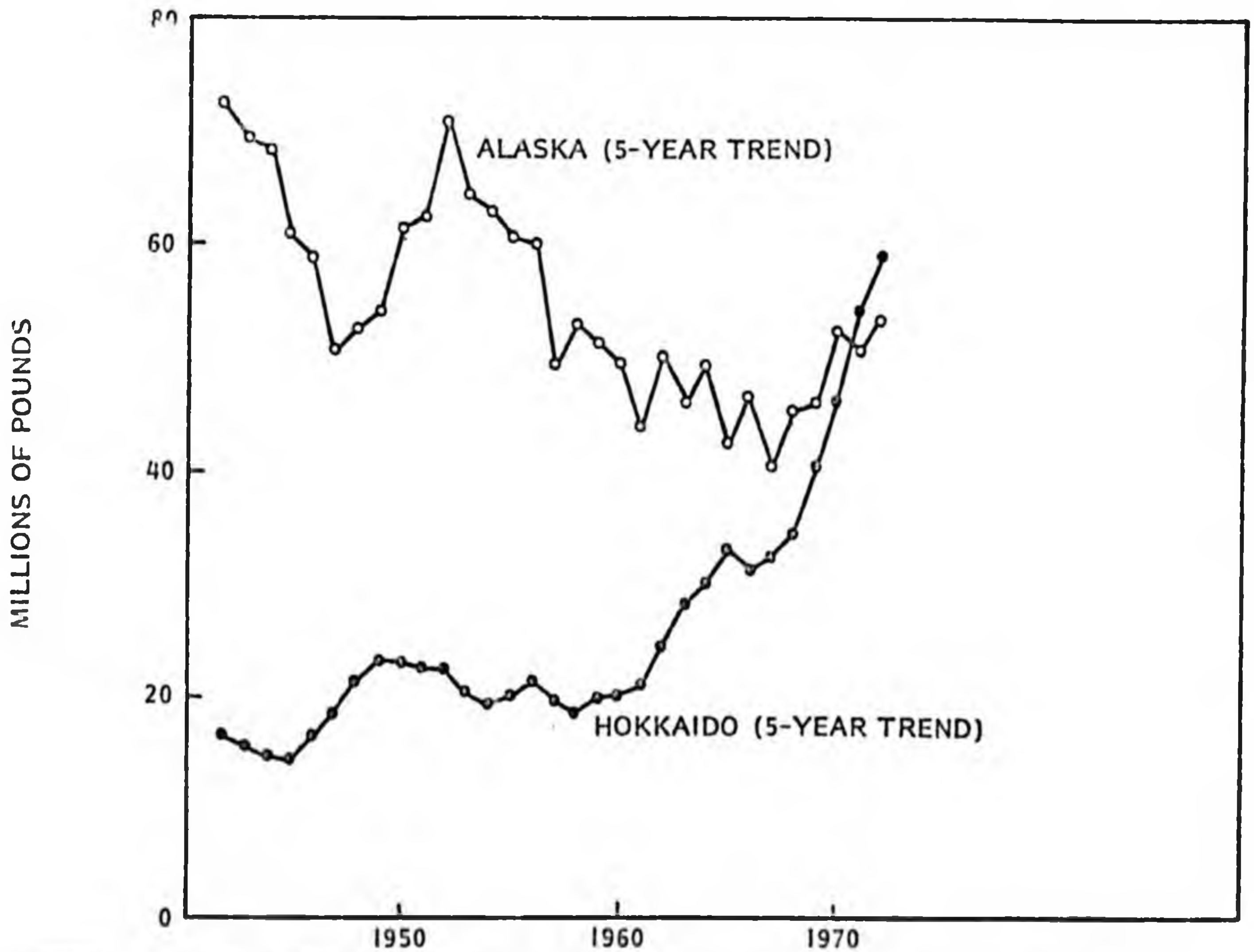

Figure 22: Trend of production of hatchery chum salmon on Hokkaido Island and wild chum salmon in Alaska.

Uses of Warm Water in Ocean Ranching

The operation of facilities in Alaska for salmon ocean ranching is complicated in many cases by severe freezing conditions in winter. Salmon spawn in summer and autumn and the fry emerge in spring when seasonal increases in natural food production occur in nursery waters. Avoidance of freezing requires that water used for incubation systems either must contain adequate heat or heat must be added. The artificial addition of heat requires expensive equipment and facilities, and places a heavy demand on fossil fuels. This can be avoided by using sources of fresh water where temperatures remain naturally above freezing during winter.

Lakes and geothermal springs are attractive sources for hatchery water supplies in Alaska since they are natural reservoirs for warm water in winter. Several hatchery projects now in operation or in planning in Alaska rely on lakes for water in winter. The use of geothermal water sources should also be evaluated.

Use of warm water for salmon ocean ranching can produce these effects:

1. Accelerated early development will contribute to early fry emergence.

2. Early fry emergence may require short-term rearing on artificial diets to insure that the time of release of juvenile salmon coincides with seasonal availability of natural food. (The Japanese follow this practice.)

3. Where juvenile salmon are raised to smolt size before release, early fry emergence should shorten the period of rearing, resulting in the release of smolts at age I (possibly at age 0) rather than at age II or III, which is common for wild fish.

Proposed Program

Two things must be done before potential benefits of geothermal water in salmon ocean ranching can be evaluated in Alaska:

1. Sources of low-grade geothermal water which are suitable for salmon aquaculture need to be inventoried.
2. Feasibility of using geothermal water in ocean ranching needs to be evaluated with five species of Pacific salmon.

Inventory of Geothermal Waters: Promising sources of geothermal water should be identified and cataloged on a state-wide basis. Quantity and quality (temperature, dissolved solids, gas content, etc.) need to be determined. Relatively cold (55°F and lower) geothermal waters of suitable quality might be used directly as a medium for raising salmon. Relatively warm (above 55°F) geothermal water of suitable quality would probably be diluted with colder water, and the availability of cold water would need to be considered. Where relatively warm geothermal water contains dissolved substances which are toxic to salmon, the use of heat exchange systems to warm cold water should be considered. The total volume of water available from a given source for raising salmon should probably be at least 5 cfs (2,250 gpm) for commercial-scale aquaculture.

Feasibility of Using Thermal Waters: The use of geothermal water in salmon ocean ranching should be studied at one or more locations in Alaska with several species of salmon. Two locations are discussed here and should be considered for possible feasibility studies. They are Gulkana springs (near Paxson) in the Copper River drainage and springs in the Fort Glenn area of Umnak Island (in the Aleutian Islands).

Umnak Island is remote and is served once a week by Reeve Aleutian Airlines. The Fort Glenn area possesses a complex of roads and airfields which were constructed in World War II and are still useable. A cattle ranch, with a functional cold storage plant, now operates on the former military reservation. A network of spring-fed streams which individually deliver more than 5 cfs of waterflow, arise from lava beds. The topography of the area lends itself to the construction of low-cost hatchery facilities.

An important feature of Umnak Island is its location near the geographic center of the North Pacific Ocean-Bering Sea nursery ground of salmon from North American and Asian streams and lakes. Pink and chum salmon would be the primary target species on Umnak Island. Sockeye and coho salmon would be secondary target species.

Hatcheries at Gulkana and Umnak springs can be developed with gravity feed water delivery systems. Demand for energy from fossil fuels would be limited to illumination and heating of modest support facilities. Supplementary power for a demonstration hatchery on Umnak could potentially be obtained from wind-driven generators. Hatcheries at both locations could be designed to operate without a full-time attendant.

Total cost of a feasibility study at Gulkana and Umnak springs is estimated to be about $500,000 for each location. This amount would include construction of facilities and operations for 5 years. The estimated costs are based on:

- Planning and site evaluation	$ 50,000
- Construction (10 million egg hatchery)	200,000
- Operation (5 years @ $50,000/yr.)	250,000
Total	$500,000

A hatchery facility at Gulkana springs would produce mostly sockeye fry to supplement recruitment of wild fry into Summit and Paxson Lakes. The present levels of fry recruitment to these lake nursery areas should first be evaluated to determine if such a project might be warranted.

A demonstration hatchery facility at Gulkana springs might also be used to raise chinook and coho fingerling from Copper River stocks to boost recruitment of these species at selected locations within the Copper River drainage.

A hatchery facility on Umnak Island would produce primarily pink and chum fry for release into the ocean. Some sockeye and/or coho fry might be produced for stocking lakes. A successful demonstration project at one site would most likely lead to larger projects on Umnak, other Aleutian Islands, and the outer Alaska Peninsula by the Aleut Corporation and possibly other fishery interests. The salmon fisheries of the Aleutian area are very depressed (Figure 23), and the emergence of a hatchery program capable of producing 500 million pink and chum fry has the potential of contributing at least $10 million annually to the economy of this region.

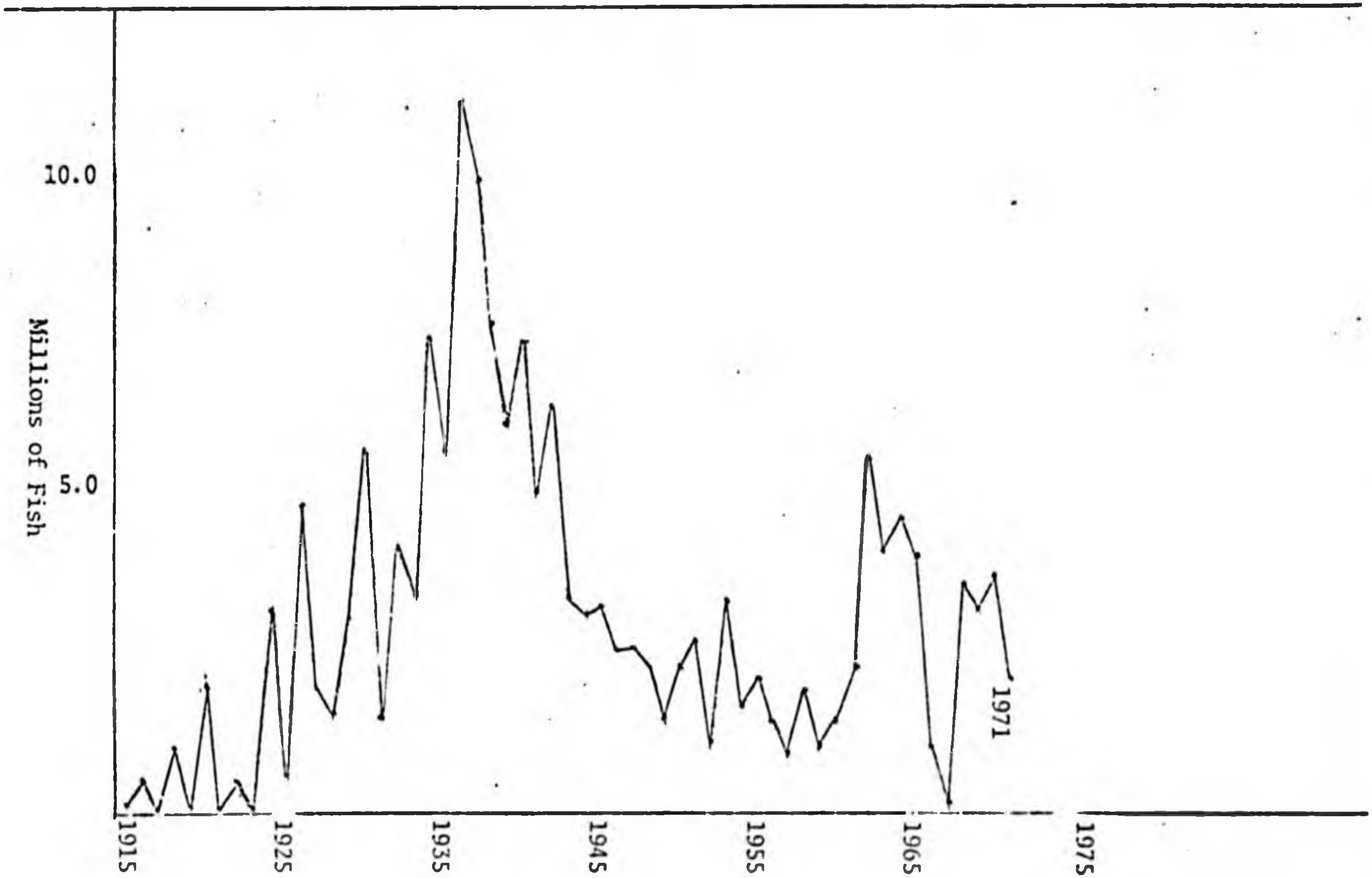

Figure 23: Annual catch of pink salmon in the Alaska Peninsula and Aleutian Island area.

CONCLUSIONS AND RECOMMENDATIONS

Geothermal Potential and Applications

Classification of Geothermal Resources: Although the assessment of Alaska's geothermal resources is in its infancy, the presence of over 40 active volcanoes and many thermal springs suggests that Alaska has geothermal energy resources similar to those which occur in other regions of the world, including:

1. subsurface steam reservoirs
2. subsurface hot water reservoirs (including geopressured reservoirs)
3. thermal springs (surface hot water)
4. subsurface geothermal anomalies (hot-dry rock)
5. volcano-related systems, including hot-dry rock and potential "magma tap" applications
6. deep drill hole applications in areas underlain by a normal geothermal gradient (30°C/kilometer).

Geothermal Resources Applied to Alaskan Needs: Although the generation of electricity has received more public attention than other uses of geothermal energy, there are many non-electrical applications of geothermal resources which may also be important to Alaska, including:

1. space heating and waste disposal
2. aquaculture (including fish hatchery and farming operations)
3. gardening, farming and greenhouse applications
4. melting of snow on roads and airfields
5. manufacturing
6. extraction of valuable heavy metals and salts from brines
7. potable water

Convective Systems: Currently, our optimism toward the geothermal potential of Alaska is based on the Alaskan segment of the circum-Pacific volcanic belt, and the possibilities offered by thermal spring waters in several districts. To date, however, geothermometry studies on thermal spring waters by the U. S. Geological Survey have not yet detected any vapor-dominated reservoir temperatures -- and only two thermal spring systems appear to have reservoir temperatures greater than 180°C -- which is the currently accepted temperature minimum for steam turbine systems utilizing the present technology (see page 47).

Volcano-related Systems: U. S. Geological Survey investigations (Miller and Barnes, in press; Smith and Shaw, 1975) indicate that several silicic volcanic fields, including the Wrangell Mountains, deserve further exploration as potential geothermal targets (see Figure 6 and Table 5). To date, however, no test holes have been drilled in any of these fields, and no heat flow or thermal gradient measurements have been made.

The energy potential of volcanoes is tremendous (Table 6). The amount of energy that is dissipated by uncontrolled and unuseable, worldwide volcanic eruptions each year is of mind-boggling order in terms of today's energy crunch. For example, the 1883 eruption of Krakatoa Volcano released about 10^{25} ergs of energy -- roughly equivalent to the total power consumption in the United States in the year 1970. The energy expended in the 1952 eruption of Kilauea Volcano would have been worth $350 million if it could have been converted to electricity.

To date, significant geothermal power production has been from the so-called vapor-dominated geothermal reservoirs. If a technology could be developed to extract electricity from magma reservoirs or from induced steam systems in volcanic piles, huge and previously unobtainable energy resources would become available.

Heat Flow and Thermal Gradient Measurements: High heat flow and/or geothermal gradients are th characteristic signatures of economically-significant geothermal anomalies. Although high heat flow values can be obtained on many active Alaskan volcanoes, published Alaskan heat flow determinations taken from drill holes have not yet exceeded 2.6 hfu (hfu = heat flow units). Based on the worldwide average of 1.5 hfu, and the association of heat flow values of 4 hfu and above with meaningful geothermal anomalies, we have not yet located any geothermal targets in Alaska by means of high heat flow, other than volcanic vents.

This does not mean that there are no zones of high heat flow in Alaska, as no more than 20 reliable heat flow determinations have been extracted from Alaskan drill holes; and considering the vast area of Alaska, little can be concluded from these initial determinations other than the need for more data.

To date there have been no known exploratory geothermal holes drilled in Alaska, other than a shallow (86 ft.) hole drilled in the lava dome (destroyed during the eruption of January 1976) near the summit of Augustine Volcano by the Geophysical Institute, University of Alaska (J. Kienle, et al., unpublished research).

Total Energy Utilization of Thermal Springs: Alaska has a large number of thermal springs which constitute potential energy sources other than geothermal subsurface steam reservoirs. The recent development of hot-water generating systems offers promise for the production of electricity from thermal spring water (60°C) with outflow water temperatures which are high enough for second-stage energy extraction for space heating and agricultural application.

The exploitation of an energy source which could generate heat and power at less cost and develop the on-site production of vegetables through hydroponic farming and greenhouse operations would increase the economic stability and standard of living of remote resident populations.

The Geophysical Institute is now studying the total energy potential of three thermal springs in northern Alaska as possible sites for energy conversion experiments and pilot plant studies. Priority targets include Manley Hot Springs in the Tolovana District, and Clear Creek, Pilgrim and Serpentine Hot Springs on the Seward Peninsula (see Appendix E).

Rural Geothermal Priorities and the Total Energy Concept

High priority should be given to the development of geothermal resources in rural Alaska, rather than the cities. In addition to the previously-mentioned economic constraints, none of the presently recognized geothermal targets are located in the immediate vicinity of the cities. There are, however, potential geothermal resources which are located in or closely adjacent to villages in the outlying areas. The need i. also most acute in the rural areas, and the development of any resource which can reduce the ependence on expensive fossil fuels and/or help establish local industry on any scale would be high desirable.

Electric Versus Non-Electric Applications

In our discussion of Alaskan economics, we pointed out the difference between Alaskan needs and priorities and those of the other 49 states.

It follows that the utilization and economic potential of geothermal energy resources will be based on special criteria related to Alaskan problems and needs. Although non-electric applications of Alaskan geothermal resources deserve highest priority, it may also be advisable to generate small amounts of electricity in some rural settings. In many areas of rural Alaska, electricity is not continuously available in any form at the present time, and it would not be sensible to develop a geothermal resource exclusively for non-electric applications under such conditions. Secondly, the amount of electricity under consideration ranges from 2 to 250 KW -- quantities which are substantially below the levels considered feasible for large-scale developments in other parts of the nation. Since economic competition with other forms of power generation does not exist in many parts of rural Alaska, it makes good sense to consider generating small quantities of electricity by geothermal means wherever possible.

Sources of State Funding

We have reached a point in time when many rural areas could benefit greatly from geothermal resources, if we begin now to develop a technology which is compatible with environmental considerations and the cultural needs of the people. Capital to invest in such an enterprise may be available from two resources. The Alaska Native Claims Act of 1971 has given the native people the economic leverage to undertake development of geothermal energy. However, these monies are restricted by act of Congress to profit-making ventures by the regional and village corporations; and research and development expenditures on geothermal resources are not permissible. The State of Alaska has oil and gas revenues which could be used to develop geothermal resources in rural areas.

Research and pilot plant experiments must be initiated as soon as possible to insure that the technology is ready when the funds become available.

Present State of Geothermal Research and Development

Development: Currently, geothermal development by the private sector in Alaska has been restricted to hot spring resort activities and one large greenhouse operation at Manley Hot Springs.

Several Alaskan native regional and village corporations have received exploration proposals from private consultants and corporations during the last year, but to our knowledge none of these proposals and/or programs has progressed to the field stage.

Research: To date, most of the research on Alaskan geothermal resources has been done by the U. S. Geological Survey and the Geophysical Institute, University of Alaska. The U. S. Geological Survey's contributions date back to the pioneering work of Waring (1917) on Alaskan thermal springs. More recently (since 1971), the U. S. Geological Survey has been conducting a helicopter-supported assessment of Alaskan geothermal resources, with special attention devoted to the Alaskan volcanoes and thermal springs. Under the direction of T. Miller, this program has concentrated on the geothermometry, chemistry and geologic setting of thermal springs, and the age, petrology and setting of young (Tertiary and Quaternary) volcanic fields. With the exception of a gravity study conducted in the Wrangells, this program has not involved geophysical surveys.

The work done by T. Miller, I. Barnes and R. Smith was essential to the data presented on the energy potential of Alaskan geothermal resources, as recently published in U.S. Geological Survey Circular No. 726, "Assessment of Geothermal Resources of the United States - 1975."

The Regional Geophysics Branch of the U.S. Geological Survey (A. Lachenbruch and J. Sass) has been conducting a "target of opportunity" heat flow program in Alaska by capitalizing on available drill holes, when possible, which were drilled for other purposes. Funding for this program has been minimal, however, and no geothermal holes have been drilled by the U. S. Geological Survey in Alaska.

The Geophysical Institute, University of Alaska, initiated its geothermal program in 1971, with a revision of Waring's map of Alaskan thermal springs (Biggar, 1971). Biggar (1973) conducted a geophysical and geological study of Chena Hot Springs, and Forbes, et al. (1975) located a possible geothermal reservoir beneath Pilgrim Hot Springs with geophysical methods in 1974.

Forbes, et al. (1975) recently completed a feasibility and planning study on the utilization of geothermal energy resources in rural Alaskan communities under the provisions of a contract with the Atomic Energy Commission (AEC); and at present, Forbes, et al. are doing research on fossil versus present thermal gradients in deep drill holes, with the assistance of a research grant from ERDA.

J. Kienle, et al. (Geophysical Institute) are presently conducting an investigation of the magma tap potential of Augustine Volcano, with the aid of an ERDA research grant.

A Proposed Geothermal Research and Development Program

We believe that there is an urgent need for an integrated state, federal and private sector geothermal research and development program in Alaska.

Optimally, this program should be composed of cooperative projects involving the U. S. Geological Survey, the Energy Research and Development Administration, the State of Alaska and the private sector.

In our opinion, the program should reflect the following guidelines:

1. Heat is a precious commodity in the Alaska subarctic and arctic. Although geothermally-generated electricity may not be competitive with that generated by mine-mouth, hydroelectric and natural gas power plants for transmission to major population centers, hot water and vapor-dominated geothermal systems, where available, could improve the standard of living and economic viability of village populations.

2. Thermal springs have great promise as total energy systems in remote Alaskan villages. Applications engineering studies and pilot plants should explore this potential.

3. Volcanoes are confirmed targets. High priority should be given to the development of a technology which will extract useful energy from Alaskan volcanoes.

4. A systematic heat flow and thermal gradient measuring program should be initiated, involving the required cooperation of industry, and a federally-funded cooperative drilling program in Alaska.

5. Vast areas of Alaska are mantled by vegetation, alluvium and permafrost. Remote sensing techniques, including ground conductivity, infrared, gas detection and other methods should be investigated as possible geothermal exploration tools.

Three proposed geothermal research projects, concentrating on total energy utilization of selected Alaskan thermal springs are contained in Appendices E-3, E-4 and E-5.

Wind Power Potential and Applications

Potential: There are large areas of Alaska that appear to be uniquely favorable for wind power applications. The most promising areas are located on the coastal plains in the arctic, northwest (including Seward Peninsula), and southwest (Yukon-Kuskokwim Delta and Bristol Bay areas) regions. These areas experience strong, persistent winds which have their highest potential in winter, when energy requirements are the largest. Wind extremes are probably less in these areas than in coastal areas in Southeast Alaska, the Gulf of Alaska and the Aleutians. These "favorable" areas include many villages and a few small cities which are now totally dependent on fossil fuels.

Generally, interior Alaskan villages are less favorable sites for wind power applications due to a lack of suitable winds in the winter months.

State of Technology: Commercially-available wind power units up to 2 or 3 KW, including conventional storage batteries, are well proved. Initial costs and performance characteristics are fairly well known, but there are differences in opinion on long-term costs, including maintenance and repair.

Large wind power units are not yet readily available, and energy storage problems will become more serious when the larger units become available.

Present federal and industrial research and development programs include the construction of prototype windmills up to 100 KW capacity, and it seems likely that wind power units in this size range may be available within a few years. Longer-term research and development goals envision even larger machines, and it is possible that a 1000 MW prototype may be constructed within a few years. Windmill technology will probably progress more rapidly than energy storage technology for the next several years.

Applications: The wind power potential of Alaska is high. The annual power potential averaged for Alaska is of the order of 3400 MW, assuming that 1/1000 of the available kinetic energy in the first 1100 meters (3600 ft.) of the atmosphere could be extracted. The wind power potential of most coastal areas is assured; in the interior, however, the potential is low and variable with location.

The best and most immediate application of windmills would be in the electrification of many small communities, especially in coastal Alaska. Fuel oil conservation and an improvement in the quality of life are implicit to this application. Windmills (individual or clustered) in the 10 to 50 KW range would have considerable impact in the villages. A major problem in windmill utilization in rural Alaska is that those who could profit most, in a social sense, can least afford the capital investment. Demonstration projects are clearly needed; state and federal agencies should support and initiate early tests and demonstrations to educate potential users.

Longer-term applications will depend on the availability of large wind machines, producing 100 KW-rated (or above) output. The first Alaskan users would probably be privately-owned central utilities in intermediate-size communities (1000 or so population), and the seafood canning industry. The industrial production of methanol, ammonia and urea with windmill-produced power is feasible, but at present it is uneconomical. The economics of mass-produced large wind machines will be better understood in the near future.

While windmills rated at 100 KW or above offer the economy of scale, more emphasis should be placed on the development of reliable units rated in the 10- to 30-KW range, especially for rural applications. Logistics considerations, installation problems, and the need for redundancy indicate that the "windmill farm" (WECS complex) concept is superior to that based on one large unit, at least in Alaska.

We expect engineering improvements in wind-generating units to be ahead of those in energy storage systems, for many years. Therefore, we recommend the early study and field demonstration of hybrid (wind-oil) energy systems, using existing small and medium (up to few hundred KW) diesel-fueled generators that are fairly common in Alaskan communities. Emphasis in these hybrid systems must be on automatic and reliable switching.

Our wind surveys are necessarily incomplete, and none of the locations considered from existing data have been surveyed at specific sites selected for wind power purposes. Yearly mean wind speeds range from about 18.3 to 7.0 knots (excepting several Interior Alaska locations known for lack of wind). Topographic shielding is often present where the lower means prevail.

A useful numerical factor arising from our analysis of Alaskan wind data is the power factor (pf) which describes the potential use of the maximum installed power capability. While our surveys confirm the generally-held view that Alaska locations can be very windy, the power factors of available windmills dictate careful site selection and the use of tall towers (cost permitting). Only machines like the very expensive Aerowatt seem to have merit at average wind speeds near 10 mph (pf=0.39); others have pf of 0.13 to 0.19 at that $\overline{V}$. At $\overline{V}$ = 20 mph the computed pf of the Aerowatt, Elektro and Jacobs-like windmills treated in this report are 0.80, 0.53 and 0.62, respectively.

An Alaskan test center should be established to run various WECS in the same weather regime, to confirm these calculations and determine mechanical integrity under subarctic and arctic conditions. We recommend Cold Bay or Ft. Greely for this purpose.

Many small cities and villages are promising candidates for windmills, in terms of winds and need. For initial large-scale test installations, we recommend Nelson Lagoon, Cold Bay and Kotzebue. These were selected because of wind conditions, diversity of climate, relative ease of access for freight and personnel, and the degree of local interest.

A major windmill design effort should be made to minimize the wind speed necessary for achievement of the generator-rated output, and on the reduction of the weight and size of the generator (to avoid overrating). Heavy emphasis also should be placed on automatic controls for this purpose. Designers should specify the voltage output of their wind systems versus wind speed, as well as power output, and decisions on energy storage devices (active loads, batteries, heat sinks, etc.).

Gusting may cause windmill blade problems that are more severe in Alaska than in lower latitude locations. Generator braking due to ice build-up behind the blades may actually be a greater problem than blade-icing. Slow speed operation during icing, or careful thawing of iced blades before start-up, are important procedures. However, much more study in different parts of Alaska needs to be done to better define these problems.

The cycle of Alaskan winds is usually in phase with the cyclic power requirements of Alaskan communities. Thus, the strongest winds occur during the colder and darker months. This is the reverse of the situation encountered with northern hydroelectric power sources. In that case, water flow is often minimal in the winter and early spring, before snow melting and river thawing.

For many Alaskan coastal sites the average decrease in the mean wind speed from the maximum monthly mean to the minimum monthly mean is about 30%. Because of the exponential velocity dependence of the power output of a windmill, this 30% amounts to a factor of 2 to 3 decrease in the average monthly power output of an idealized windmill. Factors of this order must be considered in setting the maximum power rating of a windmill (for winter use) or in estimating the summer (in coastal Alaska) yield of a windmill and storage system designed for winter loads. Cold Bay is a favorable exception to the large swing (16% versus 30% above).

Electricity: There are several possible levels of wind power application in Alaska which depend largely on the level of technology and the relative costs of the wind generators.

1. Presently available small capacity wind generators are suitable for some remote area applications when energy and power requirements are small. This might include single windmill units for very small loads or groups of units, where requirements are on the order of 10 to 20 KW.
2. The prospect that windmills up to about 100 KW in size may be available soon is of particular interest for many remote areas in Alaska which have power requirements in the 50 to several hundred KW range. It is not difficult to visualize a ready market for several hundred wind generators in the 50 to 100 KW range -- when proved machines become available at reasonable cost.
3. The application of wind power to the larger power systems will not be significant until generators in the 1000 KW size range and larger become available.
4. The State's electric utility systems offer some unusual opportunities for testing the wind power applications. Integration of windmills with other types of power generators in an electric system could avoid all energy storage problems during no-wind periods; any energy produced from windmills in such a system would provide a direct fuel savings. The very high fuel cost for remote cities and villages in Alaska suggests potential benefits from wind power applications would be very large.

Wind Power Demonstration Projects

Preliminary proposals for wind power demonstrations at selected Alaskan sites (Umnak Island, Cold Bay, Kotzebue and Nelson Lagoon) are contained in Appendix F.

Institutional Considerations

The Alaska State Energy Office and Statewide Coordination of Geothermal Activities: In coordination with the federal and private efforts in the geothermal and wind power field, the Alaska State Energy Office hopes to aggressively pursue worthwhile energy research, development and demonstration projects in areas of concern to Alaska. The wind power and geothermal research and development requirements and applications addressed in this report will receive very high priority. There has not been a traditional coordinating point in the State of Alaska for geothermal and wind power affairs and activities. The Alaska Energy Office is a logical vehicle for the state-wide administrative coordination of geothermal and wind affairs. This office could also improve liaison between state and federal agencies. The Alaska Energy Office should also serve as the state center for the dissemination of geothermal and wind power information.

State of Alaska Geological and Geophysical Survey: The State of Alaska Geological and Geophysical Survey should become increasingly involved in state geothermal affairs and be assigned an active role in state geothermal research and development activities.

State Versus Federal Funding: To date, the State of Alaska's investment in geothermal and wind power resources has been confined to work by the Geophysical Institute; participation of the Alaska Energy Office in the recent Geothermal and Wind Resources Planning Conference; and the assignment of cognizance for geothermal affairs to the State Geological and Geophysical Survey. As of March 1976, federal agencies have contributed more that $500,000 to geothermal and wind power research in Alaska; and to date, no State of Alaska funds have been appropriated for research and development in either of these areas.

Considering socio-economic needs and the importance of alternate energy sources in Alaska, the State of Alaska should initiate a funded geothermal and wind power program as soon as possible and develop incentives to attract the private sector.

Possible ERDA-State of Alaska Memorandum of Understanding: The Energy Research and Development Administration has been empowered to negotiate and finalize "Memoranda of Understanding" with state governments for cooperative energy programs. We recommend that the State of Alaska negotiate and sign such a memorandum of understanding with ERDA in the fields of geothermal and wind power research and development, involving a possible matching fund agreement.

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APPENDIX A

Program for the

Alaska Geothermal and Wind Resources Planning Conference

ALASKA GEOTHERMAL AND WIND RESOURCES PLANNING CONFERENCE

Anchorage Westward Hotel
July 8 & 9, 1975

Program Chairman: Dr. Robert B. Forbes   Convenor: Dr. William Ogle

Tuesday - July 8, 1975

MORNING SESSION

8:30 - 8:35	Welcome & Opening Remarks	Dr. William Ogle Anchorage, Alaska
8:35 - 8:40	Introduction of Lieutenant Governor Lowell Thomas, Jr.	Mr. William C. McConkey Director Alaska State Energy Office
8:40 - 9:00	Greetings from State of Alaska	Honorable Lowell Thomas, Jr. Lieutenant Governor State of Alaska
9:00 - 9:40	Alaskan Energy Economics (5-minute discussion period)	Dr. Arlon R. Tussing Chief Economist United State Senate Committee on the Interior and Insular Affairs
9:45 - 10:25	Geothermal Resources of Alaska --- A Status Report	Dr. Thomas Miller Geologist Branch of Alaskan Geology U.S. Geological Survey
10:30 - 10:45	Coffee Break	
10:45 - 11:25	Wind Resources of Alaska --- A Status Report (5-minute discussion period)	Dr. Tunis Wentink Professor of Physics Geophysical Institute University of Alaska
11:30 - 12:00	Geothermal & Wind Resources as Applied to Alaskan Needs	Dr. William Ogle Anchorage, Alaska
12:00 - 1:30	Lunch	

AFTERNOON SESSION

1:30 - 2:10	The U.S. Geological Survey Geothermal Program (5-minute discussion period)	Dr. L.J. Patrick Muffler Coordinator Geothermal Research Program U.S. Geological Survey

AFTERNOON SESSION (Cont'd.)

2:15 - 2:55	Agricultural Applications of Geothermal Resources	Dr. Don Dinkel Professor of Agronomy Institute of Agricultural Science, University of Alaska
3:00 - 3:15	Coffee Break	
3:15 - 3:45	Possible Utilization of Thermal Waters in Salmon Rearing Operations	Part 1: Dr. William McNeil Auke Bay Fisheries Laboratory National Marine Fisheries Service
3:45 - 4:15	(5-minute discussion period)	Part 2: Mr. Joe Wallis Hatchery Superintendent Firelake Hatchery Service Department of Fish & Game State of Alaska
4:20 - 5:00	Space Heating & Industrial Applications of Geothermal Energy Resources (discussion)	Dr. Jay F. Kunze Manager Geothermal Projects Aerojet Nuclear Company
5:30 - 6:30	Post Session No-Host Cocktails	

Wednesday - July 9, 1975

MORNING SESSION — Convenor: Mr. William C. McConkey, Director, Alaska Energy Office

8:30 - 9:10	The Hickel Report --- Two Years After	Honorable Walter J. Hickel Former U.S. Secretary of the Interior & Governor of the State of Alaska
9:15 - 9:55	The U.S. Geothermal & Wind Resource Research & Development Program & Possible Alaskan Assistance	Dr. Louis Werner Assistant Director for Research Utilization Division of Geothermal Energy Energy Research & Development Administration
10:00 - 10:40	National Science Foundation Geothermal & Wind Resource Program (discussion)	Mr. Ritchie B. Coryell Geothermal Program Manager Advanced Energy Research & Technology Division National Science Foundation

MORNING SESSION (Cont'd.)

10:40 - 12:00	Working Groups Convened by Chairmen
12:00 - 1:30	Lunch

AFTERNOON SESSION

1:30 - 5:00	Working Groups Convene in Assigned Rooms
5:00 - 7:30	Dinner

EVENING SESSION

7:30	Working Groups Convene in Assigned Rooms

WORKING GROUPS

Agriculture	Dr. Don Dinkel Professor of Agronomy Institute of Agricultural Science University of Alaska	Chairman
Electrical Power	Mr. Robert Cross Chief Project Development Division Alaska Power Administration	Chairman
Fisheries & Aquaculture	Dr. William McNeil Auke Bay Fisheries Laboratory National Marine Fisheries Service	Chairman
Geothermal Resource Research & Development	Dr. Robert B. Forbes Professor of Geology Geophysical Institute University of Alaska	Chairman
Space Heating & Industrial Applications	Dr. William Ogle Energy Consultant Anchorage, Alaska	Chairman
Wind Power Development & Applications	Dr. Tunis Wentink Professor of Physics Geophysical Institute University of Alaska	Chairman

APPENDIX B

Attendance List for the

Alaska Geothermal and Wind Resources Planning Conference

ALASKA GEOTHERMAL AND WIND RESOURCES PLANNING CONFERENCE

Anchorage Westward Hotel
July 8 & 9, 1975

Attendance List

Atuk, Richard K.	Bering Straits Native Assn., Nome, AK 99762
Barnes, William	Windlite - Alaska, 4303 Forest, Anchorage, AK
Bewley, Georgia	Geological Asst., Alaska Geological & Geophysical Surveys 3001 Porcupine Drive, Anchorage, AK 99501
Bodnar, Andrew J.	Electrical Engineer, Engineering Div., Directorate of Engineering & Construction, HQ AAC/DEEE, Elmendorf AFB, AK 99506
Boston, Clark D.	Director, Div. of Rural Development Assistance, Pouch B, Juneau, AK 99801
Boucher, H.A. "Red"	H.A. "Red" Boucher & Assoc., 805 W. Third, Anchorage, AK 99501
Boudreau, Barry	Supervisory Physical Scientist, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025
Braasch, Richard, Dr.	Sandia Laboratories, P.O. Box 5800, Albuquerque, NM 87115
Brink, Irvin	Mayor, Village of Akolmiut, Nunapitchuk, AK 99641
Bruce, Jim	Architect, James B. Bruce, A.I.A. Architect, P.O. Box 2376, Anchorage, AK 99510
Brueckner, Hannes	Associate Professor, Queens College of New York and Lamont-Doherty, Geological Observatory, New York, NY 11375
Buness, Everett W.	Director, U.W. Dept. of Commerce, 632 Sixth, Anchorage, AK 99501
Burton, Wayne E., Dr.	Assoc. Prof. of Agricultural Economics, University of Institute of Agricultural Sciences, P.O. Box AE, Palmer, AK 99645
Cameron, Robert B.	Command Environmental Engineer, Directorate of Engineering & Construction, HQ AAC/DEEV, Elmendort AFB, AK 99506
Carpenter, John	The Aleut Corporation, 833 Gambell Street, Anchorage, AK 99501
Chernikoff, Fred	Alaska Federation of Natives, 670 West Fireweed, Anchorage, AK.

Chiei, Jr., Fred	Deputy Regional Administrator, FEA, Federal Building, Anchorage, AK 99501
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Cline, Dave	Wildlife Biologist, U.S. Fish & Wildlife Service, 8th and A, Anchorage, AK 99501
Comiskey, Albert L.	National Weather Service, NOAA, 632 Sixth, Anchorage, AK 99501
Coryell, Ritchie B.	Geothermal Program Mgr., Advanced Energy Research and Technical Division, National Science Foundation, Washington, D.C. 20550
Cross, Robert J.	Chief, Project Development Div., Alaska Power Admin., P.O. Box 50, Juneau, AK 99802
Curtis, Edgar J., P.E.	U.S. Army Corps of Engineers, Elmendorf AFB, Anchorage, AK
Dart, Charles W.	Owner, Manley Hot Springs Greenhouse, Manley Hot Springs, AK 99[illegible]6
Davis, T. Neil, Dr.	Deputy Director, Geophysical Institute, University of Alaska, Fairbanks, AK 99701
Denslow, Dan	Ambler Air Service, Ambler, AK 99786
DeWitt, Michael, Capt.	AFWL-DE 2, Kirtland Air Force Base, NM 87117
Diershaw, A.	Engineer, Wincom, 4134 Ingra, Anchorage, AK 99510
Dinkel, Donald, Dr.	Professor of Agronomy, Institute of Agricultural Science, University of Alaska, Fairbanks, AK 99701
Doak, Barney R.	Area Mechanical Engineer, Alaska Area Native Health Service, Box 7-741, Anchorage, AK 99503
Dobey, Patrick	Chief Petroleum Geologist, Alaska State Geological and Geophysical Surveys, 3001 Porcupine Drive, Anchorage, AK
Dorris, J. David	Land Systems Planner, Joint F/S, Land Use Planning Commission, 733 W. Fourth Ave., Anchorage, AK 99503
Dowling, Forrest, Dr.	National Coordinator of Geothermal Resources, Office of Rural Research in Chicago, 536 S. Clark Street, Chicago, IL 60605
Drahn, Richard A.	Civil Engineer, Alaska Geological Consultants, 702 W. 32nd, Anchorage, AK 99502

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Forrest, Lesh C.	Vice Pres., - Operations, Alaska Geological Consultants, Inc., 702 W. 32nd Ave., Anchorage, AK 99502
Fukuhara, H.	Assistant to Mgr., - Engineering Project, Nissho-Iwai Co., Ltd., 4-5 Akasaka Minato-Ku, 2-Chome, Tokyo, Japan
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Gerik, Al	3217 Redoubt Ct., Anchorage, AK 99503
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Gunness, Donald A.	Marketing Mgr., Standard Oil Company, P.O. Box 1580, Anchorage, AK 99510
Hablett, Thomas R.	Fish and Wildlife Biologist, U.S. Fish and Wildlife Service, 813 D Street, Anchorage, AK 99501
Hall, Bert	Alaska Liaison, U.S. DHEW, Box 378, Anchorage, AK
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Hoffman, Robert N.	Electrical Engineer, Crews, Macinnes & Hoffman, 4111 Minnesota Dr., Anchorage, AK 99503

Holdsworth, Phil R., P.E.	Commissioner, Federal-State Land Use Planning Commission for Alaska, 326 Fourth St., #1009, Juneau, AK 99801
Hooper, Lennon	Park Planner, National Park Service, 334 W. 5th Ave., Anchorage, AK 99501
House, J.V.	Administrator, Alaska Power Administration, P.O. Box 50, Juneau, AK
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Hudson, Ted	District Geothermal Supervisor, Portland District, U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025
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Isberg, Howard, P.E.	Chief Engineer and Assistant to General Mgr., Philleo Engineering and Architectural Service, Inc., Box 464, Fairbanks, AK 99701
Janson, Lane E.	Alaska Native Management Report
Jean, Don	Industrial Specialist for Energy Research and Development FEA, Federal Bldg., Anchorage, AK 99501
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Kay, Robert	Research Associate, UCLA Geology Dept., Los Angeles, CA 90024
Kay, Suzanne Mahlburg	Post-Doctoral, UCLA Geology Dept. Los Angeles, CA 90024
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Kunze, Jay F., Dr.	Manager, Geothermal Projects, Aerojet Nuclear Company, Idaho Falls, ID
Kuwada, J.T.	Vice Pres., Rogers Engineering Co., Inc. 111 Pine St., San Francisco, CA 94111
Lathan, Bill	Inventor, Anchorage, AK
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Menaker, Vivian C.	P.O. Box 118, Haines, AK 99827
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Menard, Betty	Star Route Box 384, Willow, AK 99688
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APPENDIX C

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Alaska Geothermal and Wind Resources Planning Conference

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APPENDIX D

CHEVAK'S CURRENT ENERGY PICTURE:
(Fall, 1975)

A STUDY OF A SOUTHWESTERN ALASKAN ESKIMO VILLAGE
(61°30'N, 165°W)

This especially lucid presentation of the problems of a small Eskimo village near the coastline on the Bering Sea is typical of the situation facing many of Alaska's native peoples. It was written by an unidentified Chevak resident.

CHEVAK'S CURRENT ENERGY PICTURE:

A Study of a Southwestern Alaskan Ekimo Village

When time became a consideration in the changing lifestyle of the subsistence hunters in Southwestern Alaska, energy became a problem. Unlike the days of past, where dog teams consumed renewable resources for their fuel, and the people harvested natural fuels for their energy needs as they migrated to seasonal locations, the present Eskimo villages are normally located in places where both subsistence foods and natural fuels are dwindling, or are extinct. The reasons for the location of permanent settlements in areas devoid of natural support systems is due to time conditions.

When the government gave gifts, it established its schools and services in central locations, and demanded that the villagers cease their seasonal movements. Instead of subterranean houses, the government established framed, above ground dwellings as its standard of housing, and discouraged native efforts to maintain their former ways. The the limited amounts of wood that washed ashore during the summer near the permanent location, limited winter storage. Competition among households for the available fuels occured, and many families were without fuel for space heating or cooking. Whereas the house buried in the hillside and covered with sod was warm enough without added heat to prevent water from freezing, the above ground houses were exposed to the wind, and freezing conditions. Fuel oil was cheap at that time, and when money became available in the village, the people converted to oil.

The seasonal migration to locations of abundant food was also terminated through permanent settlements. Hunters had to go farther away from their villages to harvest their foods, more often than in the past, but hunters also had to make money to pay for the imported lumber and heating fuel. The summer was the only period of the year when seasonal work was available, which is also the most important time of the year for the harvest of subsistence foods. The compromise that was struck with technology was the advent of the outboard motor and the framed boat for the summer that allowed quick, and at that time, inexpensive access to food sources and to continuation of summer employment in the village. In that less time was being spent in the harvest of fish, feeding the dog teams during the winter became a burden, and the dogs gave way to the snowmachine that did not require the constant, and year round attention dog teams demand.

From a community self-sufficient on natural fuels and transportation, the coastal Eskimo village became dependent on imports; transportation developed as a limiting factor to the way of life, and energy became the largest single type of imported goods in the village. Although the harvest of foods has possibly diminished in terms of per capita consumption, the average household still depends on 80% of its gross nutrition, and 95% of its protein on local species. It is in the field of energy however where a permanent change has occurred.

The village of Chevak sits 120 airmiles west of Bethel, the regional transportation center of that part of Southwestern Alaska drained by the Yukon and Kuskokwim rivers. It receives its goods from the Bureau of Indian Affair's (BIA) annual "Northstar III" ship out of Seattle, and by Wien Air Alaska, and two barge companies out of Bethel.

Energy in the village is produced totally by imported fuels. The Alaska Village Electrical Cooperative (AVEC) has homogenized electrical delivery, operating a plant capable of 300 KW prime production. Current consumption in the village is 45-60 KW prime during the summer when the school is closed, and 100-110 KW prime during the winter. The new school, being built by BIA to replace a school that burned in 1972, will demand a 85 KW prime, with a peak of 115 KW when the shop is operational. The BIA subsidizes AVEC, $700,000 from the BIA's agency Plant Maintenance budget, which allows AVEC to charge its residential users a minimum of $21/month at 17.1¢/KW average. Bulk users, the school, pay 9.5¢/KW. AVEC currently consumes 45-52,000 gallons of diesel Its bulk storage capacity has recently been upgraded to 110,000 gallons, in preparation for the opening of the school, which will increase its consumption to 85,000 gallons of diesel. The BIA maintains auxiliary diesel for electrical emergency, but does not have bulk tanks for its diesel supply.

Both the BIA and the village owned store have bulk storage for fuel oil. Space heating the current BIA school requires 35,000 gallons of fuel. The BIA has a 130,000 gallon capacity and presently tops its tanks each year. The new school will demand up to 122,000 gallons of #1 and #2 mixed fuel oil when completed, leaving a surplus of only 8,000 gallons, if the tanks are topped. No new bulk storage tanks are being purchased for the school.

The fixed nature of federal contracting normally guarantees the supply of diesel and fuel oil by the local barge companies and the North Star. It is the problem of the village's growing need for fuels, and the doubt that illages can pay that makes the yearly delivery of enough fue. an. oline to the village a gamble. The village of Chevak has 45,000 gallons bulk storage capacity for fuel, and '5,000 gallon capacity for gasoline. Unlike other villages on the coastline, Chevak is well prepared for its needs. But for three years in a row, Chevak ran out of fuel oil because its summer re-supply never arrived or was not enough. In 1973, Black Navigation of St. Michaels sold 20,000 gallons of Chevak's fuel on the Yukon before coming to the village. The village ran out late in February. In 1974, the same situation duplicated itself. Turning toward Bethel's distributors, Chevak fuel was ice locked on the the Yukon in 1975 when the tug pulling the barge burned in late July, and no replacement barge could be located before freeze-up. When the village runs out, the Council borrows fuel from the BIA, which has had, to this time, a surplus. In 1975-76, Chevak's tanks are full, and the BIA will have a surplus, but in 1976, when the re-supply of the village will again remain to chance, and the BIA will require all its fuel, a problem may develop. In villages that have had to fly their fuel in, the amount per drum rises from an average of $48/55 gallon drum to $65-75/drum.

Gasoline storage in Chevak is favorable, and the village normally supplies its neighboring villages which do not have bulk gasoline storage. The average cost of a drum is $50. Gasoline consumption has risen from 12,000 gallons in 1970 to 39,000 gallons in 1975, and the rate of consumption is expected to continue to rise until supply is exhausted within the next two years, the village store's manager declared.

Per capita income in the village of Chevak, located in Wade-Hampton census district, was $1,300 in 1970. The listing of 24 families in Chevak made in 1975 reveals that 20-40% of the cash income of these families is consumed by imported fuels, well out of line with the natural average.

The statistics of energy in the village do not reveal the entire story, however, for growth in the public sector principally influences the village's way of life, and growth in the public sector is undisciplined, and not coordinated with the village.

Bethel's tug industry is concentrated on oil; freight is secondary. The growth in public facilities dependent upon fuels for energy has outgrown the barge companies ability to delivery. While public facilities are normally re supplied, the villages become the supply casualities; 1972, 14 villages ran out of oil; in 1973, 24 villages; in 1974, 36 villages; and in 1975, 39 of Bethel region's 57 villages had fuel oil shortages.

Total energy planning for the community is non-existent and the failure to plan causes an undisciplined demand for more oil, which is duplicated in all other villages. Alternate energy systems do not exist, nor do total energy systems employing waste heat recovery. Federal and State of Alaska agencies to this date have not initiated studies on the utility of these alternate forms of energy involving hydro-electric, geothermal, and aerogenerators in the plan and design of new facilities, or the consolidation of existing energy demand by public facilities.

The BIA's new plant will sit 70 feet from the existing AVEC plant. AVEC's engineers have initiated studies that determined that the majority of the space heating demand of the new facility could be produced by AVEC using water jackets, and a utilidor to convey the waste heat to the school for distribution. The BIA has not accepted this idea to date. Because BIA subsidizes AVEC, AVEC is committed to selling all of its waste heat to BIA. Even though BIA does not want the waste heat, AVEC cannot release the heat to other customers. At this time, AVEC believes that 650,000 BTU will be wasted each hour when the plant is operating at full capacity in 1976.

The Chevak store wishes to buy the waste heat. Concerned with fire from its domestic boiler, and consuming 6,000 gallons of fuel in its store/hall, the village determined that it could save money, while reducing the village's total demand for fuel, by converting to waste heat. AVEC will not sell the village the heat until the BIA makes up its mind. The village built a community hall this summer, and wished to place the hall near the store and close to the heat recovery system. BIA personnel informed the village that building the hall on the selected location would present a fire hazard to the new school, and with the waste heat recovery system idling, the village moved the hall across the village, requiring an additional 1,500-2,000 gallons of fuel depending on use, and the necessity of burrowing a new path through the village to roll the drums to the hall.

New housing in the village, sponsored by the Alaska State Housing Authority and the Bureau of Indian Affairs, is well designed, and properly insulated. The houses sit in rows that would make utility hook-ups convenient, and a centralized heating plant economically feasible. However, the houses are located across the village from the AVEC plant, almost 3/8 mile, making waste heat recovery impossible. Villagers now have to roll their drums that distance from the village store, or use gasoline in their snowmachines to accomplish the task.

The village also runs a modified village safe water act facility that drains the local economy. Built in 1974 by the villagers, the

State of Alaska Department of Environmental Conservation awarded the village $60,000 to finish off the system. Containing a water pump, showers, flush toilets, and a laundromat, the facility would have consumed $26 to $34,000 worth of energy along if operated like other VSFW facilities in the State. The annual operating cost for the Emmonak EPA and the State Alukanuk facilities is $100,000 in which energy accounts for almost $42,000 of the costs. The villages raise approximately 15% of the annual costs through user fees, with the remainder being subsidized by the State and Federal governments. Realizing the financial burden, The State "educated" Chevak to the energy costs it would face, and informed the village that no budget subsidy could be expected. The village opened the facility only 3 hours a day during the winter of 1975, all day Saturday and Sunday, and kept its electrical and oil costs to $12,500 gallons of oil, and added a further burden to the village's capacity to remain within its bulk capacity. The new facility is located 1/4 mile from the AVEC facility.

Wind blows constantly in Chevak. The Cape Romanzoff Early Warning Station 26 miles northwest of the village records ambient wind velocities above 15 mph at 70 feet the majority of the year. One individual aware of the Romanzoff readings declared that in his stay at the EW site, only 12 days had less than 15 mph for their average.

The village of Chevak is interested in breaking loose of the oil burden. Aware that shipping costs, supply, and storage are outstripping the village's ability to pay, the Council and the Corporation are seeking technical information on aerogenerators. The Alaska Native Claims Settlement Act deposits yearly funds into the Chevak Corporation, and the Corporation is re-cycling its funds to support the village's fuel economy, and recognizes the dead end this yearly re-investment means for its only capital, but State and Federal responses to date have been negative.

(1) HOUSEHOLD	INCOME (2) FAMILY INCOME	DRUMS(3) OIL USED	DRUMS GAS USED	TOTAL(4) FUEL COSTS	% OF INCOME
1.	$2,450	18	4	1,052	42.9%
2.	$3,000	20	6	1,296	43.2%
3.	$3,650	19	4	1,136	31.1%
4.	$2.560	16	4	992	38.8%
5.	$4,060	15	5	1,000	24.6%
6.	$2,760	16	4	990	35.9%
7.	$2,800	14	5	952	34.0%
8.	$3,340	20	5	1,240	37.1%
9.	$2,800	14	4	896	32.0%
10.	$2,360	11	2	640	27.1%
11.	$4,000	19	6	1,248	31.2%
12.	$3,560	17	4	1,040	29.2%
13.	$3,110	10	3	648	20.8%
14.	$2,760	12	4	800	31.9%
15.	$3,340	16	5	1,048	31.4%
16.	$2,380	14	5	952	40.0%
17.	$2,900	15	6	1,056	36.4%
18.	$2,460	14	4	912	37.1%
19.	$3,500	18	5	1,144	32.7%
20.	$2,670	18	6	1,200	44.9%
21.	$5,500	21	7	1,400	25.5%
22.	$3,070	17	5	1,096	35.7%
23.	$3,600	16	6	1,004	27.9%
24.	$4,590	20	7	1,352	27.6%

1) Chevak has 67 heads of the households; some families have substantial cash incomes.

2) Transfer payments and cash income combined.

3) Estimate in terms of 55 gallon drums

4) Based on summer, 1975 price of fuel in Chevak: $48/drum #1 heating oil; $56/drum gasoline.

APPENDIX E-1

PROPOSED USE OF GEOTHERMAL WATER FOR SALMON AQUACULTURE ON UMNAK ISLAND, ALASKA

by

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PROPOSED USE OF GEOTHERMAL WATER FOR SALMON AQUACULTURE ON UMNAK ISLAND, ALASKA

Introduction

Several streams on Umnak Island in the Aleutian Islands have been identified as possessing significant potential as hatchery water sources for ocean ranching of salmon (McNeil, 1974). The streams in question drain fairly recent volcanic formations and are believed to have sufficient warmth to remain ice free throughout the winter, although water temperature regimes remain to be determined. If temperature and chemical quality of these streams should prove to be favorable for anadromous salmonid fishes, a successful salmon ocean ranching industry is a distinct possibility for the Aleutians, as well as other areas of Alaska, where geot'ermal sources of water might be developed for aquaculture at relatively low cost.

This proposal is for an ocean ranching demonstration project, primarily with pink salmon. A successful demonstration of ocean ranching in the Aleutians could lead to a large-scale hatchery program which might ultimately produce several million pounds of salmon annually for harvest.

First year of the program would be devoted to hydrological and biological surveys of several spring-fed streams on Umnak Island to determine their suit ility for salmon aquaculture. Should water quality prove to be suitable, the surveys would be followed by construction of a demonstration hatchery capable of producing 8 million juvenile pink salmon annually for release into the ocean as unfed fry. The hatchery would be operated 4 years to demonstrate economic feasibility of ocean ranching using geothermal water on Umnak Island.

Total cost of the 5-year project is estimated to be about $485,000 plus overhead. Application of the technology for large-scale ocean ranching on Umnak Island would have the potential annually of contributing millions of pounds of high quality animal protein with virtually no expenditure of energy. The major economic benefits would accrue directly to the Aleut Indians who are about to acquire from the Federal Government ownership of land on Umnak Island where the geothermal water sources are located.

Study Area

The study streams are located within the boundaries of the former Fort Glenn military reservation on the east end of Umnak Island (Figure 1). Tulik Volcano (4,100 feet elevation) is the dominant feature of the lava formations where the study streams originate. Several of the streams flow in an easterly direction into the Bering Sea and into Umnak Pass which connects the Bering Sea and the North Pacific Ocean.

Intense upwelling of marine waters along the Aleutian Islands creates conditions which are highly favorable for plankton. As a consequence, salmon from many regions around the rim of the North Pacific Ocean and Bering Sea feed in the area. Thus, marine waters surrounding Umnak Island should be well suited as nursery waters for hatchery-produced fish.

Hydrological Surveys

Temperature recorders would be installed on at least 5 streams and operated one season (August or September - April or May) to evaluate temperature regimes of the study streams. The Aleut Corp. own 5 automatic recording thermographs which might be rented for this work.

There is also a need to acquire qualitative information on stream discharge patterns and quantitative information on chemical water quality. Workers at an existing cattle ranch on Umnak Island might be trained and employed part time to make periodic observations on streamflow and to collect water samples for laboratory analysis.

Biological Surveys

These surveys will be required to catalog the existing fish fauna in the study streams and to estimate the size and species composition of existing stocks of salmon which might be used to supply eggs for hatcheries. Surveys of streams would be required during the August-September spawning period. The existing road system is extensive and crosses most, if not all, of the study streams. A motorized land vehicle could therefore be used for transportation.

Hatchery Design

Construction of a demonstration hatchery would proceed only if it is evident that water quality is suitable. It would be preferable to obtain eggs from a stock of salmon which is native to the hatchery stream, but eggs could be transplanted from nearby Unalaska Island which is known to have pink and chum salmon. Umnak, unfortunately, has never been surveyed at the proper time of year to establish the size of salmon stocks.

A demonstration hatchery would be a simple, inexpensive design which is used primarily by private hatcheries on coastal streams in Oregon and Washington. The design is sometimes called a "shallow-matrix gravel incubator" or "Netarts gravel incubator" after Netarts Bay, Oregon, where the system was first employed in 1968. Hatchery tanks can be constructed onsite from plywood or prefabricated and shipped to the site. About 500 square feet of level ground is required for each million eggs of installed tank capacity. Water can be delivered to the hatchery site through open canals and distributed from canals to tanks through plastic pipe. Figure 2 shows a schematic diagram of a hatchery layout. The hatchery is not housed, but lids are placed on tanks to shield eggs and alevins (larval salmon) from light, weather, predators, etc.

The Umnak Island study streams have modest gradients and pass through small valleys which are covered by a mantle of top soil. Canals and other excavations can be done with farm machinery.

Pink and chum salmon are easy to trap and spawn artificially. Fish are almost fully mature when they leave salt water, and it is s[illegible]n necessary to hold adults in captivity for more than one week while they ripen. A weir diverts spawners from the stream into a hatchery discharge canal (Figure 2), and they are sorted and spawned at the site where hatchery tanks are located.

Eggs and alevins require little or no care after the fertilized eggs are placed in tanks. Eggs are placed on screen trays suspended in the water column in tanks during September. Hatching occurs in December, and the alevins drop through the trays to the bottom of a tank which has a shallow layer of gravel or artificial plastic turf for support. The unfed fry emigrate from tanks in the spring and follow the discharge canal to the stream which carries them into the ocean. Pink salmon mature at 2 years of age. Chum salmon mature after 3, 4 or 5 years.

Work Schedule

The work schedule is conceived as follows:

Year 1 - (a) Complete hydrological and biological surveys.

(b) Select hatchery site and donor stock.

(c) Design hatchery.

Year 2 - (a) Construct water delivery system for 900 gallons per minute.

(b) Excavate site for hatchery tanks and fish spawning.

(c) Install hatchery tanks.

(d) Construct adult trapping facilities.

(e) Stock hatchery with eggs from donor stock.

Year 3 - Stock hatchery with eggs from donor stock.

Year 4 - Stock hatchery with eggs from returning hatchery fish (pink salmon only).

Year 5 - (a) Stock hatchery with eggs from returning hatchery fish.

(b) Formulate an expanded program, depending on results of demonstration project.

Economic Considerations

Pink salmon have the shortest life cycle (2 years) of all salmon species and are recommended for evaluating the feasibility of ocean ranching on Umnak Island. Chum salmon have a 3- to 5-year life cycle. Sockeye and coho salmon also spawn in the Aleutian area, but these species require a year or longer of freshwater rearing before they go to sea.

Pink salmon have been released from three pilot incubator hatcheries in Alaska since 1972, and six experiments involving up to 1 million fry per experiment have been evaluated. The number of adults returning to hatcheries has varied between 0.7 and 3.0 percent of the number of fry released, with an average of about 1.5 percent.

A hypothetical projection of production of pink salmon from gravel incubator hatcheries on Umnak Island is given in Table 1. The assumptions are:

1. Egg-to-fry survival = 80 percent.
2. Fry-to-adult survival = 1 percent.
3. Fecundity = 1,600 eggs per female.
4. Amount of water available for hatcheries = 50 c.f.s. on the expectation that several spring-fed streams can be developed for hat hery use.

At this point we can only speculate about our ability to generate returning r of 2 million adult pink salmon to Umnak Island. This is probably a much higher level of production than Umnak streams have achieved with natural spawning because spawning area is limited.

It is not inconceivable, however, that such a potential exists with hatcheries, since streams entering Makushin Bay, Unalaska Island (50 miles east of Umnak Island), are known to have produced several hundred thousand adult pink salmon.

If a demonstration project should be successful, the ultimate potential for Umnak Island for salmon ocean ranching would probably be determined by the availability of fresh water for artificial recruitment of pink and chum salmon fry. It is assumed that the capacity of marine nursery waters to grow salmon to maturity is not limiting.

Each adult pink salmon returning to a hatchery would generate about $2.50 of wholesale value as a canned product (1974 prices). There would also be a substantial added value (more than $1 per female), for surplus roe. Thus, wholesale value of a processed pink salmon should average at least $3 per fish. Value of chum salmon would be almost three times higher per fish, reflecting their larger size at maturity.

Cost of Project

The project would include two phases. Phase I would take place in the first year and would include hydrological and biological survey work to evaluate the desirability of a demonstration hatchery. Phase II would take place in the 2nd through 5th years to evaluate economic feasibility of an ocean ranching industry on Umnak Island and to establish pink salmon brood stock for expanding the project into a large-scale commercial venture. Expansion into a commercial venture should be the responsibility of the Aleut people working through their regional and village corporations.

The total cost of a 5-year project would be about $500,000 to $600,000. This cost may seem low to some reviewers, but keep in mind that this project is not intended for the construction of a permanent edifice. The hatchery would be simple and temporary and would be operated as inexpensively as possible for the purpose of determining feasibility of salmon ocean ranching in the Aleutians with geothermal water.

Reference

McNeil, W. J., 1974, Preliminary analysis of aquaculture potential in the Aleutian Islands, Alaska. U.S. Dept. of Commerce Economic Development Admin. Tech. Assistance Project, Sept. 1974:13p.

APPENDIX E-2

A PROPOSAL FOR ALASKA MUNICIPAL GEOTHERMAL HEATING

by

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A PROPOSAL FOR ALASKA MUNICIPAL GEOTHERMAL HEATING

he use of warm geothermal waters from drilled holes or springs for space heating has proven economic in many regions of the world. The costs vary with the ease of obtaining the hot water, its purity, the distance that it must be piped, and the duty cycle determined by the climate. Following are some examples:

Reykjavik, Iceland: Homes for approximately 100,000 people are heated for about $4.00/gigacalorie, equivalent to oil for about $5.60 per barrel. The duty cycle is almost 100%. Wells very in depth from 2100 feet to 6000 feet and the water is piped from 1/2 mile up to eleven miles. Total system capacity is about 190 gigacalories per hour, equivalent to 135 barrels of oil per hour. Water flow is about 2700 cubic meters per hour (equals about 800,000 gallons/hour).

Husavik, Iceland: Some 2500 people reap the benefits of hot water piped from natural springs 11 miles away. The household is charted about the same as in Reykjavik. Total capacity is about 6 gigacalories per hour with a flow rate of 125 M^3/hr. The electrical heating equivalent of this is about 7000 kilowatts.

Hungary: Some 4000 apartments and large areas of greenhouses are heated by geothermal wells. The cost is $3.00 per gigacalorie. Coal heat in the same region is $11.00 per gigacalorie.

Klamath Falls, Oregon: Some 450 homes are heated by individual wells 200 to 450 feet deep. The costs are competitive with other sources even though the systems are quite inefficient due to the householders desire to independance. The normal well would supply five to ten houses if its entire capacity were used.

Oregon Technical Institute: This institute is entirely heated from its own well drilled to 1715 feet. At 30 cubic meters of water per hour the cost is $18,000.00 per year, or $.70 per gigacalorie, corresponding to oil for about $1.00 per barrel.

Menlun, France: There is an apartment complex of 3500 apartments for which all of the utility heat and part of the space heating is provided at costs competive with $6.00/barrel oil. The well is 5900 feet deep and supplies 13 to 100 cubic meters per hour of water at 163°F. This is in a region with no geothermal anomaly.

There are many other examples in Japan, Italy and Russia. Depending on the local conditions, the cost of heat runs from a price equal to that which would be obtained if oil were being used, to a factor of ten less, or better.

The Melun experience is of special interest for application in Alaska. A system that is competive with oil in France should be very attractive in the remoter regions of Alaska where oil costs are very high because of transportation costs. In principle, one should be able to drill almost anywhere in Alaska and reach usable temperatures at depths of 6000 to 7000 feet. While it is in principle feasible to extract that heat even if there is no water present, the techniques for so doing have not yet been developed. Thus one must, at the moment, depend on hitting water at depth. No good data on the prevalency of water at depth are available for Alaska; however, informed geologic guesses would put it above 50%. What little data that are available would also imply that the geothermal temperature gradient in Alaska is a bit above normal, implying that on the average, one would not have to go so deep to obtain usable temperatures.

Thus it appears that over perhaps half or more of the area of Alaska, the question becomes, not whether it is feasible to heat using geothermal waters, but what are the economics involved? In principle, one can drill anywhere and have a roughly 50% chance of obtaining usable hot water. The question of economics will depend upon local conditions.

Obviously appropriate geological studies will improve the likelihood of picking a favorable site. However, the record of geology and geophysics is not good in this field, and one must be careful of being either encouraged or discouraged by judgments from these disciplines. Certainly, where anomalies are being sought, the techniques are more reliable.

The high cost of labor in Alaska would probably run the costs up over those mentioned above, for similar installations. However, one should still be able to produce heat for the equivalent of $10.00/ barrel of oil or less. This price is much less than the cost of oil in many regions of the state now. The disparity will probably become greater in the future.

While the economic geothermal space heating systems can be of almost any size, there is an effective minimum if one is to not depend on local geothermal anomalies. With present drilling and casing techniques a production hole at 8 1/2" diameter will cost approximately what is given in the following table:*

depth (ft)	cost per foot	cost to depth
2000	$34.50	$69,000.00
4000	$50.00	$200,000.00
6000	$61.00	$366,000.00
8000	$73.00	$584,000.00
10000	$83.00	$830,000.00

* Tivi Meidav - Geonomics

These costs will, of course, vary with location and geology. They are estimated assuming reasonable transportation to within 50 miles of the drill site. Thus, if one assumes at 6000' hole, which is reasonable on the average, the hole alone will cost $366,000.00. If reinjection is necessary, this cost doubles. Obviously, exploratory hole costs are much less. T e expected load must therefore be such as to amortize such costs.

To illustrate this point better, let us assume a Melun type system producing 100 cubic meters of water per hour at 80°C (176°F) and assume the dump temperature as 50°C (122°F), thus producing 3 gigacalories of usable heat per hour. We further assume $2.50/hour running costs (one man). The following table then obtains:

Cost of Installation	cost of money	necessary sale price of heat*	equivalent oil cost
$2,000,000.	15%	$12.33/Gcal	$17.39/bb
$2,000,000.	6%	$6.23/Gcal	$ 8.78/bb
$ 500,000.	15%	$3.66/Gcal	$ 5.16/bb
$ 500,000.	6%	$2.13/Gcal	$ 3.00/bb

*assuming 30 year amortization.

Obviously costs can become even less if the resource is closer to the surface, hence reducing hole costs, or if the water temperature is higher.

The above table illustrates why such installations may be more feasible in Alaska than in the lower 48. There are many places in Alaska where heat, at even the higher prices shown, would be cheaper than the sources now used, with the lower costs much cheaper still.