

ALASKA LEGISLATURE SPECIAL COMMITTEE / SUBJECT FILES 86 / 2
990 SCOMM44: HOUSE POWER ALTERNATIVES STUDY COMM. 1979-80 990

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1 upon the peripheral nerve electrical potentials
2 (Becker, Science, 134, 101 (1961)) and upon the
3 electroencephalogram from the brain in animals
4 (Becker, Proc XI Int. Cong. Tsfiol., 1753 (1966)).
5 In conjunction with Dr. Howard Friedman, I have
6 investigated and reported on interactions between
7 changes in the earth's natural magnetic field
8 (magnetic storms) and human behavior (Becker, Nature,
9 200, 626 (1963) and Becker, Nature, 205, 1050 (1965)).
10 We have also reported on the effects of low strength
11 magnetic fields modulated at 0.1 and 0.2 on reaction
12 times in human volunteers (Becker, Nature, 213, 949
13 (1967)). I was asked to review the literature on the
14 biological effects of magnetic fields in 1963 for
15 publication (Becker, Med. Elect. Biol. Eng., 1, 293
16 (1963)). This was done to provide a base line for
17 the experimental interest in this area that was on
18 the increase at that time. Most recently, I have
19 been consulted by the AEC on possible hazards associated
20 with the ultra-high strength fields necessary for
21 fusion reactors.

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1 Q. What is the current state of research in the area of
2 biological effects of magnetic fields?

3 A. There has been increasing interest in this area over
4 the past 10 years. Two books have been published in
5 the United States (Barnothy, M.F., ed., Biological
6 Effects of Magnetic Field, Vol. I. Plenum Press,
7 New York 1964 and Vol. II, Plenum Press, New York 1969
8 and several volumes in the Soviet Union.) Of particular
9 pertinence to the present hearing are several reports
10 of effects produced by very low strength magnetic
11 fields (i.e., from 1 to 10 gauss). The most recent
12 was by Dr. William Keeton (Proc. Nat. Acad. Sci. U.S.A.
13 68, 102, 1971) who was able to show that the homing
14 pigeon utilized the earth's magnetic field for
15 navigation with a sensitivity and precision that
16 our best instruments cannot attain. His observations
17 have recently been corroborated by Wolcott and Green
18 (Science 184, 180, 1974) and extended to several other
19 species of birds (Southern, W.E., Bioscience 22, 476,
20 1972 and Wiltshko, W. in Animal Orientation and
21 Navigation, p. 569, Government Printing Office, Washington,

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1 D.C. 1972). I believe that this is an instance of
2 these particular animals developing the same system
3 that is present in all animals into a specific sensing
4 mechanism of survival value. Dr. James Hays has shown
5 that naturally occurring reversals in the earth's
6 magnetic fields in the geological past were accompanied
7 by the extinction of animal species. During reversal
8 periods, the magnetic north and south poles exchange
9 their position. We know only that this is not associated
10 with a drop in the field strength below half normal nor
11 is it associated with any major increases in field
12 strength. Since no reversals have occurred in the
13 documented past, we cannot speculate on such factors as
14 the appearance of specific frequencies or alterations
15 in the earth's electrostatic field. The point is that
16 such seemingly minor variations in the magnetic
17 field are quite apparently events of major biological
18 magnitude. (Hays and Updyke, Science 158, 1001, 1967).
19 Dr. Frank Brown, who is primarily interested in the
20 phenomenon of biological cyclic behavior has shown
21 that it can be influenced by applied magnetic fields

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1 as low as 1 gauss. Since the biological cycles have
2 periodicities the same as the natural geomagnetic
3 field cycles, the suspicion is that the biological
4 cycles are driven by the earth's naturally fluctuating
5 geomagnetic cycles (Brown, F. Nature 209, 533, 1966,
6 Encyclopedia Britannica 292, 1966).

7 The work of Friedman and his colleagues may be
8 relevant to Brown's observations in that he has been
9 able to demonstrate that magnetic fields of 200 gauss
10 strength are definite stressors for the exposed organisms
11 (Friedman, H. and Carey, R. Physiol. & Behavior 9,
12 171, 1972 and Physiol. & Behavior 4, 539, 1969). Most
13 recently Dr. Dietrich Beischer of the Navy's Aerospace
14 Medical Research Laboratory has shown effects upon
15 human volunteers of exposure to very low strength (1 gauss)
16 45 Hz magnetic fields. The primary findings were an
17 increase in serum triglycerides observed in two
18 experimental runs (Beischer, D., Navy Aerospace Med.
19 Res. Lab. report # 1180, 1973). The Sanguine Biological
20 Study Committee to which these findings were reported
21 was also advised by the responsible Navy personnel

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1 that following Dr. Beischer's report, the personnel
2 at the Wisconsin Test Facility (a test antenna similar
3 to the proposed Sanguine Antenna located at the proposed
4 Wisconsin site) were examined and all were found to
5 have elevated serum triglycerides. The mechanism
6 producing this effect is currently under study. The
7 significance of the elevated triglycerides is in the
8 fact that this material is one of the steps involved
9 in fat metabolism and such elevations beyond the normal
10 range are generally believed to indicate an increased
11 risk of arterioscleratic disease.

12 Q. Why haven't you determined safe levels for human exposure
13 to 60 Hz magnetic fields?

14 A. We do not have sufficient funding to conduct these, or
15 any other additional experiments on power frequency
16 fields.

17 Q. Would you recommend construction of the 765-kV line as
18 proposed by the applicants?

19 A. No, for the reasons that the strength of both the
20 electric field and magnetic field produced by the
21 line will be in the range possibly productive of

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1 biological effects. I believe that chronic exposure of
2 humans to such fields should be viewed as human
3 experimentation, and subjected to the rules previously
4 mentioned. I believe that the most prudent course to
5 follow would be to determine the complete spectrum of
6 biological effects produced by exposure to 60 hz fields.
7 It should then be possible to establish firm levels of
8 permitted exposure both as to field strength and to
9 exposure times.

10 Q. Do the conclusions you have proffered apply to
11 transmission lines whose voltage is less than 765 kV?

12 A. Yes, proportionally so.

13 Q. Would you state for the record whether the conclusions
14 you have reached apply equally to an underground 345 kV
15 line, a 400 kV d-c overhead line and an underground d-c
16 transmission line?

★ 17 A. Our conclusions do not apply to the d-c case. In the
18 case of the underground 345 kV line, it is my
19 understanding that these lines may be shielded to
20 reduce the ground level electrical and magnetic
21 fields to the ambient level.

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1 Q. Does this conclude your testimony?

2 A. Yes.

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ENVIRONMENTAL PROBLEMS IN EXTRA HIGH VOLTAGE TRANSMISSION^{1/}Louise B. Young^{2/}

Abstract.--This paper discusses health hazards caused by EHV transmission line corona and electrostatic fields. Comparative measurements of electric field gradients under EHV lines taken according to methods used in the U.S. and the Soviet Union show that, according to the Soviet standards, the electric fields under some U.S. lines are strong enough to represent a danger to people who are exposed to them for appreciable lengths of time.

INTRODUCTION

During the last two years several new questions about environmental effects of extra-high-voltage overhead transmission lines have surfaced as significant issues. As a result, a series of studies investigating these problems recently was commissioned by the Electric Power Research Institute, but these questions also deserve consideration by other agencies and research funded by sources other than the electric power industry.

A well-known fact that is acknowledged by the electric industry is that EHV transmission lines have an adverse impact on any environment in the immediate vicinity of these lines. They create audible noise, radio and television interference, and some hazard from transient electric shocks. These effects have been under scrutiny by the scientific community for at least a decade, and research studies are continuing in an attempt to understand and control these problems.

There are, however, two possible health hazards that the United States has only just begun to take seriously: (1) air pollution resulting from chemical reactions in corona discharge; and (2) electromagnetic effects, particularly the strong electric field that exists in the vicinity of EHV lines. Research into the biological effects of electric fields has been conducted in Russia since 1962. Scientists conducting these studies have con-

cluded that there is significant biological effect resulting from frequent exposure to electric fields in EHV substations and under EHV transmission lines.

In 1962, shortly after the first 500 kilovolt (kV) lines had been operating in the Soviet Union for several months, men working at the substations began to complain of headaches and a general feeling of malaise. Abnormal fatigue and sleepiness were mentioned by a majority of the workers. They associated these symptoms with exposure to the electric fields.

In view of these reactions, a long-term study was instituted, with systematic medical examinations of approximately 250 men working at 500 and 750 kV substations. These results were compared with medical examinations of men working at lower-voltage substations. The studies showed that long-time work at 500 kV substations without protective measures resulted in "shattering the dynamic state of the central nervous system, heart and blood-vessel system, and in changing blood structure. Young men complained of reduced sexual potency" (Korobkova, et al 1972). The severity of these effects depended directly on the length of stay in the field.

Unfortunately, there has been a tendency in the United States to brush off the results of these studies as unscientific and exaggerated, while at the same time, there has been no serious attempt to replicate the experiments in a manner which would be completely acceptable to the international scientific community. Some of the differences of opinion about the significance of these experiments concern the strength of the fields that exist under the Russian lines as compared to those in the United States and

^{1/}Paper presented at Symposium on Environmental Concerns in Rights-of Way Management, Mississippi State University, January 6-8, 1976.

^{2/}Author of Power Over People, Winnetka, Ill.

the validity of Soviet measuring techniques. Of course, no scientific research can even get off the ground without standardization and complete agreement on the methods of quantifying the various parameters. During the past year I have researched these problems, and this paper summarizes the results of my findings.

ELECTRIC FIELD GRADIENT MEASUREMENTS

Although the vertical electrostatic field to which people are exposed under a transmission line can be computed theoretically, it also is advantageous to make actual field measurements in order to confirm these calculations. We should bear in mind, however, that the measurement of a truly unperturbed field is impossible since the combined presence of any measuring device plus the observer must of necessity perturb the field. The size and position of both the meter and the observer are significant factors in determining the degree to which the field is perturbed. When measurements are made at a height above ground, the degree of perturbation caused by the meter and the observer is greater than measurements at ground level.

Up until about a year ago, electrical engineers in the United States reported the electrical field gradients under transmission lines at ground level. In this case, the instrument in contact with the ground does not appreciably distort the field. However, it was found that results did not always correspond to theoretical ground level gradients, because the presence of vegetation and irregularities in the ground surface caused significant variations in the electric field intensity.

More recently, measurements in the United States have been made at one meter above ground level with an instrument held on a hot-stick or a similar long, insulating handle. Measurements made in this way generally confirm the theoretical calculations of the unperturbed field. It must be remembered, however, that these unperturbed values are useful only for comparing different transmission lines. From a biological standpoint, it is important to consider the fields that actually impinge on the body of a person exposed to the electric field. For example, the intensity of the field impinging on the top of a man's head may be as much as fifteen times as strong as the unperturbed field at that position (Schneider 1974). The taller the person (or other perturbing object) the greater the

field intensity at head height.

Results of the Russian studies of health effects from exposure to alternating electrostatic fields first were reported at the international symposium in Paris in 1972 (Korobkova, et al. 1972). Four other reports on this work subsequently have become available in translation. Because the Russian scientists concluded that long-term exposure to fields that exist under their 500 kV and 750 kV lines did cause significant and important biological changes, safety regulations were designed to protect workers from the influence of these fields (Knickerbocker 1975). Accordingly, new regulations provided that no one should be exposed for any time to fields over 25 kV per meter (kV/m) without special protective screens or Faraday cages. In a field of 25 kV/m, for example, maximum exposure time was determined to be no more than 5 minutes in a 24-hour period. The number of minutes allowed increases as the field strength diminishes. At 10 kV per meter, 180 minutes is allowed; 5 kV/m or less is considered the only safe levels for unlimited exposure (Table 1).

Table 1.--Safety Regulations - U.S.S.R.

Electric field intensity kV/m	Permissible duration of personnel stay in electric field during 24 hours minutes
5	unlimited
10	180
15	90
20	10
25	5

(From "Rules and Regulations on Labor Protection at 400, 500, and 750 kV AC Substations and Overhead Lines of Industrial Frequency [In the U.S.S.R.]," translated by G. G. Knickerbocker.)

In trying to interpret the significance of the Russian results in relation to our own lines, a number of difficulties have been encountered. There appears to be an important difference, for example, between electric

field gradient levels measured under their lines and those reported by our electrical engineers for lines carrying similar voltages.

In the CIGRE paper by Korobkova et al (1972), maximum field intensity figures of 22 kV/m are reported for roads under 750 kV lines. Korobkova also states that "at 750 kV switchyards, there is practically no area with an intensity lower than 10 kV/m." A graph of field intensity versus distance to the conductor of a 500 kV line shows a maximum intensity reading beneath the outer conductor of 22 or 23 kV/m and this occurs when the conductor is approximately 10 meters away. I understand this to mean that the line in this case is at least about 33 feet above ground level. Citing from "Rules and Regulations on Labor Protection," (Knickerbocker 1975) work carried out on the ground in the zone of influence of a 750 kV transmission line without the use of protective measures is permitted in the span of the transmission line and close to anchor and corner towers for no more than 10 minutes. If the work is off the ground protective measures must be used. Since the field that the Soviets allow their workers to be exposed to for a maximum of 10 minutes is 20 kV/m, we can reasonably assume that they believe fields of this intensity occur within the span as designated (fig. 1).

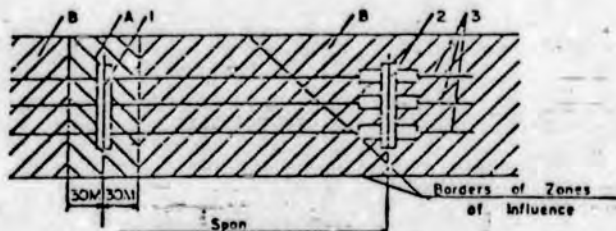


Figure 1.--DIAGRAM OF 750 kV TRANSMISSION LINES WITH ZONES OF INFLUENCE

1--intermediary tower

2--anchor or corner tower

3--conductors

A--zones in which work is permissible without protective measures for durations of no more than 180 minutes (distances given in the diagram)

B--zones in which work is permissible without protective measures for durations of no more than 10 minutes

From "Rules and Regulations on Labor Protection," in (Knickerbocker, 1975).

The above statements quite clearly reveal that the Russians were measuring field gradient intensities as high as 22 kV/m under both 750 kV and 500 kV lines. Maximum levels actually measured by electrical engineers in the

United States, however, are 10 kV/m under 765 kV lines and 8 kV/m under 500 kV lines. There appears to be a difference, therefore, of a factor of more than two between U.S.S.R. and U.S. readings.

Some of this discrepancy may be accounted for by differences in line design. For example, Russian lines are somewhat lower than lines in the United States. It is difficult to quantify this factor precisely because not enough specific information is available on the height of Russian lines that were in operation at the time these first health studies were being conducted. The only indication we have of line height is the one previously mentioned - a 500 kV line which appears to have a minimum height of about 33 feet above ground level. Our 500 kV lines theoretically have minimum heights of 35-37 feet under maximum load and temperature conditions. However, even when lower clearances of this order of magnitude are taken into consideration, there still remains a significant discrepancy, a factor of somewhere between 1.5 and 2. It is important that this difference be resolved before the significance of the Russian studies can be applied to our own lines.

During the past year, I made several field gradient measurements under 765 kV lines, duplicating as closely as possible with the instruments available to me the Russian measuring techniques, as well as those of our own engineers. I now believe that the discrepancy between the two sets of figures can be simply explained on the basis of the different methods used in measuring fields in the two countries.

Russian reports state that the strength of fields in their substations and under their lines was determined by measurements with a specially-designed field gradient meter. The meter itself and the manner in which the readings were taken is described in detail. However, theoretical calculations do not appear to have played any part in the determination of the field gradient by Russian scientists. Only one reference in the five reports relates to theoretical field strengths, and this single reference indicates that their theoretical understanding of the spatial distribution of the electric field differs significantly from ours: Morozov and Gromov (1975) "...data from calculations and measurements of the distribution of the electric field on high voltage lines show that field intensity is proportional to the square of the distance from the source of the field (conductor, connecting bus, etc.)" Even assuming that the authors mean "inversely proportional", this statement does not correspond with a theoretical formula for field gradient. It also indicates that their

field gradient measurements increased in intensity fairly rapidly as height above ground increased - much more rapidly than occurs in our field gradient readings, which do not alter significantly until more than half the distance between the ground and the conductor has been traversed.

To measure their fields, the Russians used a small ungrounded meter held by an observer on a short handle at 1.8 meters above ground. This meter is described in the report by Morozov and Gromov. (fig. 2). The authors specify that the handle of insulating material be 250mm long, and they say that "the operator holds the instrument by the handle and inserts it into the measured area." The height at which the instrument is held is described as 1.8 meters above ground (see "Rules and Regulations on Labor Protection," in Knickerbocker 1975).

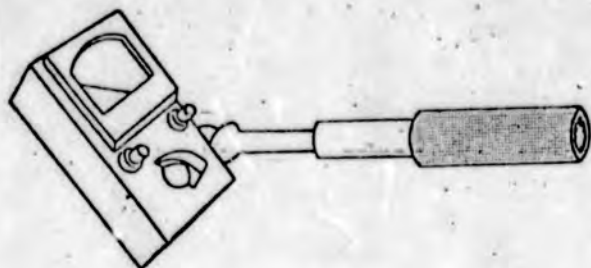


Figure 2.--An instrument for the measurement of electric fields of 50 HZ. From Morozov and Gromov, 1975).

A handle of 250mm (about 10 inches) is so short that the observer holding the instrument cannot avoid causing considerable concentration of the field by the presence of his body. I found that a Monroe meter (Model 238A-1 Portable Differential AC Electric Field-meter) held close to the meter (thus simulating a 10-inch handle) and raised to a height of 1.8 meters above ground gave readings that ranged from 1.5 to 2 times higher than the same meter held out on a 4-foot-long handle at approximately one meter above ground. Figure 3 shows a field profile under a 765 kV line with readings taken according to the standard U.S. method (on a 4-foot-long handle at one meter above ground); and according to the Russian method (using a 10-inch handle with the instrument held at 1.8 meters above ground). In the short handle configuration, the position of the hand is extremely important. The hand itself, of course, must occupy part of the 10-inch handle. If the hand is moved several inches nearer the body of the instrument, readings increase by as much as 50%.

For the measurements in figure 4, the hand was placed as far from the meter as possible on the 10-inch handle. The readings taken by the Russian method average 1.6 times the readings taken by the U.S. method.

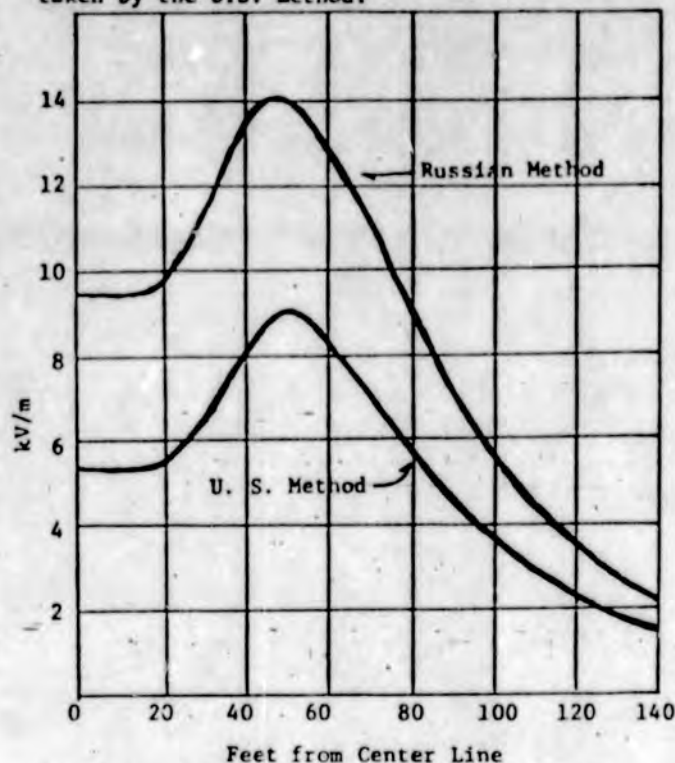


Figure 3.--Field gradient readings under 765 kV line, Peotone, Ill., June 21, 1975

It is also interesting to note that the height at which the Russian measurements are made tends to magnify the discrepancy between the two ways of measuring electric field gradient. If the observer crouches down and holds the instrument in the short handle position at one meter above ground, the readings for field gradient are 1.26 times higher than those taken when the full handle is used. In other words, the presence of the observer has a more perturbing effect on the field at 1.8 meters than it does at one meter (an observation that could also be predicted by theory).

It seems apparent that the Russians were measuring a more perturbed field than the U.S. engineers measured, which may account for a large part of the discrepancy in the two sets of readings. The Russian method of measuring electric fields was valid within their own frame of reference as long as all their results were based on this same technique. A paper given in February, 1975, at a US/USSR exchange meeting in Washington indicates that Soviet scientists are now revising both their measuring techniques and their theoretical calculations in order to bring them more in line with

accepted international procedure. For example, they have increased the length of the insulating handle used on their meter from 250mm to about 500mm, in addition, when discussing the variation of the theoretical electric field with height above ground, they now speak of an inverse proportionality relationship of 1.35 or 1.45 instead of 2 (Lyskov et al, 1975). However, these recent changes do not alter the fact that field measurements which were used as their basis for health studies during the decade from 1962 to 1972 were made in the manner I have described above. Therefore, in order to relate the conditions of these studies to fields created by our lines, a correcting factor of approximately 1.6 must be applied. For example, Russian safety regulations state that 25 kV/m is the maximum field to which people should be exposed at all. If we multiply this maximum figure by 1/1.6 or .6, we would obtain a limiting field gradient of 15 kV/m.

There is an additional factor which must be taken into account in studying the Russian research findings. The frequency of the AC current in Russia is 50Hz, while 60Hz is used in the United States. For a given field intensity, the higher frequency causes a 20 percent larger charging current to run in the bodies of people exposed to these fields. Since electrical current is thought to be the principal cause of biological influence, we must apply a factor of .8 to the U.S.S.R.'s fields in order to arrive at the biologically equivalent field for 60Hz. Russian standards with these two correcting factors applied are summarized in table 2.

It should be remembered, of course, that the actual size and characteristics of the Russian meter are slightly different from the Monroe meter which we used, and this may affect

the degree to which the field is perturbed. In order to determine the exact factor between the fields measured by the U.S. and the U.S.S.R. techniques, the Russian instrument should be used according to their method and compared directly with ours over a range of field strengths. However, the above charts and graphs provide at least a rough estimate of the way our field gradients would compare with the fields to which the Russian workers were exposed and which were used as the basis for their Rules and Regulations on Labor Protection. It is apparent from the figures that the fields experienced under our 765 kV lines fall well within the range of intensities which were found to cause biological effects in the Soviet Union. A graph of theoretical ground level gradients under such a line (see figure 4) shows maximum intensities of 13 kV/m

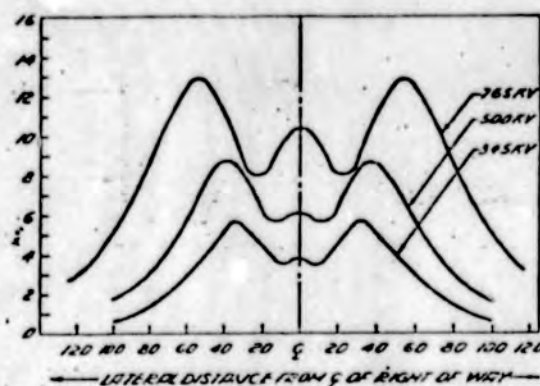


Figure 4.--Typical Electrostatic Ground Gradient Profiles of Various EHV Lines. From E. S. Zobel and F. J. Dormady, Charles T. Main, Inc. Report of Tests with Fluorescent Tubes to Indicate Electric Field Strength Under 500-kV Transmission Lines, Colstrip Project - 500 kV Transmission Lines, March, 1975.

Table 2.

Russian field intensity in kV/m	same fields measured by U.S. method	biologically equivalent fields kV/m	maximum permissible time in field in 24 hours
5	3	2.4	unlimited
10	6	4.8	180 minutes
15	9	7.2	90 minutes
20	12	9.6	10 minutes
25	15	12	5 minutes
over	over 15	over 12	no exposure

and gradients at 100 feet from the center line (the edge of a typical right-of-way) of approximately 5 kV/m. It is also significant that the Russians emphasize that people exposed to these fields for the maximum times must not also be subjected to transient shock currents. In our country people walking and working under transmission lines frequently complain of transient shocks from farm machinery, and even from leaves of corn or blades of grass.

Charging Currents

A more direct and precise method of estimating the biological significance of alternating electrostatic fields is by determining the amount of charging current that flows through the bodies of people exposed to EHV fields. I have measured currents as high as 200 microamps in the body of a 6-foot man standing with both arms raised at the strongest point of the field under a 765 kV line. With one arm raised the maximum current was 160 microamps. These measurements were made with the subject standing on an insulating pad and holding one electrode of an ammeter between the thumb and forefinger. The other electrode was grounded. At the edge of the right-of-way (100 feet from the center line) body currents of 90 microamps were measured.

The CIGRE report by Korohkova et al (1972) states that studies of the biological influence of charging currents were being carried out in the U.S.S.R., "Preliminary data show that a 80-120 microampere current flowing through a man for a long time unfavorably affects him." The current levels measured under a 765 kV line were within or considerably above this U.S.S.R. danger level. Again, these current measurements indicate that electric fields under U.S. lines would be considered by Russian scientists to be biologically significant.

A group of German scientists (Schneider et al 1974) reported current levels similar to the ones cited above. They found that a person standing on the ground with one hand raised would have a charging current of 18 microamps for each kV/m of unperturbed field gradient. Therefore, at the maximum point under the 765 kV line where we measured 9.1 kV/m, the total charging current flowing in his body would be 162 microamps. At the theoretical maximum of 13 kV/m, a current level of 230 microamps would be anticipated.

Measurements made by Bonneville Power Administration and reported by T. D. Bracken (1975) yielded an average value of 16 microamps per kV/m for a 1.75m man with arms held at his side. Bracken also noted that the charging current is directly proportional to the square

of the height of the person exposed to the field. Although the experiments on which this relationship was based did not consider heights above 2 meters or differently shaped objects, the implication is strong that a taller object in the field - e.g. a man on a horse or a piece of farm machinery - would sustain a higher body current (see fig. 5).

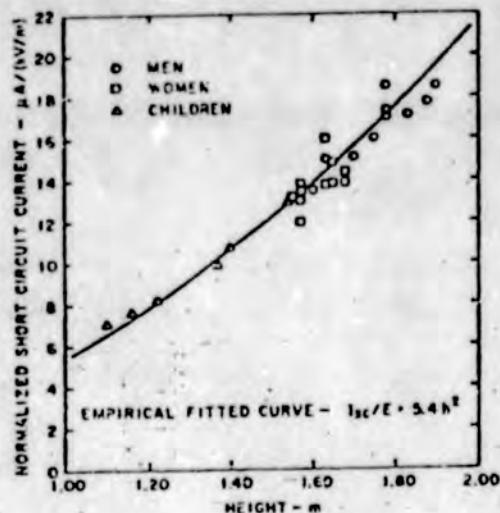


Figure 5.--Normalized short circuit current versus height for persons. From T.D. Bracken, (1975).

The above findings all lead to the conclusion that a person walking or working under the main span of the 765 kV lines now in operation in the United States, would have continuous displacement currents of 90 to 200 microamps in his body, and under special circumstances the levels could even be greater. These levels are significantly higher than the amounts considered safe by the Russians (Asanova and Rakov 1975). Since definitive research on this subject has not yet been conducted in this country, I believe that this health question should be answered before more such lines are constructed.

CHEMICAL PRODUCTS OF CORONA DISCHARGE

All EHV transmission lines create varying degrees of corona discharge, the amount depending upon design of the lines, voltage, surface of the conductors, and weather conditions. Electric breakdown of air causes a variety of chemical changes which lead to the production of reactive chemicals such as ozone, nitrogen oxides, hydroxyl radicals, and singlet oxygen. Of these, ozone is thought to be the most important product. Over the past few years, a number of field investigations of ozone levels

under 765 kV lines have been made which have shown no appreciable increase over ambient ozone levels. However, at the time these tests were conducted, the 765 kV lines were operated at levels 8 to 10 percent below the rated voltage, and since corona discharge with its associated formation of ozone are threshold phenomena, this relatively small difference in operating voltage makes an enormous difference in the amount of ozone production that could be expected. When these lines are run at 690 kV or 720 kV, corona loss would be negligible except under certain climatic conditions such as rain or snow. When there is considerable water vapor present in the air, less ozone also is formed per kilowatt hour of corona loss. Under these circumstances then, it would be surprising if monitoring for ozone near a "765 kV" line energized at about 700 kV, would show significant increases above ambient levels.

It is interesting to note, however, that at Oak Ridge National Laboratory, ozone measurements at the edge of a right-of-way for two 500 kV transmission lines recorded ozone concentrations of 210 and 230 parts per billion on April 6, 1972, at 9:30 and 9:40 A.M. (Oak Ridge National Laboratory 1973). Since these figures were ten times the ambient levels, the Oak Ridge report suggested they were caused by temperature inversion. Obviously, if a temperature inversion in the vicinity of a 500 kV line can cause a ten-fold increase in concentrations at ground level, then a very considerable amount of ozone must be generated by the line and normally must be carried off by surface winds. Such amounts, therefore, generated by thousands of miles of lines, would add significantly to ozone concentrations which already are dangerously high during much of the time. In the field measurement experiments, the monitoring equipment was not arranged in the most favorable manner for detecting ozone produced by EHV transmission lines.

It is apparent from purely theoretical considerations, that maximum levels are not likely to occur directly under the line but quite a distance down wind from the line. Since ozone is hot when formed, it rises and is blown by the wind, reaching ground level at some distance from the line. Even in the lightest of winds (about 2 miles per hour), the maximum concentration of ozone would occur about 300 feet from the line (Scherer et al, 1973). Only when the wind blows parallel to the line would it be reasonable to expect higher ozone levels under the line itself. When the wind is transverse to the line, the maximum concentration is inversely proportional to wind speed. Temperature in-

versions and very light winds provide the most favorable conditions for elevated ozone levels. In order to accurately report these periods, monitoring should be conducted continuously over a prolonged period of time.

The fact that ozone is formed in high electric fields can be simply demonstrated in the following manner: a grounded needle point or a fine wire is mounted in a teflon cylinder (to protect it from the wind) which is attached to the intake tube of a Mist ozone meter. This probe is then mounted in the electric field created by a power line. (We used a wooden tripod.) At a certain field intensity, the ozone meter readings suddenly begin to rise. In fact, one has to watch very carefully because the level recorded by the meter rises so quickly at times that it can go off the scale and saturate the meter. The field intensity at which this occurs has a definite threshold which varies with each type of needle or wire. By standardizing the type of probe, this method can provide a check on field gradient readings, a check which also has the advantage of being independent of any calibrating procedure. This experiment is effective in demonstrating threshold characteristics of ozone formation in high electric fields.

Although ozone is an important product of corona discharge, it certainly is not the only one, and it would be unfortunate if public interest in ozone formation obscures the need to consider the other deleterious results of electric discharge. Monitoring for NO and NO₂ near power lines has been given only token consideration, and to date only a few spot checks have been made. Furthermore, the question of what happens during actual rain or when humidity is high, still remains unanswered. It is an actual fact that during these conditions, ozone production per kilowatt hour of corona discharge drops very sharply, and it seems apparent that another chemical reaction is absorbing this energy. The most obvious candidate is the formation of hydroxyl radicals and atomic hydrogen from water molecules. Hydroxyl radicals are known to be biologically active and they probably serve a function similar to that of hydrocarbons in the formation of toxic smog.

Since all these questions have important implications for the health of people living near major transmission lines, they should be resolved before the onset of construction of thousands of miles of extremely high voltage lines that are planned for the next few years. In the long run, it will be to the financial advantage of the power companies themselves to consider these health questions before, rather than after, major investment is made

in this technology, especially since such potential health hazards can be minimized by a few small changes in design. Typical of some of the preventive steps which can be taken are:

(1) The electric field at ground level can be reduced by increasing the height of the conductors. (2) Corona loss, and the associated chemical reactions to it, can be reduced by proper choice of conductor diameter and by the number of conductors in each bundle. (3) Since direct current transmission lines do not cause continuous charging currents to run in the bodies of people and animals near the line, biologists believe that the electric fields created by DC lines are probably less damaging to living systems than are AC fields. DC lines have other advantages also. For example, the corona loss from DC lines does not increase as sharply in foul weather as does the corona loss on AC lines. Therefore, a changeover to DC technology for EHV transmission lines could reduce considerably the major sources of environmental concern. In addition, such changeover would not carry a financial penalty when large blocks of power are moved over several hundred miles.

Underground transmission undoubtedly is the technology of the future. New techniques have been developed and already are being used in a number of countries. Underground transmission also would be much more acceptable to the American public. It would minimize the visual pollution caused by the ever-increasing number of transmission lines built to handle the escalating demand. It would solve the electric field problem and would eliminate electrochemical and noise pollution. The sooner these technologies are perfected and put into mass production on a national scale, the sooner it will be possible to achieve a satisfactory long-term resolution of the environmental problems involved in transmitting electric power.

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POWERLINE PROTEST NEWSLETTER OF CENTRAL MINNESOTA

HEALTH/SAFE UPDATE

It looks like some progress is finally being made with this health-safety issue. The direction we are heading was ratified at the February 19 General Meeting of GASP. We have been working primarily with Art Sidner, Chairperson of the MEQB, and Representative Fjoslien...so far. We all went public with the evidence already accumulated, the progress that has been made, and the direction we are headed at a Press Conference held on February 26 in St. Cloud. What follows is the initial statement we made at that conference.

The procedure outlined below is the result of negotiations between representatives of the General Assembly to Stop the Powerline, and Art Sidner, Chairperson of the Minnesota Environmental Quality Board. The procedure points us in the direction which both parties would like to take. The exact course we will be following is not carved in stone because there are many pitfalls and dead-end paths in that direction. At this conference, each party will speak to their concerns in that regard. None-the-less, it is a direction which holds some promise of an acceptable resolution to a major issue in the Powerline Controversy, and the first steps are being taken with caution, but with hope.

1. GASP and the MEQB jointly conduct a survey of people along the line route to determine the effects people have experienced, and to identify "professional" people - nurses, doctors, veterinarians, A.I. technicians, and others who have had opportunity to notice professionally any changes in their clientele along the line route.
2. Professional people will be screened by a team consisting of consultants hired by the MEQB and representatives from GASP to determine which of them should testify before the MEQB and at subsequent proceedings.
3. Selected professional people will testify before the MEQB, thus establishing "probable cause" in the relationship between the effects people are experiencing along the line route, and the powerline.
4. On the basis of probable cause, Art Sidner will advocate that the MEQB proceed on one or more of several possible courses of action. Among the possibilities are:
 - A. The MEQB will call a Special Hearing before a Hearing Examiner for the purpose of revoking the permit needed to operate the facility.
 - B. The MEQB will file suit against the operation of the powerline on the grounds that it is in violation of the Environmental Rights Act. In this event, the MEQB shall proceed that action with a motion for an injunction against further operation of the facility pending the outcome of the court proceedings.

There has been a bit of a misunderstanding already on that fourth point. At the conclusion of the last meeting we had with Sidner before the conference, Sidner categorically stated that the MEQB would take action on the basis of probable cause, and that the action would be likely to take one of those two courses. But in the meantime, he came to the conclusion that the best he could do would be to recommend to the MEQB that action be taken on the basis of probable cause. He says he will be an advocate of such

a course within the MEQB. So far, we will believe him. Sidner also (2) has problems with point 4-B of our statement, and at the Press Conference as far as he would go was to say, "The range of actions include modifying or if necessary, revoking the construction permit." None-the-less, the fact that he attended the Press Conference and spoke as strongly as he did for "action for resolving the health issue of the UFA/CPA 800 kV powerline," as his statement put it, indicates that it may be worth our while to maintain a working relationship with him.

Anyway, Sidner spoke to his concerns after the opening statement, and that was followed by a GASP position paper on the health/safety issue, and this is what it says:

On behalf of the General Assembly to Stop the Powerline, we are grateful that the Minnesota Environmental Quality Board is considering action on the powerline health/safety issue. We are particularly thankful that Art Sidner is providing the MEQB with the type of leadership needed to make progress, and we are hopeful that an acceptable resolution is possible.

However, as we proceed to address the powerline health/safety issue, it is entirely possible that the MEQB, the utilities, and the courts will take positions which are not acceptable to GASP. We are anxious that there be no misunderstandings on this matter.

It is essential that the MEQB, the utilities, the courts, and the general public understand that reduced line voltage would not solve the health/safety problem. Any move in that direction will be considered by GASP to be an attempt to divert attention away from the issue, and will be dealt with accordingly.

Likewise, courses such as widening and/or fencing the easement, converting the facility from Direct Current (DC) to Alternating Current (AC), or unsubstantial revisions of the Permit are diversionary, and therefore unacceptable.

We look forward to working with all parties concerned towards an acceptable resolution of the issue, and urge people along the line route to cooperate with the MEQB survey.

We would be glad to answer any questions about the reasons for our position.

There were plenty of questions, both for Sidner and the GASP representatives, so folks should have a pretty good understanding of where we're at, where we're trying to get to, and what's acceptable and what is not. In the course of the questioning, the matter of compiling evidence came up. That lead to the health/safety survey forms being circulated by the MEQB and by GASP people. (We urge people to cooperate with the survey, and it is particularly important that we identify the "professional" people! Also, if you haven't received a survey yet, either contact the office (612) 283-5439 or write the MEQB in care of Art Sidner at 101 Capitol Square Bldg., 550 Cedar Street, St. Paul 55101.) Anyway, that lead to a discussion of the powerline health/safety survey Representative Fjoslien has been working on for the past month. The report on that survey is still a preliminary one, seeing as how questionnaires are still being returned and there has been little work done yet to tabulate the results. But even so, the results thus far are startling. Of the 500+ questionnaires sent out, over 50% have been returned. Of those, some 60% report effects; primarily headaches, nosebleeds and respiratory problems. About 20% are unsure, and the remainder haven't noticed anything yet. But even a sizable portion of those reporting no effects did indicate that wildlife is gone from the area.

In his news release at the conference, Fjoslien stated, "My concern is that the peoples' government (of which I am an elected member) has a duty to attempt to find a solution to this health concern as long as anybody has

a legitimate complaint of adverse health effects which they believe (3)
are caused by this HVTL."

"Therefore, through my questionnaire, I am attempting to find out what the concerns are and what the adverse health symptoms of the people and the livestock are. Many of the concerns of people who live near the line are the same, although these people live hundreds of miles apart." Representative Fjoslien spoke well to his concerns at the Press Conference.

It is clear that the health/safety issue has become a legitimate one. Finally, we intend to gain an acceptable resolution to that issue, and that means SHUT IT OFF!!!

* * *
Tickets sales for the GASP Raffle are going well. We'd like to remind those of you who still have tickets out, that we'd appreciate getting them as soon as possible. If you know of anyone who would like to sell more tickets, just have them drop us a line or call the office. We have all been working towards making this fundraiser a success and want to thank all of you for your help. * *

LETTER FROM MARK

How is everything around there? I don't know if you guys are still kicking or not, I never hear from any of YA. Well I went to my Parole Board Hearing the 8th of February and they are going to make me do the WHOLE TIME, 10 months, they give me 2 months off for Good Time, that's if I'm good and don't get into any trouble around here.

I went before a Classification Board yesterday for the FARM, it is a Minimum Security Unit. Them Bigwheels won't even let me go out to the FARM, they say that they are going to make an example out of me, and they think that there is always VIOLENCE INVOLVED IN OUR PROTESTING ON THE POWERLINE, and I don't know where they get that from. "Accidents yes, Violence no." They must think, "Now we got one of those powerline protesters so we are going to really fix him." There are some guards who get pretty smart, they know who I am, they try to make it harder for me. But I just tell them, oh ya, I like it here and that I'm really having a good time here. That really gets to them boys, see they try to make it hardest for you in here. And believe me, it is not that easy. Oh well, I will just try to make the best of it. See ya all later. Say hi to everyone, ok?

Mark

(Mark's address is: Mark Hoiun, #111509, Box 55, Stillwater, Mn 55032)

WOUNDED KNEE MEMORIAL

The following letter was sent to GASP last week, and we wanted to share it with all of you.

Brothers and Sisters in the Struggle,

We extend a most sincere invitation to attend the Wounded Knee Memorial, February 27th, 1980, being held at the Porcupine Community Center.

At this time we honor those sisters and brothers who have given their lives or suffer in the prisons for the human rights of our People.

In solidarity,

Women of All Red Nations

GASP regrets that we were not able to attend this memorial which is of such importance to our Indian sisters and brothers all over this country and the world. The Indian people who were murdered at Wounded Knee are victims of the same Energy War that we are fighting. We honor them, and those who carry on, in our thoughts and in our prayers.

On Monday, February 25th, protesters assembled at the Pope County courthouse in Glenwood for the first time since the Oeltjen acquittal last fall. The occasion was the long-delayed and almost-forgotten arraignment of Darus Ehlers (Traverse County) on a charge which is now almost 1½ years old.

The charge stemmed from an incident last November 1978 when folks were out and about the countryside by the powerline one night and Trooper Mike Senf decided to be a noble and forceful cop. A search of Darus' car ensued, and Senf found a handgun (which didn't work) and ticketed Darus for carrying a handgun without a permit. So, that was that...and we all went home.

So, on February 25th, what most of us were expecting was your typical arraignment before Judge Claeson. But, no sooner had people gotten their coats off, when young-wonder-prosecutor Kuhn said, "Well, after reviewing the complaint, I don't really see how the law was violated, so I move for dismissal." To which Claeson replied with a grin, "Case dismissed." To which protesters replied, "Huh?"

After court, we ended up spending more time arguing with Trooper Senf (who we found lurking on the back streets of Glenwood) about when Darus was going to get his gun back, than we did in the arraignment itself! Such a deal.

GENERAL MEETING

At the February 19th meeting of the General Assembly, a number of things were discussed including the ongoing negotiations between GASP and Art Sidner. The negotiation process and what we wanted to come out of it was talked over in length and there was a rather hopeful but cautious attitude that prevailed. As should be evident by other portions of the newsletter, we feel that things are looking good.

There was a report from the people who attended the last of the Power Plant Siting meetings. Those who were there felt that the Siting Staff was finally realizing that the people of Minnesota are upset with the whole siting process and that there is no need for any more power plants, therefore there is no need for the Power Plant Siting Staff.

At the last PPS meeting in Brainerd our people got together with the folks fighting fluoridation. We discovered that they were circulating a petition to impeach Dr. George Pettersen, head of the state Health Department, on the grounds that he was ruining the health of Minnesotans rather than protecting it. We brought some copies of the petition back with us and circulated them at the meeting. Needless to say, everyone in the room signed it.

At the end of the meeting we watched a film we ordered from Northern Sun entitled "Lovejoy's Nuclear War". It was about Sam Lovejoy and his battle with the utilities who wanted to build a nuke plant in his back yard. He was having a time getting people in his community to inform themselves about the dangers of nuclear power and trying to gather some sort of resistance against the plant. The utilities then went and built a weather observation tower not far from his house, although he warned them that somebody might try to knock it over. Every morning he would step out his door and look to see if it was still there. One evening he decided that he would take it down himself, which he did. The next morning he wrote a statement about why he did it and went to town to turn himself in. The movie then dealt with his trial and subsequent acquittal and the impact it had on his local community. All in all, it was a great movie which everyone seemed to enjoy. A special thanks again to Northern Sun for bringing it.

You'll notice in this issue of Hold That Line, we've enclosed what we feel is an excellent pamphlet on uranium exploration and mining in northern Minnesota. As a result of our contact with these people, we hopefully will have a slideshow on the subject at the March 18th meeting of the General Assembly. It should be an interesting as well as educational way to keep updated on what's going on in other parts of the Energy Wars. Our next meeting is Tuesday, March 4th at 8:30pm in Lowry. See you there!!

"Planned power plant moved out of state." That's how the headline read for an article in the February 25th Minneapolis Tribune. The story is about a new but familiar twist in the 5 year old battle between Minnesota Power and Light and local residents in the Duluth area over a coal-fired plant.

People opposing the plant were at one time in a long court battle with MP&L on the issue of whether that utility complied with Minnesota site-selection procedures when choosing the Duluth location. Last year, however, the state supreme court said that the way the EQB went about finding a site was just fine by them. Sound familiar?

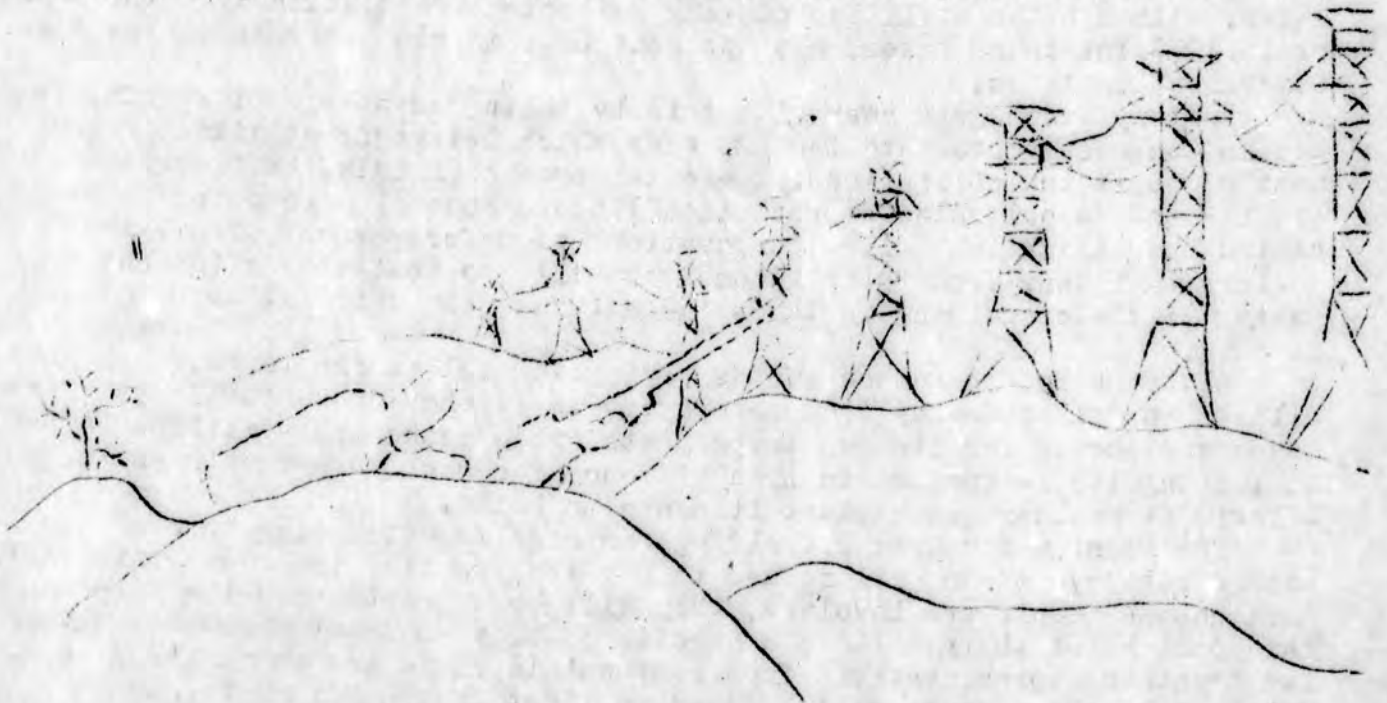
But then comes the new but familiar twist; MP&L announces that it's been investigating an alternative site in North Dakota for almost a year now. And according to company spokesman Warren Hudelson, "The indications are rather promising."

The Tribune article goes on to say that, "Worsening economic conditions in the taconite and wood product industries have reduced the need for the new plant." And that, "Wood processors and the taconite industry account for the bulk of electricity used in the MP&L area."

They even have MP&L President Jack Rowe telling his New York "stock and security analysts" that he expects the company's growth rate to drop from 15% to 1% annually in 1980. But after 1980, well then everything's going to pick up in growth and demand, according to Rowe.

Rowe is quoted in the Tribune as saying, "We see this as a breather and (it) lets us concentrate on distribution systems and allows us to get ready for the next growth period."

And what about these distribution systems commonly known as power-lines? Well, MP&L has that all figured out too. See there's an existing line in North Dakota so all they'll have to do is "upgrade it". According to the Tribune, "which might spare the company a long fight similar to the dispute in Central Minnesota." People of North Dakota, beware of an out-of-state corporation who wants to build an unneeded plant in your back yard!



The Public Service Commission (PSC) last December approved Union Electric's (UE) proposed 345 kilovolt (kV) transmission line from the Callaway nuclear plant to a substation in Bland, Missouri. However, since controversy surrounds the health effects of kV lines, the PSC has commissioned the University of Missouri Rolla Electrical Engineering Department to do a \$5,000 study on the electrical fields around kV lines and the subsequent health risks.

The Missouri study on the 345 kV lines will begin in late January or early February and will be paid for by Union Electric. Relatively little research has been done on the health effects to humans posed by the electromagnetic radiation from kV lines, especially long term effects. So the final verdict is still out. However, studies by Biophysicists Andrew Marino and Robert Becker, and others, suggest heart disease and strokes, stunted growth and cataracts may result from exposure. An additional concern stems from the use of highly toxic herbicides by utilities along transmission line right-of-ways. (A UE subcontractor employed unsupervised teenagers below the legal age to apply herbicides containing dioxin along 345 kV right-of-ways in Montgomery County.)

The New York Public Service Commission (NYPSC) acknowledges that "765 kV lines will probably cause biological effects in humans exposed to them on a chronic basis" and has set limits on the proximity of 345 kV and 765 kV lines to residential areas. In addition, the NYPSC has enlisted the help of the N.Y. Health Department to do a \$5 million study of the health hazards posed by high voltage lines.

SAFE ENERGY NEWS, JAN.-FEB. 1980

Mobilization for Survival has agreed to sponsor and form a task force to promote the Phantom Tax Rate Withholding Campaign. This campaign is a ratepayers movement against the tax breaks and the rate structure of the Boston Edison Company.

When the ratepayers receive their electric bills each month, almost 10% of it is charged by Boston Edison for Federal Income Taxes on the profit it makes. Although the utilities company collected \$26 million from the consumer in 1977 for these taxes, not one cent of this sum was paid to the Federal Government in taxes.

Boston Edison gets away with this by taking advantage of special tax breaks Congress wrote into the IRS code which let major utilities circumvent most of their tax obligations. These tax breaks (mainly the "investment tax credit" and "accelerated depreciation") and a special accounting method called "normalization" allow corporations to defer payment of millions of dollars each year from their income tax bill, so that they often end up paying little or nothing in taxes (even though the official corporate tax is 48%).

Although Boston Edison avoids paying federal income taxes, they are allowed to collect money from ratepayers as if they had actually paid these taxes and use it for its own investments. This means the utilities company is forcing its ratepayers to loan it money for such investments as the Pilgrim II nuclear power plant it wants to build.

The Phantom Tax Rate Withholding Campaign is attempting to organize enough ratepayers who will refuse to pay that part of their electric bill. When enough people are involved, they will be asked to send the "phantom tax" portion of their bill to a special "escrow" account that will have as its trustees representatives from responsible civic and community groups. Interest on the account will be used to fight Boston Edison through public education, DPU hearings and court actions. This campaign is an opportunity for citizens to express their dissatisfaction with the collusion between the government and the utilities companies in a tangible way. If you are interested in this campaign call the Mobilization for Survival office.

BOSTON MOBILIZER, DEC./JAN. 1980

The first federal review of the health effects of ultra-high-voltage powerlines may be in the offing, the result of the long struggle of Floyd County, Virginia residents to keep an Appalachian Power Co. (APCO) line from crossing their land. (7)

Now that Citizens for the Preservation of Floyd County (CPFC) has convinced the National Park Service to do an impact assessment on a proposed 765-kilovolt APCO line slated to cross the Blue Ridge Parkway, there is reportedly a "90-percent chance" that a full environmental impact statement will follow, delaying the project several years.

CPFC organizer Bill Blatter also says the impact assessment, by a University of Tennessee team headed by zoologist Arthur Echternacht, represents "the first time the federal government has ever addressed the health and safety issues of UHV lines."

With the Energy Department and the Electric Power Research Institute racing to popularize their own positions on UHV health impacts, Blatter suggests powerline opponents may want to comment on the draft statement.

Entitled "Draft Assessment of Alternatives Concerning the APCO 765-KV Transmission Line," it will soon be available from Gary Everhardt, Superintendent, The Blue Ridge Parkway, 700 Northwestern Bank Building, Asheville, North Carolina 28301.

POWERLINE, FEBRUARY 1980

The U.S. Department of Transportation has just issued a long-awaited proposed rule regulating the transportation of radioactive materials by highway in the United States. The proposed rule, "Highway Routing of Radioactive Materials", appeared in the Federal Register on January 31, 1980. We are alerting you to this rule-making because your town, county, or state is among the many which have prohibited or restricted nuclear shipments through local legislation or resolutions.

The proposed rule, if finalized, would pre-empt all state and local laws which ban radioactive shipments between any two points served by highways. States and communities would be allowed to suggest "preferred" routes; however, these suggestions could be ignored in the route-setting process if they are ruled "impracticable". The proposed rule specifically denies citizens and local officials any veto over the shipment of nuclear materials through their towns and counties.

The period for the public to comment on the proposed rule lasts until May 31, 1980. We hope that as many people as possible will make comments to the Department of Transportation. In particular, we are urging citizens to demand public hearings on the proposed rule in their state or region, with a reasonable time allowed for preparation. The DOT is presently planning to hold public hearings in just three locations - which have not yet been announced - within the next three months. Obviously, few communities will be able to send representatives to distant cities to attend the hearings. Write to the DOT and demand hearings in your area. Urge your local officials to do the same. All communities are potentially affected by the proposed rule and everyone should have the opportunity to comment. Written comments should be addressed to: Dockets Branch, Materials Transportation Bureau, U.S. Department of Transportation, Washington D.C. 20590.

NUCLEAR INFORMATION & RESOURCE SERVICE, FEB. 1980

Eleven Burns security guards at the Trojan Nuclear Power Plant in Oregon were arrested in early November of 1979 on drug charges stemming from the sale and furnishing of cocaine, amphetamines, marijuana, and LSD.

IT'S ABOUT TIMES, FEBRUARY 1980

Speaking of security guards, seems there's a new outfit at the plant in North Dakota which has a very funny name! So if you call up there and they say, "Hello this is BISMAR", say "What man is that?"

LETTERS

Dear Friends,

Enclosed is a check to cover our newsletter subscription, and the rest to be used where you think best. Keep up the good work!

Farwell, Minn

To whomever it may concern,

I am very interested in your cause. Although I live far from your state, this should effect and concern all "human beings". Please send me some more information on your group, your plans for the future, and how I could help.

Brookline, Mass

Dear Gaspers,

Enclosed find \$10. We appreciate the coverage that Hold That Line gave to our struggle with expressway 60, several months ago.

We enjoy reading Hold That Line and encourage you to keep up the good work in your struggle against big power and big business.

Butterfield, Minn

Dear Friends,

Please send me a copy of Hold That Line and whatever other good stuff the 5 bucks will buy. Yours in struggle.

Nashville, Tenn

Dear Sirs,

I would like information on how I can receive your newsletter and other information on the powerline. Any help you could give me would be greatly appreciated. Thank you.

St. Peter, Minn

Dear Folks,

Thank you for your part in the fight against those individuals and corporations who seek to gain a private profit at the public's expense. The companies who have temporarily put their powerlines across your land and seek to force their deadly centralized energy program on all of us are motivated only by greed. Let's not let them get away with it. Here's \$20 to help you keep up the fight.

Please send a subscription of Hold That Line to my home address in Connecticut so that my family and friends out there can become aware of what is happening here. Thanks.

Alexandria, Minn

Dear Hold That Line,

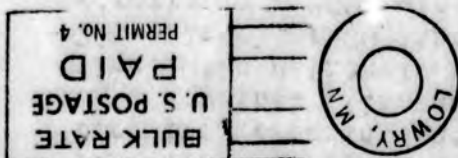
I would appreciate any information concerning the powerline that was constructed in Minnesota, as I am now doing research on a proposed powerline that may run through our valley, The North Fork Valley of Paonia. I would appreciate information concerning matters dealing with construction to health effects. Thank you very much.

Paonia, Colo

Dear Editor,

I am currently doing research on the environmental effects of high voltage transmission lines. I am very interested in the opinions of people living near and effected by the UPA-CPA transmission lines and would like to receive "Hold That Line". I have several back issues but can't find a subscription price, Is \$5 sufficient? I look forward to hearing from you.

Los Angeles, Cal



MARK WITLOW
HOUSE POWER ALTERNATIVES
POUCH V
JANUARY, ALASKA 99811
COMMITTEE

HOLD THAT LINE
LOWRY TOWN HALL
LOWRY, MN. 56349

State Involvement in Power Project Financing

Sources of Funds

APA

op. budget → \$504* total, \$294* contractual for Susitna, Cordova
 also Petersburg \$10K
 capital budget → vehicle this year for APRLF
 APRLF (probs) → \$3m all for loans up to APA*
 *doing bulk approp. like this doesn't
 provide for legis approval for projects going
 from recon to serg. + design

legislative
approval

legislative
approval

first legis. approval requires financing
 plan - for what APRLF for K budget for a
 project. Is this enough? Should include
 1) how much spent for what by who up to now
 2) what is asked for now
 3) what are future + contingent liabilities
 4) when are paid back, at what price

Commerce Div. of Business
Loans

WRRLF one shot deal for 3
specific projects

APRRLF open all year, no applies,
Rev. could have propurch.

Small Business for private + coops

Procedures

project concept → reconnaissance → feasibility (FERC) → construction → operation

↓
 locality
 engineering firms
 Feds - Corps, APA admin.
 state

APA

APA

pay back loans from
bond proceeds

APA or
utility or
locality

pay back rev. bonds

APA or
utility or
locality

E. Dev

Key Functions

Research Technical Assistance	Pilot Demonstration	Commercialization Financing	other assistance-maintenance
E. Ent. ARRC	"	ARRC; loan progs. ; pri. sector	E. Ent.

Power Dev.

planning	~~R+D~~ pilot demonstration	Feas. + Rec. on.	Fin. + Construction
Feds ISER E+PD APA	E+PD ARRC	ARRC	ARRC

DOT PF

Economic Planning + Analysis

E. ent vs. DPDP
300 money etc.

DOT

Conservation	Rationing etc.	non-Fed Outreach	Fed. R+D	Power Development
E+PD	E+PD	E+PD	? E+PD	? E+PD

of clearing houses for information too many?

Q. where should demand estimation and planning take place?

A. → E+PD, Reorganized Div. of Energy Development, DPDP, ARVC, etc.

WHAT IS NEEDED: load projections, planned additions, look at resources + alternatives
select best approach thru hard path, soft path framework, communicate with utilities + state agencies

PLUS
For each community and/or project identification of state aid anticipated from who and when - plan should get state on notice for its role.

SCOMM
#44.30

STATE OF ALASKA

DEPARTMENT OF COMMERCE & ECONOMIC DEVELOPMENT

DIVISION OF ECONOMIC ENTERPRISE

JAY S. HAMMOND, GOVERNOR

POUCH EE
JUNEAU, ALASKA 99811

February 22, 1980

Mr. Mark Wittow
House Power Alternatives Committee
Pouch V
Juneau, Alaska 99811

Dear Mark:

Based on a whole series of considerations my idea of responsible optimistic forecasts of Alaska's economic performance for the next twenty years is (roughly) as follows:

- (i) population and employment growth of 2.5 to 3.0 percent per year;
- (ii) inflation of about 6.5 percent per year;
- (iii) real per capita income growth of about 3.0 to 3.5 percent per year.

These are long-term averages.

Between 1980 and 1985 I look for population and employment growth to average about 5.5 percent per year. Between 1985 and 1990 this should dip to about 1.5 percent per year (wind down of gas pipeline, Prudhoe revenue begins to decline). After 1990 when we are face to face with the loss of Prudhoe revenue, the public should be ready for relatively bold moves on the development front (private nonpetroleum). If so, after 1990 the combination of further weakening of oil flows and growth elsewhere in the economy will probably leave us with about a 2.5 percent, or so, growth rate of population and employment through the year 2000 (1990 to 2000).

The Institute's method of asking for a judgemental assessment from each of a number of persons may have some merit, although not much. The reason is that the fate of many of the projects to which judgement was applied will be determined in the political arena, rather than solely on the basis of their economic merits. I have in mind ALPETCO, capital move, Beluga coal for export, the Northwest gas pipeline, and Fairbanks petrochemicals. With the exception of the Northwest gas pipeline pro-

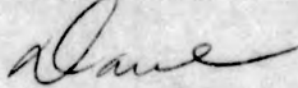
February 22, 1980

ject, none of these projects, in my opinion, are economically viable as private sector ventures. If they are to go, they will need subsidies. If they are to receive subsidies, a political judgement will need to be made. The ISER procedure amounts to a crude opinion poll of little, but not zero, merit.

I have enclosed a copy of a speech I drafted recently for Chuck Webber. It addresses some of the development issues of the 1980's. Let me know if I can be of further help, or if you would like more specific comments.

For the record, the problems facing Beluga coal are (1) Wyoming/Montana coal and (2) nuclear energy. I would not be surprised if within five years nuclear power was both cheaper than coal with respect to supplying Alaska's electricity needs and environmentally safer. President Carter has called for a crash program to solve the nuclear waste problem. If the program succeeds, the atmospheric pollution associated with coal may be more of a threat than the danger of nuclear accident.

Yours truly,



David M. Reaume
Principal Economist

DMR/jar4/13

THE ANSWERS TO FOUR QUESTIONS WILL LARGELY DETERMINE ALASKA'S ECONOMIC

PERFORMANCE DURING THE 1980'S. QUESTION NO. 1: HOW MUCH OIL AND GAS

WILL BE FOUND AND EXTRACTED? QUESTION NO. 2: HOW LARGE WILL ALASKA'S

HARD ROCK MINING, FISHING, AND TOURIST INDUSTRIES BECOME? QUESTION NO. 3:

HOW MUCH REVENUE WILL THE ALASKA STATE GOVERNMENT RECEIVE EACH YEAR?

QUESTION NO. 4: HOW WILL STATE GOVERNMENT APPORTION ITS REVENUE ACROSS

THE THREE CATEGORIES SPENDING/GIVING AWAY, PORTFOLIO INVESTMENT, AND REAL

INVESTMENT?

THE ANSWERS TO THESE FOUR QUESTIONS DEPEND HEAVILY ON THREE FACTS OF LIFE.

FACT NO. 1: THE QUANTITY OF OIL PUMPED FROM PRUDHOE BAY WILL BEGIN TO

DECLINE ABOUT MID-DECADE. FACT NO. 2: THERE WILL ALMOST CERTAINLY

BE NO MORE DISCOVERIES LIKE PRUDHOE BAY. (BEAUFORT SEA ESTIMATED CRUDE

OIL RESERVES ARE LESS THAN TEN PERCENT OF PRUDHOE BAY'S. AT PRESENT

RATES OF FLOW, TAPS WOULD PUMP THE ENTIRE ESTIMATED RESERVES FROM NORTON

SOUND IN 1.47 DAYS.)

FACT NO. 3: THE FEDERAL GOVERNMENT HAS THE AUTHORITY TO REGULATE ENERGY PRICES AT ANY TIME AND AT ANY LEVEL.

~~THE POSSIBLE COMBINATIONS THAT MIGHT UNFOLD FOR THE ALASKA ECONOMY OVER~~

~~THE NEXT TEN YEARS ARE NUMEROUS~~ AT ONE EXTREME, NEW PETROLEUM DISCOVERIES

AND SUSTAINED HIGH ENERGY PRICES MIGHT PRODUCE HUGE STATE REVENUE SUR-

PLUSES THAT MIGHT BE USED TO BOTH INSURE THE STATE'S FINANCIAL FUTURE AND

TO STIMULATE THE GROWTH OF NEW NONPETROLEUM INDUSTRIES. AT ANOTHER EXTREME,

ALASKA'S ECONOMY MIGHT BECOME SERIOUSLY DEPRESSED IF EXPECTED PETROLEUM

RESERVES IN THE BEAUFORT SEA AND ELSEWHERE FALL FAR SHORT OF EXPECTATIONS,

AND IF A COMBINATION OF INTERNATIONAL CRISIS AND DOMESTIC OPPOSITION TO

HIGH ENERGY PRICES LEADS THE FEDERAL GOVERNMENT TO LEGISLATE AN UNDULY LOW

PRICE FOR ALASKAN OIL. AT THE PRESENT TIME, APPROXIMATELY FORTY PERCENT

OF ALL JOBS IN ALASKA ARE DIRECTLY OR INDIRECTLY DEPENDENT ON PETROLEUM

REVENUE. ~~ANYTHING THAT JEOPARDIZES ALASKA'S OIL REVENUE JEOPARDIZES~~

~~THESE JOBS.~~

CONSIDERABLE UNCERTAINTY ATTENDS

IT SHOULD BE CLEAR THAT ANY STATEMENT AS TO WHAT IS "LIKELY" TO TRANSPIRE ECONOMICALLY IN ALASKA OVER THE NEXT TEN YEARS. THE FARTHER AHEAD ONE LOOKS, THE MORE UNCERTAIN THE PICTURE BECOMES. WITH THIS CAUTION IN MIND, LET ME OFFER YOU WHAT CAN BE TERMED A "RESPONSIBLE BEST GUESS" AS TO WHAT THE 80'S WILL BRING.

SETTING THE STAGE, LET ME START BY OFFERING SEVERAL KEY ASSUMPTIONS:

(1) THE BEAUFORT SEA WILL BE FOUND TO HAVE PROVEN CRUDE OIL RESERVES OF APPROXIMATELY 1 BILLION BARRELS AND IT WILL BE DEVELOPED; (2) A COMPROMISE D-2 BILL WILL PASS THIS YEAR; (3) ALASKA CRUDE OIL PRICES WILL RISE THREE PERCENT PER YEAR FASTER THAN THE OVERALL RATE OF INFLATION; (4) THE STATE OF ALASKA WILL SEEK TO STIMULATE NEW NON-

PETROLEUM ECONOMIC GROWTH; AND, FINALLY, (5) THE ALASKA GAS PIPELINE PROJECT WILL BE DELAYED NO MORE THAN ONE YEAR FROM ITS PRESENT SCHEDULE.

GIVEN THESE ASSUMPTIONS, THE PERIOD FROM 1980 THROUGH 1985 WILL BE ONE OF EXTREMELY RAPID ECONOMIC GROWTH. THE PER YEAR JOB AND REAL INCOME GAIN WILL AVERAGE FIVE TO SIX PERCENT, AND WILL AFFECT ALL SECTORS AND ALL GEOGRAPHICAL SUBREGIONS OF THE STATE.

BETWEEN 1985 AND 1990, THE GROWTH RATE WILL TAPER OFF TO AN ANNUAL

AVERAGE OF BETWEEN ONE AND TWO PERCENT, CAUSED LARGELY BY COMPLETION

OF THE GAS PIPELINE AND THE SLOWING OF THE CRUDE OIL FLOW FROM PRUDHOE

BAY. THE PERIOD WILL BE CHARACTERIZED BY A RECONSIDERATION OF OUR

GOALS AND OBJECTIVES IN LIGHT OF THE LESSONS LEARNED DURING THE

PREVIOUS FIVE YEARS OF HECTIC GROWTH, AND IN LIGHT OF NEW ADVANCES

IN ENERGY USE TECHNOLOGY.

INFLATION WILL BE A PERSISTENT PROBLEM THROUGHOUT THE DECADE. THE

CAUSE OF THE INFLATION WILL BE THE ^{SAME} AS IT IS TODAY, A STEADY RE-

DISTRIBUTION OF THE WORLD'S WEALTH AWAY FROM MOST DEVELOPED WESTERN

COUNTRIES AND TOWARD THE OIL RICH UNDERDEVELOPED COUNTRIES. ALASKA

INFLATION WILL BE SOMEWHAT LESS THAN THAT IN THE REST OF THE UNITED

STATES BECAUSE INCREASING ECONOMIC DEVELOPMENT WILL CONTINUE TO ERODE

THE ALASKA COST OF LIVING DIFFERENTIAL. AN AVERAGE ANNUAL INCREASE

OF ABOUT SEVEN PERCENT IN ALASKA CONSUMER PRICES CAN BE EXPECTED

GROWTH IN THE ALASKA ECONOMY OVER THE NEXT TEN YEARS WILL BE FUELED

BY PETROLEUM REVENUE BUT WILL ACTUALLY OCCUR IN OTHER SECTORS OF THE

ECONOMY. HARD ROCK MINING, TOURISM, BOATMEISH, AND SUPPORT INDUSTRIES

OFFER THE BEST INVESTMENT POTENTIAL BOTH FOR PUBLIC MONEY AND FOR

PRIVATE INVESTORS

HOWEVER, ~~GROWTH IS NOT TO BE EXPECTED WITH CERTAINTY.~~ TO A DEGREE

THAT IS HARD TO OVER EMPHASIZE, ALASKA'S FUTURE IS IN THE HANDS OF
GOVERNMENT DECISION MAKERS, BOTH FEDERAL AND STATE. ~~WORLD EVENTS~~

~~AND THE FEDERAL GOVERNMENT WILL SET THE CONDITIONS UNDER WHICH~~

~~WE, IN ALASKA, WILL OPERATE.~~ WE, IN TURN, WILL COLLECTIVELY DETERMINE

OUR FATE WITHIN THE CONDITIONS LAID DOWN. THE POTENTIAL FOR GREAT

GOOD AND THE POTENTIAL FOR GREAT ^{MISUSE} ~~MISUSE~~ OF OPPORTUNITY ARE BOTH VERY

REAL. WE MUST WORK TOGETHER TO MAKE THE MOST OF WHAT WE ^{HAVE BEEN} ~~ARE~~ GIVEN.

ROUGH DRAFT/shN/1

ISER workshop 2/15

coyneas activities - resource/development project.

MAP model elements

single most important - future petroleum development in the state

Alaska population growth - free immigration

function of employment

demand - function of pop

need good idea of employment/pop ratio

- variables - # of females -

of native population -

will these increase

immigration - changes ratio - ^{traditionally} working age w/o large families

current rate - probably as high as it will get

future employment increases $\rightarrow$ has to be met by
future population growth

What will happen to real (disposable) income
wages - taxes

Fed govt - 40,000 - largest single employer

if real wages rise, result is large increase overtime

Fed income tax is rising slowly (its bit)

★ assumption - stabilization of Fed income tax

Structural change - import substitution

^{some} activities which were unprofitable in 60's, have become profitable

Some now-available, imported products now available

growth in market sector $\rightarrow$ import substitution/structural change

how will this continue into the future?

Algeria pipeline effects

will approach national level of support ratio
but not within time frame

State govt - exogenous or endogenous

(independent of economy)

function of population & revenues (private sector)

both are appropriate & degree

— problem is multiplier effect - growth in private → growth in public sector

(see below critique)

Above are critical elements in using this model

✓ Erickson - demographic parameters need to be figured
(eg - significant decline in birthrate since 1970)

Cannot predict whether trend will continue

changes in public health in rural areas → more young people

Critical variables for outside state economy

- ① - How state will spend its \$
- ② - levels of resource development activity

① State + local employment - 35,000 / 180,000 total force



changing ratios / oil within state land
impact on US development

Permanent Fund share

BER

(3)

Methods of prediction

Aim for year 2000

for 3 variables

- gov't (state) spending / what it responds to /

employment in resource industries

- population



TO Rep. Brian Rogers

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DETAILED WORK PLAN

Electricity Requirements for the Railbelt

A Study for the House Special Committee
And the Alaska Power Authority

Scott Goldsmith
Assistant Professor of Economics
Institute of Social and Economic Research

November 14, 1979

(comments welcome)

Task A. Methodological Review and Data Collection

Subtasks

1. Review existing models of Alaska economy for applicability to projecting relevant economic variables for electric power demand analysis.
 - a. MAP econometric model
 - b. State of Alaska, Department of Commerce and Economic Development, Econometric Forecasting Model
 - c. State of Alaska, Department of Labor, Econometric Forecasting Model
2. Review alternative potential economic projecting techniques.
 - a. Extrapolation
 - b. Input-output model
 - c. Economic base model
 - d. Harris regional model
 - e. Delphi technique
- *3. Choose a projection technique and document both its strengths and weaknesses as well as those of economic projections in general.

* Indicates a written product

Susilna
~~15ER~~
~~15ER~~
~~15ER~~
Work Plan

4. Review methods for projecting the level of electricity consumption within a region.
 - a. Extrapolation
 - b. Econometric analysis
 - c. End-use analysis
5. Review the existing studies of electric power requirements for the railbelt and other parts of Alaska.
 - a. Institute of Social and Economic Research, Electric Power in Alaska 1976-1995
 - b. Alaska Power Administration, Alaska Power Survey, 1976
 - c. _____. Upper Susitna River Project Power Market Analyses, 1979.
 - d. _____. Devils Canyon Status Report, 1974
 - e. Southcentral Alaska Water Resources Study, Electric Power Needs Assessment, 1979
 - f. Battelle Pacific Northwest Laboratories, Alaskan Electric Power 1978
 - g. U.S. Corps of Engineers, Susitna River Basin Feasibility Study, 1976
- *6. Choose a load growth projection technique and document its strengths and weaknesses.
7. Collect annual electricity consumption data by user type from Alaska Public Utilities Commission and Federal Energy Regulatory Commission filings for the following utilities:
 - a. Chugach Electric Association
 - b. Anchorage Municipal Light and Power
 - c. Golden Valley Electric Association
 - d. Fairbanks Municipal Utility System
 - e. Cordova Public Utilities
 - f. Copper Valley Electric Association
 - g. Homer Electric Association
 - h. Matanuska Electric Association
 - i. Seward Electric System

This will include total consumption, number of customers, average price, large consumers, and usage by all-electric homes.
8. Collect electricity consumption data from the military for railbelt facilities. This will include:
 - a. Elmendorf Air Force Base
 - b. Fort Richardson Army Base
 - c. Eilson Air Force Base
 - d. Fort Wainwright
 - e. Clear Air Force Base
 - g. Greely Air Force Base

9. Collect electricity consumption data from existing industrial consumers of electricity who presently generate their own power and energy consumption data from industrial consumers of energy who could potentially switch to electricity consumption should conditions warrant such a change. These users would include:
 - a. Refineries
 - b. Pipelines
 - c. LNG plants
 - d. Ammonia-Urea producers
 - e. University of Alaska
 - f. Others as identified during the course of the study
10. Collect data from various sources on the number of households in the railbelt, type of space heating and other major appliances in use, age distribution of the housing stock, other quality characteristics, and space heating requirements. Data sources will include:
 - a. 1960-1970 Census
 - b. 1975 Anchorage Housing Survey
 - c. Real estate industry sources
 - d. National Association of Homebuilders
 - e. Anchorage Borough
 - f. Matanuska-Susitna Borough
 - g. Fairbanks Borough
 - h. Kenai Borough
 - i. Anchorage Natural Gas Utility
 - j. Electric Utilities
 - k. University of Alaska Cooperative Extension Service
 - l. End-use studies conducted in other states and regions
 - m. Other sources which are identified during the course of the study
11. Collect economic data necessary to update economic component of MAP econometric model through 1978. Sources of this data are Alaska Department of Labor and Bureau of Economic Analysis of U.S. Department of Commerce.
12. Collect time series data on relevant economic, social, and other variables necessary for econometric analysis of demand for electricity in railbelt. In addition to data collected under sub-task A.1., this would include:
 - a. Heating-degree days
 - b. Price of alternative fuels--gas, fuel oil
 - c. Personal income
 - d. Population
 - e. Employment

- *13. Write a report indicating the sources of all data collected as well as the possible uses and limitations of that data.

Task B. Economic Model Specification

Subtasks

1. Add 1978 economic data to the MAP statewide econometric model data base within TROLL.
2. Calculate 1978 values for gross state product by industry for incorporation within the model.
3. Investigate the potential for updating the income tax sector of the state revenue component of the model.
4. Reestimate wage rate, gross product, and employment by industry equations as well as price and personal income equations with new data.
5. Test the validity of the updated version of the model through statistical analysis of the individual equations and the behavior of the simulations.
6. Make changes in model specification necessitated by structural change in the Alaskan economy.
7. Calibrate the model with updated startup values and exogenous variables.
8. Extend the exogenous data series to the year 2005.
9. Evaluate the validity of the economic projections on the basis of analysis of the most important and critical variables and relationships within the model. These include:
 - a. The ratio of residentiary employment to basic sector employment
 - b. Migration response to economic activity in the state and nation
 - c. Labor force participation rate and unemployment rate
 - d. Growth of and size distribution of real wages
 - e. Relationship between government expenditures and employment
 - f. Relationship between private sector economic activity and government spending

- *10. Prepare a report documenting the changes made to update the state model and the results of the analysis of the plausibility of model output, including sensitivity to model structure and assumptions.
11. Test the validity of the MAP regional econometric model in allocating the level of statewide economic activity to the existing regions utilized within the MAP regional model. This will be done on the basis of ex-post simulation of the recent past.
12. Adjust the population allocation mechanism or other equations as necessary in the regional economic model to produce satisfactory tracking results for the recent past.
13. Develop a procedure for allocating the economic activity within the Southcentral Region of the state as defined in the MAP econometric model to the following subregions:
 - a. Greater Anchorage market
 - b. Greater Fairbanks market
 - c. Valdez-Glennallen
 - d. Non-railbelt
 - 1) Kodiak
 - 2) Seward?
 - 3) Other small communities not linked to public electric utilities

This procedure will be based upon a historical analysis of the relative growth rates of employment in these subregions.
14. Validate this technique where possible by independent analysis of the growth patterns and prospects of these subregions.
- *15. Prepare a report documenting the theory underlying the allocation method chosen as well as a description of that method itself.

Task C. Economic Projections

Subtasks

1. Review the input scenarios developed for previous projects utilizing the MAP econometric model, in particular the Southcentral Water Study.
2. Update the input scenarios for the basic sectors and develop three scenarios which can be described as follows:
 - a. A low case which is, in the judgment of the authors, the least likely possible level of future exogenous economic activity in the state
 - b. A high case which is, in the judgment of the authors, the highest likely possible level of future economic activity in the state
 - c. A likely case which, in the judgment of the authors, is the most likely level of future economic activity.
3. Develop updated projections of petroleum revenues and state and local government expenditure patterns in response to both population growth and revenue availability. Examine three cases of state government growth.
 - a. Growth at an exogenous rate
 - b. Growth related to population increase
 - c. Growth related to availability of revenues
4. Use the input scenarios to generate projections of Alaskan economic activity using the MAP model.
5. Test the relative sensitivity of the economic projections to variation in both individual components of the basic sector input scenarios and the government spending scenarios.
6. Hold a workshop at which the projections as well as the input scenario assumptions for the basic sectors and the government sector are presented to the Project Director and to invited experts.
7. Revise the input scenarios on the basis of comments received at the workshop.
8. Using the MAP model, generate economic projections for the statewide economy on an annual basis through the year 2005. Also generate projections for the three railbelt areas indicated under Task B.12. Nine projections will be obtained combining the assumptions of C.2. and C.3.

- *9. Document the input scenarios and the economic projections as well as the sensitivity of projections to variation of input scenario assumptions.

Task D. Assessment of Interfuel Substitution Possibilities

Subtasks

1. Review the literature on econometric studies of electricity demand (load).
2. Assess the value of such studies and appropriateness of such a technique in the estimation of electricity load for the railbelt.
3. Utilizing an econometric procedure, analyze the price and income elasticity of residential electric power requirements in the railbelt area. This must utilize a time series analysis because of the lack of data to do a cross-section analysis. The Institute previously attempted a cross-section econometric analysis with limited success. This is documented in "Future Electricity Requirements in Alaska," by Scott Goldsmith. Based upon that analysis, the most important variables will likely be electricity price, natural gas price, income, and heating-degree days.
- *4. Report and interpret the results of this analysis.
5. Develop "econometric-end-use" model to be used in forecasting residential and commercial railbelt electricity load requirements (see attached article by Robert W. Shaw). The essential feature of the model is the end-use detail which is explicitly incorporated within the analysis. This approach offers the advantage of being able to evaluate the effects of a large variety of factors in addition to price on electricity requirements. Policy-regulatory factors and technical factors causing demand to change can be considered. The problem with such a model lies in the amount of data necessary to implement the model.

The idea behind such a model is that electricity use is a derived demand--derived from the demand for end uses which electricity as well as alternative fuels or conservation can meet. To determine electricity requirements, one must calculate the number of electricity-using appliances and the amount of electricity consumed in each. The most important factors in this analysis include:

- a. Population
- b. Income
- c. Initial capital stock
- d. Age of capital stock
- e. Price of electricity and alternate fuels
- f. Relative efficiency of new additions to capital stock
- g. Utilization rate of capital stock
- h. Economic structure
- i. Regulations restricting the free choice of alternatives

The basic model structure is presented diagrammatically as Figure 1.

- 6. For each of the three areas of the railbelt indicated in Task B, develop a base line inventory of existing end-use patterns in the residential, military, and commercial markets.
 - a. Number of housing units, distribution by type, distribution by age
 - b. Square feet of floor space and insulation properties by type and age and trends over time
 - c. Average household size and trends over time in this parameter
 - d. Electricity residential hookups relative to households and trends
 - e. Vacancy rate of housing stock
 - f. Depletion rate of housing stock
 - g. Average and incremental percentage of consumers by housing type utilizing electricity, gas, oil, wood, coal, and propane for space heating
 - h. Saturation levels and percentages supplied by electricity for modern cooking, refrigeration, clothes drying, water heating, and other appliances
 - i. Electricity consumption per unit in as much detail as possible
 - j. Number of commercial units (nonresidential apartments, etc.)
 - k. Square feet of floor space and insulation properties of buildings as well as trends over time
 - l. Historical relationship between income, households, population, and commercial space
 - m. Commercial vacancy rates and depletion rate
 - n. Electricity use for space heating
 - o. Electricity use for other activities
- 7. Develop parameters for estimating the saturation levels and rates of growth to those levels of:
 - a. Electricity hookups
 - b. Modern space heating
 - c. Modern cooking facilities
 - d. Modern refrigeration facilities
 - e. Modern clothes drying facilities
 - f. Small electric appliances

Figure 1. Electricity End-Use Model

$$\begin{aligned} \text{RESIDENTIAL ELECTRICITY REQUIREMENTS AT TIME } T \text{ (KWH)} &= \sum_i \left(\text{INITIAL HOUSING UNITS TYPE } i * (1 - \text{RATE OF SCRAPPING } i) \right)^T * \sum_j \left(\% \text{ OF INITIAL UNITS } i \text{ WITH ELECTRIC APPLIANCE } j, \right. \\ &\quad \left. \left(\text{AVERAGE ELECTRICITY CONSUMPTION IN APPLIANCE } j \text{ IN UNITS IN INITIAL HOUSING TYPE } i \text{ (KWH)} \right) * (1 - \text{CONVERSION RATE TO NON-ELECTRIC APPLIANCE } j) \right)^T + \\ &\quad \left. \left(\text{SATURATION FUNCTION FOR APPLIANCE TYPE } j \right) * \left(\% \text{ OF INCREMENTAL APPLIANCES OF TYPE } j \text{ FUELED BY ELECTRICITY} \right) * \left(\text{AVERAGE ELECTRICITY CONSUMPTION IN INCREMENTAL APPLIANCE } j \text{ IN INITIAL HOUSING UNITS TYPE } i \right) \right\} \end{aligned}$$

i = SINGLE FAMILY
DUPLEX
APARTMENT
TRAILER

j = space heat
water heat
refrigeration
cooking
clothes drying
other

$$+ \left\{ \left[\frac{\text{POPULATION AT TIME } T}{\text{AVERAGE SIZE OF HOUSEHOLD AT TIME } T} \right] - \left[\text{INITIAL HOUSING UNITS} * (1 - \text{RATE OF SCRAPPING}) \right]^T \right\} *$$

$$\sum_i \left(\% \text{ OF NEW HOUSING UNITS OF TYPE } i \right) * \sum_j \left(\% \text{ OF NEW UNITS WITH ELECTRIC APPLIANCE } j \right) * \left(\text{AVERAGE ELECTRICITY CONSUMPTION IN APPLIANCE } j \text{ IN NEW UNITS } i \right) * \left(\text{SATURATION FUNCTION FOR APPLIANCE TYPE } j \text{ IN NEW HOUSING UNITS} \right)$$

$$\begin{aligned} \text{COMMERCIAL ELECTRICITY REQUIREMENTS AT TIME } T \text{ (KWH)} &= \end{aligned}$$

SAME FORMAT WITH AVERAGE BUILDING SIZE IN SQ FEET AN ADDITIONAL VARIABLE

8. Develop parameters for estimating the depletion rate of the housing and commercial building stock.
9. Develop parameters for estimating the scrapping rate for major appliances in the residential and commercial sectors.
10. Develop parameters for estimating the percentage of specific end uses which will be supplied by electricity as a function of price of electricity and other fuels. Different parameters will apply to the present stock of appliances and to the new stock.
- *11. Write a report summarizing the base line study, describing the model, and indicating the sources for all parameter and variable estimates.

Task E. Electricity Use Projections

Subtasks

1. Inventory the present level of industrial and other non-residential or commercial (such as government) electricity consumption in the railbelt, both purchased and self-generated.
2. Develop assumptions for the growth in electricity consumption of these consumers.
3. Inventory present industrial and other residents presently consuming energy not in the form of electricity. Estimate the potential electricity load requirements of each.
4. Identify major commercial and industrial uses of electricity which may be technically feasible within the projection period and estimate the load requirements of each.
5. Develop a set of energy price scenarios which will be used in the determination of appliance saturation levels, relative percentages of different fuel-using appliances, and growth in energy use in the industrial sector.
- *6. Write a short report describing these price scenarios.

7. Using the MAP econometric model and the end-use model developed under Task D, estimate electric power requirements for the residential and commercial components of the railbelt electricity market by five-year increments to 2005. Individual projections will be based upon the following sets of end-use assumptions:
 - a. Increasing saturation in appliance use, existing intensity of appliance utilization, and moderate increases in the prices of coal and natural gas relative to oil (approaching BTU parity). This implies an increase for Anchorage in the relative price of natural gas space heating. For Fairbanks, the outcome is less clear because of the alternative electric power generating modes possible for the community.
 - b. Conservation in intensity of use in new installation based upon presently available technology, increasing saturation in appliance use, and same relative price assumptions as in (a).
 - c. High electricity-use case where electricity substitutes for other fuels where possible over time.
 - d. Low electricity use where alternatives substitute for electricity where possible.
8. Analyze the problem of attempting this type of price-sensitive end-use analysis over long time horizons when changes in relative prices of fuels may occur several times during the period and thus influence the appliance stock in ways different than if the time period had a fixed set of relative prices.
9. To these projections, add military and industrial load requirements, divided into probable purchased and produced components to obtain total load requirements.
10. Using the end-use model, analyze additional special cases as indicated by other components of the study.
11. Separately estimate on the basis of a simplified version of the end-use model the requirements of electricity consumers not connected to the present or projective grid.
- *12. Prepare a report describing the analysis carried out under this task and the results.

Task F. Assess Projection Probabilities

Subtasks

1. Identify the range of electric power requirements forecasts based upon the previous analysis.
2. Develop a subjective probability distribution for the forecasts.
3. Identify those specific assumptions regarding economic growth and electricity use growth which are most sensitive to the load growth forecast.
4. Choose a forecast which appears the most probable.
- *5. Prepare a report describing this sensitivity analysis.

Task G. Prepare Final Report

Subtasks

1. Present study results to legislative committee as directed by the Project Director.
- *2. Write summary report in nontechnical language presenting principal findings and conclusions of study.

New Factors in Utility Load Forecasting

By ROBERT W. SHAW, JR.

LOAD forecasting is the cornerstone of all utility planning. To provide useful input to facility and financial planning, utility load forecasters must be able to project electric energy sales and peak loads fifteen or twenty years into the future. Yet load forecasting has become an increasingly difficult challenge as social, economic, demographic, and political forces converge to form an ever-changing pattern of complexity. The relatively primitive trend line forecasting methods of past decades — which were adequate in their time — are today being replaced with more sophisticated approaches needed to cope with the "new factors" which the forecaster must address.

Two general load forecasting approaches are currently in widespread use in the utility industry: (1) econometric models, and (2) end-use (or engineering) models. Econometric models rely on historical data and statistical techniques to forecast future use of electric energy — in the aggregate for a service area or by customer class — as a function of the price of electricity, the price of alternate energy sources, population,

personal income, and other economic-demographic variables. These models are based on the assumption that customer response to changes in these variables will be the same in the future as it was in the past. They cannot deal explicitly with factors such as technological change or regulatory initiatives other than those affecting prices.

The author suggests that the deficiencies in two existing general approaches to utility load forecasting — econometric models and end-use engineering models — may be corrected through a combination of the best features of both. The utility load forecaster would, as one result, be given greater flexibility in assessing the many factors with which he is confronted. This article identifies many of those factors — which constitute a changing forecast environment — and provides a schematic description of the kind of econometric end-use forecasting approach proposed by the author.



Robert W. Shaw, Jr., is a vice president of Booz, Allen & Hamilton Inc., where he manages the firm's technical and planning practice for electric utilities. He has directed projects on load forecasting, corporate planning, and technology assessment. Dr. Shaw received his PhD degree in applied physics from Stanford University, a Master's degree in electrical engineering, and a Bachelor's degree in engineering physics from Cornell University. He is serving as executive director of the Electric Power Research Institute's utility modeling forum.

End-use models build a forecast on detailed information regarding the way electric energy is used in each consuming sector of the utility's service area. Although these models frequently suffer from a severe lack of data, they do provide a way to deal with the multitude of factors which can cause end-use patterns to change. These models have a serious drawback, however, in that they usually do not explicitly consider the effect of price on the consumption of electricity. This is not an essential flaw in the model structure, but merely an indication that forecasters have not yet pushed the modeling art far enough.

Econometric End-use Forecasting Models

To correct the deficiencies in both general approaches and give the utility forecaster greater flexibility in addressing the new factors he must consider, a forecasting approach which combines the most important features of both econometric and end-use models has been suggested. The basic elements of the method are shown in Figure 1 (this page). In simplified terms, the forecast of electric energy consumed during a particular year is the product of the number of utility customers (disaggregated into categories such as residential, commercial, industrial, etc.), the number of electricity-consuming devices that each customer has connected to the grid, and the amount of electricity consumed by each device during the year. Econometric relations are developed to describe the projected change in these three basic components as a function of price and other economic and demographic variables. This type of "econometric end-use models" has recently been used by several utilities to improve their forecasting capability.

The econometric end-use model is simple to describe in concept but much more difficult to execute in practice, because it requires an extensive data base defining the structure of end-use patterns in detail. Very few utilities have such a data base at their disposal. The first and most challenging task in the forecasting effort is to assemble and refine the necessary data over a period of years.

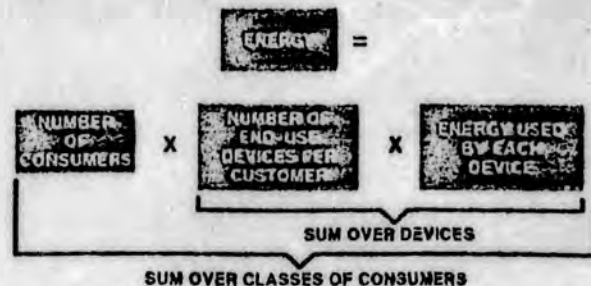
Once the end-use data have been assembled, price and income effects are built into the model — as indicated schematically in Figure 2 (page 21). The econometric methods used in the analysis are essentially identical to those used in market-penetration models. The models describe how the number of different devices used by customers in each sector depends on: price of electricity, prices of alternative fuels that could operate comparable devices, marketplace price of the devices, income (personal or corporate), and characteristics of the sector; i.e., for the residential sector, number of persons per household.

The final step is to develop models such as those illustrated in Figure 3 (page 22) which link the amount of energy consumed by typical devices with:

- The price of the electricity used to run them
- The income of the user
- The efficiency of the device
- The characteristics of present or planned load management programs
- Other socioeconomic and technical variables.

This schematic and highly simplified description of the econometric end-use forecasting approach masks the complexity of the models involved and gives little indication of the extraordinary level of effort required to assemble the necessary data base. To overcome these problems in the early stages of forecast development, the level of disaggregation used in the models can be tailored to fit the data base available. In later years, as

FIGURE 1
AN ECONOMETRIC
END-USE MODEL COMBINES
THE BEST FEATURES OF BOTH



the data base expands, the level of disaggregation can be increased.

The Changing Forecast Environment

The econometric end-use approach to utility load forecasting has the capability to deal with the changing social and economic environment which influences load growth. The "new factors" which characterize this uncertain environment were of little importance in the past, but they must now be taken into account if forecasts of electric energy consumption and peak demand are to be useful in utility decision making. These new factors fall into three generic groups: policy-regulatory factors, technical factors, and economic-demographic factors.

Policy-regulatory factors include fuel price and use controls, efficiency standards, mandatory conservation regulations, load management programs, incentives to adoption of alternative technologies, and changes in rate structure. Changes in policies and regulations can occur at almost any time, taking the forecaster by surprise, and sometimes causing an immediate impact on load growth.

Technical factors, on the other hand, are easier to deal with because changes in technology typically do not penetrate the market very rapidly. Technical factors important to load forecasting include: new end-use devices, improved efficiency of traditional devices, dispersed energy supply technologies (such as solar heating or cogeneration), and new systems for load control and management.

Sometimes these first two categories overlap. For instance, technical advances in solar heating may occur over time, but the use of solar heating may be accelerated by economic incentive mechanisms and government-supported research and development. A similar relationship exists with technical achievements in appliance efficiency, and government-imposed efficiency standards.

Economic-demographic factors also are important to accurate load forecasting. Like technical and policy developments, regional economic and demographic characteristics are changing more rapidly than they did in the past. These factors can best be addressed by constructing a regional economic-demographic model of

a utility's service territory, accounting for population shifts, employment, personal and corporate income, etc. Such models are difficult to create and specify, but they have been built and they work reasonably well.

New Factors Affecting Residential Load Growth

For the remainder of this discussion, we shall assume that a state of the art regional model exists and produces acceptable forecasts of population, employment, and so on in the utility's service area. Our major concern will be to examine specific new factors in the areas of policy regulation and technology as they impact the residential, commercial, and industrial components of a utility's load and energy sales.

There are many new factors which could affect residential load growth over the rest of this century, including improvements in the efficiency of buildings and appliances, greater use of solar heating systems, load management programs, and new energy-consuming devices.

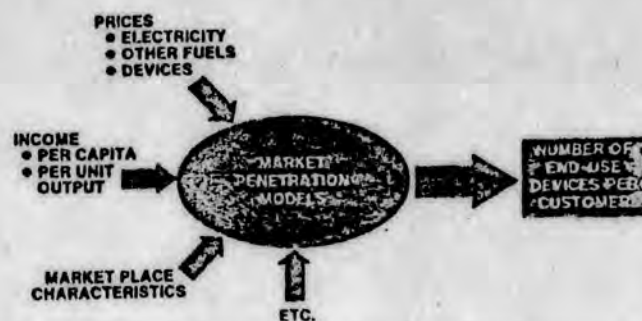
Building Shell Efficiency Improvements. The recently legislated National Energy Act (NEA) requires utilities to help home owners install improved attic and wall insulation, caulking, weather stripping, etc., to decrease heat loss from their homes. Technically it is feasible to make the typical residential building far more efficient than it currently is — reductions in energy use by factors of two or three are possible. The economics of various levels of improvements are the subject of much debate. The results depend strongly on regional differences and on assumptions regarding fuel price increases. It is generally accepted that a modest investment in ceiling insulation, for example, can lead to a significant energy savings (up to 25 per cent of the heating load) and pay off in a year or two.

These NEA provisions could lead to a substantial near-term reduction in utilities' electric heating loads — though perhaps less than has been suggested because electric homes are typically quite efficient already. To account for this effect in its forecast, the utility would have to monitor the number of retrofit installations in its service area, conduct measurements to determine the average reduction in energy use per building, and project the eventual saturation level of retrofit installations. It also would be desirable to obtain data on the energy efficiency of new homes in the service area.

Appliance Efficiency. Appliances are a major component of residential electric load. The NEA mandates improvements in the efficiency of major appliances, but the standards will not become effective for several years. To account for these future appliance efficiency improvements, the utility forecaster must differentiate between old and new appliances after the early 1980's, and develop new data on electric consumption levels for the new appliances which enter the market.

Although the use of more efficient appliances will tend to decrease energy consumption, net energy use will increase if people continue to buy more and more electricity-consuming devices. The introduction of

FIGURE 2
MARKET MODELS CAN BE USED
TO PROJECT HOW MANY END-USE
DEVICES THERE WILL BE



entirely new devices — such as electric vehicles — could also result in sharp growth of electric energy sales. The consequences of an increasingly electrified economy must be accounted for in the load forecast, as new electricity-consuming devices enter the marketplace over the next few decades.

Solar Heating Systems. Another factor of concern to utility forecasters is the market penetration of solar heating systems. Although solar heating currently is not economical in most parts of the country, it is possible that the NEA's solar incentives coupled with rising fuel prices could cause significant market penetration of solar heating systems within the next decade. In many cases the backup for solar heating systems will be electric. As a result, it is conceivable that increased use of solar systems could reduce electric energy consumption on an annual basis, but exacerbate the peak-load problems.

To account for increased use of solar heating systems, the forecaster must use market models to predict how rapidly solar technology will penetrate the service area, as a function of various price and policy factors. Measurements must be made to determine the annual electric energy consumption — and the impact at peak — of solar systems with electric backup. A similar approach can be used to account for the possible introduction of passive solar designs in new homes.

Load Management. While increased use of solar heating systems may be detrimental to utilities' load factors, improved load management programs will likely offset these effects and benefit the entire utility industry. A variety of schemes has been recommended to help flatten the load duration curve, ranging from ripple controls on water heaters to time-of-day rates. Many of these schemes are being tested now, and there is already evidence that poorly designed load management programs can have adverse effects on load shape. For example, time-of-day rates can lead to a new and even higher peak in the hour after the peak rate ends, if there is no "shoulder" rate.

Dealing with load management options in the forecast is extremely difficult, because little data are available to help predict how customers will respond to load management efforts. It is important, therefore, for utilities to gather and disseminate data from the

experiments which are now being conducted. These data will help predict the average usage rate per controlled appliances; the impact of storage, feedback meters, etc., on usage levels; and response of customers to various rate structures.

In principle, the econometric end-use forecasting model has the flexibility to deal with both rate changes and engineering-oriented load management options. The problem is lack of data; but this problem should be resolved as the results of ongoing experiments are disseminated, and new experiments are initiated. The importance of load management cannot be overstated. Improved load management means more efficient use of the industry's capital stock — its generating plants and transmission lines — and that is good business.

New Factors Affecting Commercial Load Growth

The nonmanufacturing or commercial sector often represents the fastest-growing component of load in a utility's service area. Yet it is the most difficult component to deal with in forecasting, because it includes a broad spectrum of customers — ranging from restaurants, to shopping centers, to high-rise office buildings — using energy in a variety of ways.

The new factors which could have a major impact on commercial sector load growth include building efficiency standards, dispersed energy sources, and improved equipment efficiency.

Building Efficiency. Among the conservation-related provisions of the National Energy Act are standards to improve the energy efficiency of commercial buildings. These standards, which are not expected to be in place until the mid-1980's, will not have an immediate effect because the building stock turns over slowly. In the long run, however, the impact of these standards on load growth may be substantial, reducing the energy consumption of new office buildings by a factor of two or more. Even now, many states are in the process of adopting the voluntary ASHRAE 90-75 standard, and advanced building-design concepts are being developed with the aim of attaining even greater reductions in the energy consumption of new buildings.

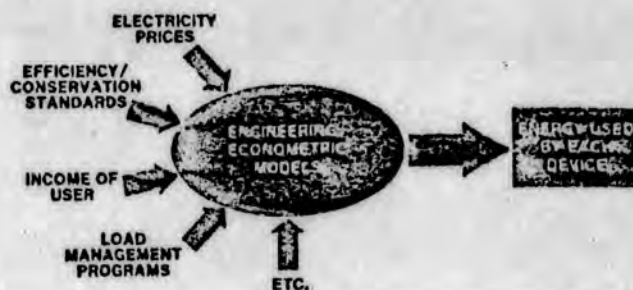
Dispersed Energy Sources. Not only are commercial buildings the prime targets of new energy-efficiency standards, they are also attractive candidates for pioneering the use of dispersed energy sources, including solar heating and cooling, total energy systems, and fuel cells. These innovations may penetrate the market rapidly, particularly if the commercial sector becomes subject to interruptible service as part of state or federal load management policies. There are two crucial issues which the forecaster must address in dealing with these new sources:

- The penetration rate of each type of device on a standard industrial code specific basis.
- The impact of each device on the utility's load, particularly at the peak.

To account for the possible introduction of dispersed

FIGURE 3

ENGINEERING/ECONOMETRIC MODELS CAN BE DEVELOPED TO PROJECT CHANGES IN CONSUMPTION OF VARIOUS DEVICES



energy sources, the utility load forecaster must construct market models to estimate penetration rates, based on historical experience with similar new technologies (such as central air conditioning). Load profiles for the new devices will have to be established through field measurements of early users.

Equipment Efficiency. A third factor important in forecasting commercial sector load is the improved efficiency of lighting, office machines, compressors, pumps, commercial ranges and ovens, and other equipment. The approach used in dealing with these efficiency improvements is similar to forecasting the impact of appliance efficiency improvements in the residential sector, but is complicated by the heterogeneity of commercial sector users.

The commercial sector will also be influenced — perhaps more strongly than the residential sector — by changes in the way electricity is priced, and by the prices of competing energy sources. Econometric models which incorporate price explicitly into the penetration and consumption models — for both current and future end uses — are of particular importance in the commercial sector. The same point holds true for the industrial sector.

New Factors Affecting Industrial Load Growth

Projecting load growth in the industrial sector is complicated by three factors. When a new industrial facility locates in the service territory, or leaves it, the load can change by a large increment at one time. Also of importance is the fact that industrial energy use is strongly dependent on the health of the national economy — it was the industrial load that dropped most sharply in the recession that followed the 1973 oil embargo. A third factor is that fuel shifting and process changes, initiated for economic or regulatory reasons, can create large new loads in a short time period.

In order to understand better their industrial load, most utilities are moving toward highly disaggregated industry (or plant) specific forecasting techniques. These techniques address end uses at the process level, and account for industrial output in the service territory as a function of national as well as regional economic

indicators. Once these models are in place, it is a relatively straightforward task to deal with new factors such as energy conservation standards, process efficiency improvements, regulations constraining the use of oil and gas, and alternative energy sources.

Energy Conservation Standards. Although the federal government has promulgated a set of energy-efficiency targets for the ten most energy-intensive industries, compliance is still voluntary, and may remain so. Industry's primary concern is not the cost of energy, but the certainty of supply — the efficiency of end use is of secondary importance. Thus in order to pursue conservation targets, industries may switch to electricity-based processes, shifting the burden of inefficient fossil fuel conversion to the utility.

Process Efficiency. Improvements in process efficiency, although part of the overall conservation effort, warrant special attention because they are the focus for substantial research and development effort on the part of both industry and the federal government. Dealing with process efficiency improvements is not much different, in principle, than examining the efficiency of specific appliances in the residential sector. Because there is so much room for process efficiency improvements in most industries, it behooves the utility forecaster to disaggregate his models to the point where these improvements can be captured when there is evidence that they are occurring.

Coal Conversion. A highly disaggregate model is also desirable in order to capture the influences of new NEA-mandated regulations providing for industrial use of coal instead of oil or gas. In many cases, industrial users may choose to convert to electric energy rather than cope with the problems inherent with coal use, including environmental effects and supply uncertainties. As with process efficiency improvements, a highly disaggregated end-use model is essential if these effects are to be addressed correctly in the forecast.

Alternative Sources. The NEA also provides incentives for industrial use of cogeneration, as well as for the use of solar energy, geothermal resources, and other advanced technologies. Increased use of such technologies could reduce electric energy sales to the industrial sector significantly. Again, detailed end-use models — reflecting specifically the potential for use of alternative sources in industrial process applications — will be necessary to account for switchovers in the load forecast.

Limitations of Models

This discussion has stressed the use of analytical models to address the new factors affecting electric load growth. It is important, however, to remember that models are only a tool. They are intrinsically:

- Nothing more than a systematic way to structure the available data and information about a situation. They can in no way transcend the data used to create them, although they may occasionally help the forecaster to discover relationships which were not intuitively evident.

- Limited by the "boundaries of the modeler's understanding"* of what is happening in the world around him. If he does not know, for example, how customers will respond to changes in regulation or technology based on past experience, then models cannot help the forecaster out of the bind imposed by his ignorance.

The art and science of load forecasting will have taken a major step forward when it progresses to the point where accounting — in an explicit way — for the types of factors discussed here is truly feasible. But the challenge of trying to foresee what new factors — beyond those we already envision — will emerge in the years ahead is even more forbidding. Unfortunately, anticipating basic changes in the course of society is something that no utility forecaster will ever be able to do. The tool of sensitivity analysis, which can help him address the "what-if" questions, is perhaps the most effective way of assessing the potential impacts of events such as new regulations or potential technological breakthroughs on load growth.

Dealing with the new factors affecting load growth requires a commitment on the part of utility managers to the development of analytical tools and the data necessary to understand what is going on in the service territory, and to specify the forecasting models. It is legitimate to ask if the investment in data and models is worth the return. There is no simple answer to this question. The returns from improved forecasting come both in reduced levels of uncertainty and in a better understanding of the potential impacts which various futures could have on the utility. Only senior management can decide when an incremental improvement in its perspective on the future is outweighed by the marginal cost of achieving it.

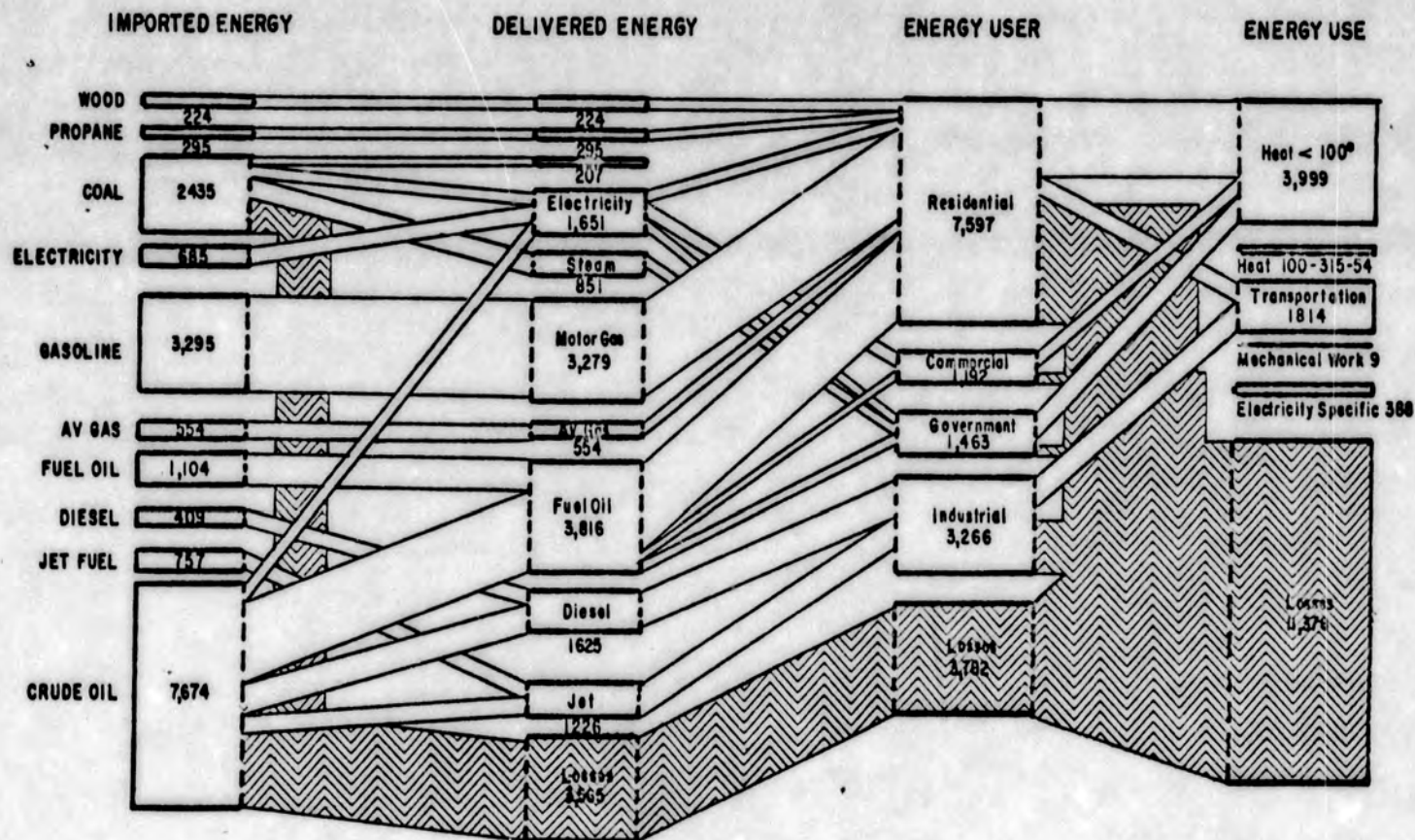
*"Electric Load Forecasting: Probing the Issues with Models," EMF Report 3, Vol. 1, Energy Modeling Forum, Stanford University, Stanford, California, April, 1979, p. 7. EMF is sponsored by the Electric Power Research Institute.

Telecommunications Policy Conference: Call for Papers

The eighth annual Telecommunications Policy Research Conference (scheduled for spring, 1980) will provide a forum for analysis and discussion of important telecommunications policy issues. Participants will include researchers and policymakers from academia, government, and industry. Those engaged in research which has implications for telecommunications policy are invited to submit abstracts (500 words or less) by December 1, 1979. Authors of papers selected for presentation at the conference will be reimbursed for travel and conference living expenses if no alternative source of funding is available. Please send abstracts to: TPRC Organizing Committee, c/o Robert Dansby, American Telephone and Telegraph Company, 195 Broadway, Room 1942B, New York, N. Y. 10007.

NET ENERGY BALANCE Fairbanks North Star Borough - 1978 (Units = 1×10^9 BTU)

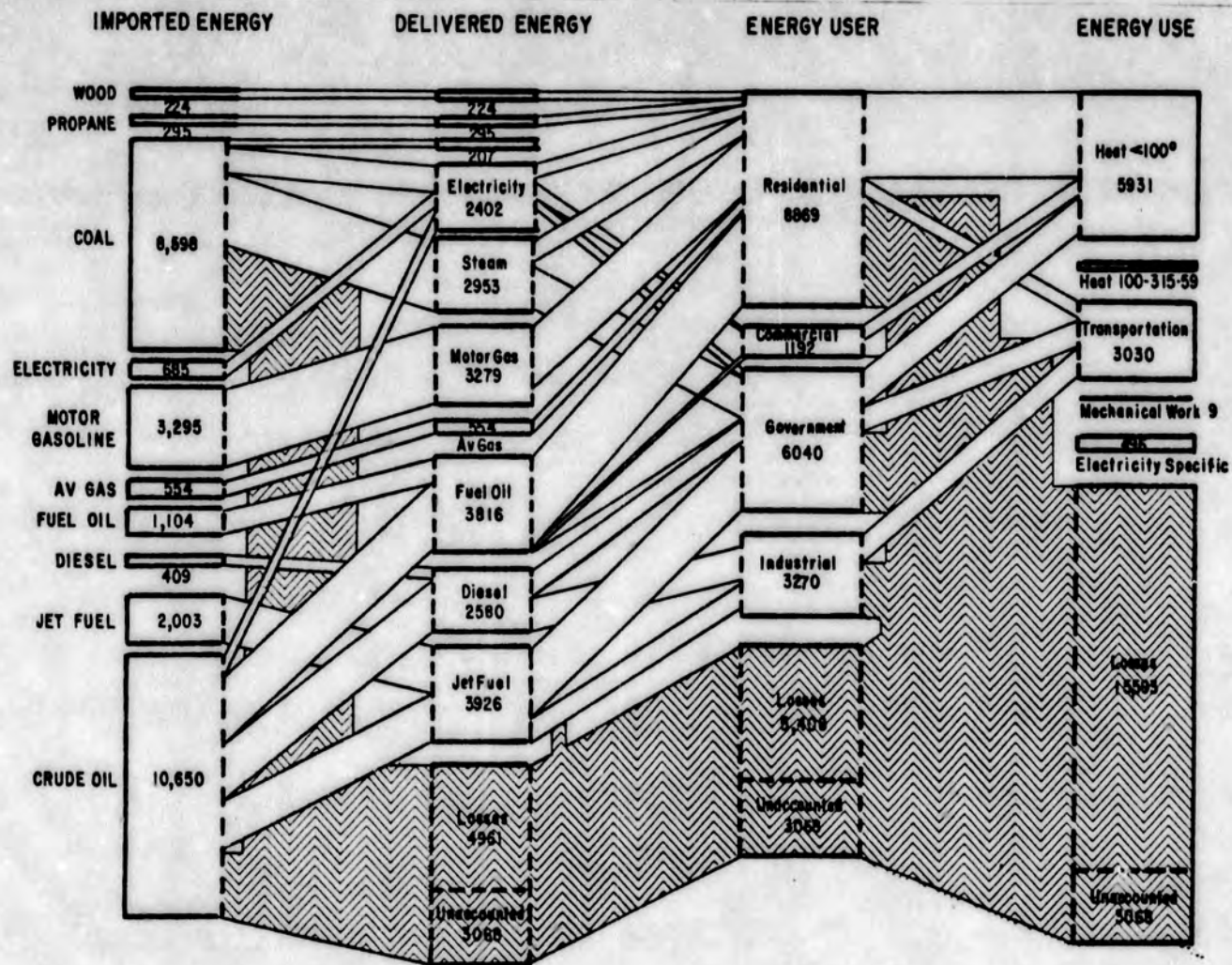
*Excluding
Military*



NET ENERGY BALANCE

Fairbanks North Star Borough - 1978

(Units = 1×10^9 BTU)



Power Alt



GOLDEN VALLEY ELECTRIC ASSOCIATION INC. Box 1249, Fairbanks, Alaska 99707, Phone 907-452-1151

November 30, 1979

Mr. Oliver Scott Goldsmith
Institute of Social and Economic Research
University of Alaska
707 "A" Street
Anchorage, AK 99501

Dear Mr. Goldsmith:

Mr. Huffman has asked me to assist you by providing data which will facilitate your arriving at a reasonable and accurate projection for electrical load growth in our service area. Enclosed for openers is a copy of our 1978 annual report. Please contact me when you wish to set up a meeting.

Sincerely,

Michael P. Kelly
Administrative Assistant

MPK:es

Encl

cc: Rep. Rogers
Mr. Yould, APA

ELECTRIC POWER DEMAND FORECASTS AND
THE SUSITNA HYDROELECTRIC PROJECT

A proposal by Bradford H. Tuck, Economic Consultant.

One of the central questions in the evaluation of the proposed Susitna Hydroelectric Project is that of future electric power demand in areas potentially served by the Project. Forecasts of electric power demand have been made by the Alaska Power Administration, ISER, and others, and there are significant differences among these forecasts. In addition, the divergence between high and low growth demand scenarios is so large as to raise questions regarding their usefulness. The proposed study is intended to provide an indepth review of relevant demand forecasts, as outlined below.

I. INTRODUCTION

- A. General overview of study.
- B. Identification of relevant demand forecasts.

II. ANALYSIS OF DEMAND FORECASTS

- A. Review criteria:
The review criteria would include type of forecast and methodology used, quality and reliability of input data, critical assumptions, and level of detail in components of demand. Also of concern is whether or not price elasticity and conservation possibilities have been considered.
- B. Review of specific demand forecasts:
The forecasts reviewed would include work done by the Alaska Power Administration, forecasts contained in the Interim Feasibility Report for the Susitna Project, forecasts by ISER, and other forecasts that may be relevant.

Particular emphasis will be given to ISER forecasts that will be under development concurrently with this

study. Since the ISER forecasts will, in part, be dependent upon the MAP model, special attention will be given to the properties of the MAP model and to the data scenarios used to generate the forecasts.

III. SUMMARY AND CONCLUSIONS

- A. Synopsis of findings.
- B. Usefulness of findings for decision about Project.

DATE OF STUDY: To be completed by March 1, 1980.

COST: \$5,500.00.

lamp

*interim
report*

Jan. 28, 1979

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MIGRATION AND THE DYNAMIC
STABILITY OF REGIONAL ECONOMETRIC MODELS

David M. Reaume
State of Alaska
Department of Commerce
& Economic Development
July, 1979

A survey taken in 1975 by researchers at the University of North Carolina revealed that 125 out of 191 respondent U.S. cities, towns and other planning districts employed growth controls other than simple zoning (or in addition to).¹ Citizen groups in some parts of the country are reported to deliberately play down the attractiveness of their region in an attempt to discourage new migration.² In Alaska, up to one hundred million acres of land may be classified as nondevelopable by the federal government under section 17(D)2 of the Alaska Native Claims Settlement Act.

Because of such intense public concern over the possible negative effects of economic growth, public decision makers have increasingly called upon economists and other scientists to quantify the impact of proposed economic development on population growth, government spending, and the natural environment. For their part, economists have responded by creating new analytic tools with which to examine the problem. Prominent among these is the regional econometric model.³

Taken as a whole, professional testimony based in part on econometric simulations of proposed development projects has the potential to influence greatly the inter-regional distribution of economic activity, and, thereby, the efficiency with which we use our scarce natural resources.⁴

1. Godschalk, David et al (3).

2. "Oregon Stops 'Em at the Border," Seattle Post Intelligencer, February 18, 1979, p. E2.

3. A partial list of references is given below. Data Resources, Incorporated reports that fourteen large state econometric models are now on its computer.

4. For example, the University of Alaska's MAP model, Siever (1975), has been used in producing a number of environmental and economic impact statements.

- It is, therefore, most important that we gain an understanding of the strengths and weaknesses of our regional econometric models.

A model can be weak in a variety of ways and for a variety of reasons. The weakness examined here is inappropriate dynamic behavior, that is, a significant divergence between a model's dynamic properties and the "true" properties of the real world economy which has been modeled. Such a divergence would exist, for example, if a particular model was explosive or cyclic even though the regional economy itself had no such tendencies.

For several a priori reasons the migration equation (or block of equations) appeared to me to be a particularly likely source of inappropriate dynamic behavior and therefore a candidate for research. First, unless the labor force constraint is simply not modeled, an econometric model's long run rate of employment growth is clearly constrained by the rate of growth of the regional labor force, and, thus, by the level of induced net migration. Second, despite the fact that the literature on migration strongly suggests that gross migration flows are a better choice of dependent variable for regression purposes, net migration is usually used as a dependent variable because of the unavailability of time series data on inter-regional gross migration flows.¹ Third, since net migration is typically derived as a residual, relatively small percentage errors in population estimates can produce relatively large percentage errors in net migration.

1. See Vanderkamp (12). Many regional econometric models do not explicitly model migration. In these, migration is implicitly determined by a regression of population on a variety of determinants. An example is the Philadelphia model developed by Glickman (2).

This paper is a report on research into the role played by the migration equation in generating inappropriate dynamic behavior in regional econometric models. There are two principal sections. In the next section, three different versions of a model of population, employment, and induced spending are introduced. The conditions under which each version is explosive, stable, or cyclic are then derived as functions of the structural form parameters. In the next section, the third version is fit to time series data for Alaska, and then tested for sensitivity to slight variations in the migration parameters using the stability conditions previously derived. It is found that within the range of one estimated standard deviation on one migration parameter, the model moves from stability to explosive growth.

In short, what is shown here is that (i) the net migration equation is of critical importance in determining a model's behavior; (ii) relatively small changes in the migration equation's parameters produce marked differences in model behavior; and (iii) point estimates of the migration parameters cannot be held in much confidence. The implication is that policy prescriptions based on simulations of regional econometric models (particularly long run simulations) should be formulated with even greater care than one might normally presume is prudent.

II. Migration Dynamics

Consider a regional economy which is small relative to the outside economy from which it can draw migrants. What determines the economy's dynamic behavior when net migration is specified to be a function of regional economic growth? The answer, of course, is that many things do. Intuitively, however, it seems clear that the economy's steady state rate of positive growth will be limited by the rate of growth of the effective labor force, where the latter is determined both by increases in native labor and by the level of new migration.

Suppose now that in a given model of this economy population growth stimulates additional government spending, which results in additional public and private employment, which in turn induces new migration, further population growth, and so on. At first, one might conjecture that the government's propensity to spend (however measured) and the rate of new migration would be equally important in determining whether the model was stable, explosive or cyclic, especially if government spending is assumed to be financed by a (practically) unlimited exogenous revenue source. In this section I work out the dynamic properties of three versions of such a model. A very interesting result is that only the parameters of the migration equation appear in every stability condition. Parameters of other equations sometimes appear and sometimes do not.

The model developed here is explored in three successively more complex versions. The first two consist of four equations in the four endogenous

variables -- population, net migration, total employment, and total public plus private spending. The third version of the model introduces the relative wage.

Though mathematically simple, the model's generality can best be appreciated by considering it to be an aggregated partial reduced form derived from a larger more disaggregated structural model. Exogenous spending and employment can be thought of as determined elsewhere in the larger model of which this is a part.

Version 1

Let N be population, NBD be net births and deaths, $NMIG$ be net migration, E be total employment, and S be total government and private spending. Write the structural form as:

$$[1] \quad N = N(-1) + NBD + NMIG$$

$$[2] \quad NMIG = \beta_1 (E - E(-1))$$

$$[3] \quad E = \bar{E} + \beta_2 S$$

$$[4] \quad S = \bar{S} + \beta_3 N$$

Where $\bar{E}$ and $\bar{S}$ are exogenous components of employment and total government plus private spending, and β_1 , β_2 and β_3 are strictly positive parameters.

Because Version 1 is fully simultaneous it has a single characteristic equation derived from the reduced form equation $N = N(-1) + f(\bar{E}, \bar{S}, NBD)$.

The characteristic equation is $X = 1$, where X is the latent root.

Hence, the model is stable for all values of β_1 , β_2 , and β_3 .

Admittedly, this is a much simplified model of the migration-development process. However, it does embody the important jointly determined relationship between employment creation and employment induced migration. The fact that the model in this form is stable for all values of β_1 , β_2 , and β_3 is only a little reassuring. Certainly, a specification that allowed for at least the possibility of explosive growth should be considered before any conclusions are drawn. One suspects that an explosive migration-development process should be at least theoretically possible.

Version 2

Potential instability is introduced by generalizing [2]. In addition, a one period lag is used in [3]. Version 2 is then [1], [2'], [3'], and [4] where

$$[2'] \text{ NMIG} = \beta_1 E + \beta_4 E(-1)$$

$$[3'] E = \bar{E} + \beta_5 S(-1)$$

and where by assumption $\beta_4 < 0^1$, and β_1 , β_5 , and β_3 are strictly positive.

1. From [2], $\text{NMIG} = \beta_1 E - \beta_1 E(-1)$. Equation [2'] generalizes equation [2] by allowing the coefficient on $E(-1)$ to differ in absolute value from that on E .

Straight forward substitution and simplification of Version 2 leads to the following reduced form equation for population.¹

$$[5] \quad N = (1 + \beta_1\beta_5\beta_3) N(-1) + \beta_4\beta_5\beta_3 N(-2) + \text{exogenous terms}$$

The homogeneous part of equation [5] is of the form $N = AN(-1) + BN(-2)$ where $A = 1 + \beta_1\beta_5\beta_3 > 0$ and $B = \beta_4\beta_5\beta_3 < 0$. The latent roots of its characteristic equation are X_1, X_2 where

$$[6A] \quad X_1 = (A + (A^2 + 4B)^{1/2})/2$$

$$[6B] \quad X_2 = (A - (A^2 + 4B)^{1/2})/2$$

These roots are real if $A^2 \geq -4B$, since β_4 and therefore B , is strictly negative; otherwise they are complex.² It is intuitively clear from inspection of [5] that β_1 and β_4 , the parameters of the migration equation, are pivotal.

The model's dynamic properties are not difficult to describe. Assuming that the roots of the characteristic equation of [5] are real, the model is explosive if its largest root, X_1 , exceeds unity.³ But X_1 will exceed unity if and only if $(A^2 + 4B)^{1/2} > 2-A$, where $(A^2 + 4B)^{1/2}$ is the nonnegative square root. There are two subcases since, by assumption, $A > 1.0$.

-
1. The dynamic equation for population is: $N(t) = eX_1^t + gX_2^t + F$, where F is a particular solution and e and g are parameters determined by initial conditions. It is clear from [4] and [3'] that S and E will grow explosively if and only if N does so and will oscillate if and only if N does so.
 2. Note, however, if $\beta_4 > 0$ is allowed, then $A^2 < -4B$ is impossible and cyclic behavior is precluded.
 3. Given that $A > 0$ and $B < 0$, $X_2 < -1$ is ruled out, since this requires $B-A > 1.0$.

Subcase 1: $1 < A \leq 2$

Consider $(A^2 + 4B)^{1/2} > 2 - A$

Squaring both sides does not change the direction of inequality since in this subcase both sides are nonnegative. The rule then becomes

$$A^2 + 4B > 4 - 4A + A^2$$

$$\text{or } A + B > 1$$

$$\text{But } A + B = 1 + \beta_1\beta_5\beta_3 + \beta_4\beta_5\beta_3$$

Hence, in this subcase, Version 2 is explosive if and only if $\beta_1 > -\beta_4$.

Subcase 2: $A > 2$

Here, $2 - A < 0$, and X_1 will exceed unity if $(A^2 + 4B)^{1/2} > 2 - A$. But

$$(A^2 + 4B)^{1/2} \geq 0 > 2 - A \quad \text{for all } A.$$

Hence the model is explosive for all A greater than 2.0 if the roots of [5] are real.

From the definition of A , $A > 2$, implies

$$[7] \quad \beta_1 > (\beta_5\beta_3)^{-1} \quad \text{or } \beta_1\beta_5\beta_3 > 1.0$$

It was noted above that the solutions to [6A] and [6B] are real if and only if $A^2 + 4B \geq 0$. This condition restated in terms of the structural parameters is:

$$[8] \quad -4\beta_4 \leq (\beta_5\beta_3)^{-1} + 2\beta_1 + \beta_1^2\beta_5\beta_3$$

Equation [8] gives the condition under which X_1 and X_2 are real. If the reverse inequality holds strictly, X_1 and X_2 are complex conjugates and the model is cyclic. The condition for damped oscillations, stated without proof, is $A^2 < 4(1 + B)$ or

$$[8A] \quad (1 + \beta_1\beta_5\beta_3)^2 < 4(1 + \beta_4\beta_5\beta_3)$$

Version 3

The final version of the model considered in this paper is Version 3. In this version, a relative wage term is added to the net migration equation, spending is specified to be a function of both the average wage and population, the wage is treated as an endogenous function of employment, and, finally, employment is taken to be a function of both current and lagged spending. The exogenous components of employment and spending are retained and an exogenous component of the average regional wage is introduced. The model then becomes:

$$[1] \quad N = N(-1) + NBD + NMIG$$

$$[2''] \quad NMIG = \beta_1 E + \beta_4 E(-1) + \beta_6 W/WX$$

$$[3''] \quad E = \bar{E} + \beta_2 S + \beta_5 S(-1)$$

$$[4'] \quad S = \bar{S} + \beta_3 N + \beta_7 W$$

$$[5] \quad W = \bar{W} + \beta_8 E$$

Where all parameters except β_4 are specified to be positive, W is the average regional wage, WX the average wage in the economy from which migrants are drawn, and the remaining variables are defined as above.

By inserting [5] into [2"] and the result into [1], and also inserting [5] into [4'] and the result into [3"], the model is reduced to the following two simultaneous difference equations in N and E .

$$[9] \quad N = N(-1) + (\beta_1 + (\beta_6\beta_8/WX))E + \beta_4E(-1) + \text{exogenous terms}$$

$$[10] \quad E = (1 - \beta_2\beta_7\beta_8)^{-1}\beta_2\beta_3N + (1 - \beta_2\beta_7\beta_8)^{-1}\beta_5\beta_3N(-1) + (1 - \beta_2\beta_7\beta_8)^{-1}\beta_5\beta_7\beta_8E(-1) + \text{exogenous terms}$$

These may be rewritten:

$$[9'] \quad N = N(-1) + c_1E + c_2E(-1) + \text{exogenous terms}$$

$$[10'] \quad E = c_3N + c_4N(-1) + c_5E(-1) + \text{exogenous terms}$$

where the $\{c_i\}$ are defined by comparison with [9] and [10].

Solutions to the homogenous portions of [9'] and [10'] are of the form¹

$$N(t) = p_1X^t$$

$$E(t) = p_2X^t$$

The characteristic equations are then

$$[11] \quad p_1X^t = p_1X^{t-1} + c_1p_2X^t + c_2p_2X^{t-1}$$

1. See Baumol (1) pp 327-331 for a discussion of the method of solution.

$$[12] \quad p_2 x^t = c_3 p_1 x^t + c_4 p_1 x^{t-1} + c_5 p_2 x^{t-1}$$

Letting $p = p_1/p_2$, we can divide both sides of equations [11] and [12] by $p_2 x^{t-1}$ and $p_1 x^{t-1}$, respectively, to obtain

$$[11'] \quad pX = p + c_1 X + c_2$$

$$[12'] \quad p^{-1}X = c_3 X + c_4 + c_5 p^{-1}$$

or, upon solving [11'] for X

$$[11''] \quad X = (p + c_2)/(p - c_1)$$

Substitution of [11''] into [12'] produces a quadratic polynomial in p that can be solved in terms of the c_i . Its roots can then be successively substituted back into [11''] to produce the two values X_1 and X_2 that determine the model's fundamental dynamic properties.

The quadratic polynomial is

$$[13] \quad (c_3 + c_4)p^2 + (c_2 c_3 - c_4 c_1 + c_5 - 1)p - (c_5 c_1 + c_2) = 0$$

Equation [13] has two roots. Under what circumstances will these produce values of X_1 or X_2 that exceed unity? Assuming for the moment that the roots of [13] are real we have from [11''] that

$$X > 1.0 \Leftrightarrow (p + c_2)/(p - c_1) > 1.0$$

There are two subcases. First, if $p - c_1 > 0$, the model shows explosive positive growth if and only if $c_2 > -c_1$. Second, if $p - c_1 < 0$, the model shows explosive positive growth if and only if $c_2 < -c_1$. In either case, whether or not the model is explosive is effectively determined by the migration equation's parameters, since $c_1 = \beta_1 + \beta_6 \beta_8 / WX$, $c_2 = \beta_4$ and

β_8 can be made arbitrarily small by choice of the units of measurement of W and E .¹

Consider now the case where the model oscillates. In this case, [13] has a pair of complex roots. We can therefore write

$$[14] \quad (p - (a + bi))(p - (a - bi)) = 0$$

where $a + bi$, $a - bi$ are complex conjugates and a and b are real constants.

Expanding [14] leads to [14'] where

$$[14'] \quad p^2 - 2pa + b^2 = 0$$

Now, by comparison of [13] and [14'] it can be seen that if the roots of [13] are complex

$$[15] \quad c_3 + c_4 = 1$$

$$[16] \quad c_2c_3 + c_5 - 1 - c_4c_1 = -2a$$

$$[17] \quad -c_5c_1 - c_2 = b^2$$

In general, the solutions to [13] are of the form

$$[18] \quad p = \frac{-(c_2c_3 - c_4c_1 + c_5 - 1) \pm ((c_2c_3 - c_4c_1 + c_5 - 1)^2 + 4(c_3 + c_4)(c_5c_1 + c_2))^{1/2}}{2(c_3 + c_4)}$$

1. Notice also that normalization on either β_1 or β_4 in [2"] cannot change β_1/β_4 .

But from [15] we see that complex p implies $c_3 + c_4 = 1$.

I conclude that the roots of [13] are complex and the model oscillates if and only if

$$[19] \quad (c_2c_3 + c_5 - c_4c_1 - 1)^2 + 4(c_5c_1 + c_2) < 0$$

The oscillations are damped if

$$[19A] \quad (c_2c_3 + c_5 - c_4c_1 - 1)^2 + 4(c_5c_1 + c_2)^2 < 4$$

These conditions can be readily expressed in terms of the structural parameters as shown below. The case of negative X will not be treated in this section for Version 3.

Summary of Stability Conditions

For convenience the stability conditions for the three Versions of the model are summarized here.

Version 1 - Stable for all values of the parameters.

Version 2 - Characteristic equation has real roots and is explosive if and only if

$$-4\beta_4 < (\beta_5\beta_3)^{-1} + 2\beta_1 + \beta_1^2\beta_5\beta_3 \quad [8]$$

If the roots are real and $\beta_1 \leq -\beta_4$, the model is stable. If the roots are not real the model is cyclic. The cycles are damped if and only if

$$(1 + \beta_1\beta_5\beta_3)^2 < 4(1 + \beta_4\beta_5\beta_3) \quad [8A]$$

Since the left hand side exceeds unity, it is clearly necessary that $\beta_4\beta_5\beta_3 > -0.75$

Version 3 - Characteristic equation has complex roots and oscillates if and only if

$$\begin{aligned} & ((1-\beta_2\beta_7\beta_8)^{-1}(\beta_2\beta_3\beta_4 + \beta_5\beta_7\beta_8) - 1 - (\beta_1 + \beta_6\beta_8/WX)(1 - \beta_2\beta_7\beta_8)^{-1}\beta_5\beta_3)^2 + \\ & 4((1-\beta_2\beta_7\beta_8)^{-1}\beta_5\beta_7\beta_8(\beta_1 + \beta_6\beta_8/WX) + \beta_4) < 0 \quad [20] \end{aligned}$$

The oscillations are damped if the roots are complex and if

$$\begin{aligned} & ((1-\beta_2\beta_7\beta_8)^{-1}(\beta_2\beta_3\beta_4 + \beta_5\beta_7\beta_8) - 1 - (\beta_1 + \beta_6\beta_8/WX)(1 - \beta_2\beta_7\beta_8)^{-1}\beta_5\beta_3)^2 + \\ & 4((1-\beta_2\beta_7\beta_8)^{-1}\beta_5\beta_7\beta_8(\beta_1 + \beta_6\beta_8/WX) + \beta_4)^2 < 4 \quad [21] \end{aligned}$$

Model shows explosive positive growth if and only if the roots of the characteristic equation are real and either

$$p > \beta_1 + \beta_6\beta_8/WX > -\beta_4 \quad [22]$$

$$\text{or } p < \beta_1 + \beta_6\beta_8/WX < -\beta_4 \quad [23]$$

where p is either the real root of [13] and may be found by solving [18].

III. EMPIRICAL RESULTS

Equations [2"], [3"], [4"], and [5] were fit to annual time series data for the state of Alaska. Because many, if not most, regional econometric models are fit using ordinary least squares, that method was used here. The purpose of this section is to demonstrate the sensitivity of a representative model's dynamic properties to relatively small changes in the values assigned to the parameters of the migration equation. Version 3 of the model as fitted is (t-statistics in parentheses):¹

$$[1] \quad N = N(-1) + NBD + NMIG$$

$$[2"] \quad NMIG = 1.831 \cdot 10^{-6} \cdot E - 2.663 \cdot 10^{-6} \cdot E(-1) + 36853.2 \cdot W/WX$$

(2.5) (-3.3) (3.0)

$$\bar{R}^2 = .84$$

$$DW = 2.40$$

Period of fit: 1961 to 1976

$$[3"] \quad E = EFED + 25240.4 + 51881.7 \cdot S - 25044.7 \cdot S(-1)$$

(7.4) (4.0) (-1.5)

$$\bar{R}^2 = .99$$

$$DW = 1.77$$

Period of fit: 1965 to 1976

1. The period of fit for [3"] and [4'] was shortened because of the unavailability of one component of S for the years prior to 1964. See appendix.

$$[4'] S = \text{WFED} - 5.37 + 20.93 * N + 45636.4 * W$$

$$(-8.0) \quad (6.1) \quad (0.35)$$

$$\bar{R}^2 = .98$$

$$DW = 0.80$$

Period of fit: 1965 to 1976

$$[5] W = 9.106 * 10^{-6} + 3.122 * 10^{-11} * E$$

$$(33.1) \quad (11.3)$$

$$\bar{R}^2 = .89$$

$$DW = 0.62$$

Period of fit: 1961 to 1976

The precise empirical definition of the variables is relegated to the appendix. Here I simply note that EFED and WFED are federal government civilian employment and payrolls in Alaska, respectively. Referring back to the analytic versions of these equations it can be seen that $\bar{E} \equiv \text{EFED} + 25240.4$; $\bar{S} \equiv \text{WFED} - 5.37$; and $\bar{W} \equiv 9.106 * 10^{-6}$.

Using the fitted values of the β_i and solving [13] for p yields:

$$p_a = 4.033 * 10^{-6}$$

$$p_b = 1.120 * 10^{-6}$$

From [11"] and the definition of the $\{c_i\}$ these yield $X_1 = 0.6223$ and $X_2 = 2.166$, thus, the fitted model is unstable.

Consider, however, what happens when the coefficient on $E(-1)$ in [2"] is raised by approximately one standard deviation and set equal to $-\beta_1$.

Solution of [13] gives $p_a = 1.810 * 10^{-6}$, $p_b = 1.734 * 10^{-6}$. By comparing [9] and [9'] it can be seen that $c_1 = \beta_1 + \beta_6 \beta_8 / WX$ and $c_2 = \beta_4$. Using the fitted values for β_1 , β_6 and β_8 and using $\beta_4 = -\beta_1$, it follows that (at the 1976 value of WX)

$$\begin{aligned} c_1 &= 1.999 * 10^{-6} \\ c_2 &= -1.864 * 10^{-6} \end{aligned}$$

Thus [22] now fails to hold and the model is therefore stable. In particular, solving [11"] yields:

$$X_1 = 0.948$$

$$X_2 = 0.988$$

Varying one migration parameter approximately one estimated standard deviation transforms the model from explosive growth to stability.

At least two actively used models of the Alaska economy constrain net migration to be a function of the year-to-year change in employment.¹ Because such a constraint can alter all of the fitted parameters in the regression equation, [2"] was refit under this constraint, namely that $\beta_4 = -\beta_1$. The fitted equation was

$$[2''] \quad \text{NMIG@AK} = 0.914 * 10^{-6} (E - E(-1)) - 493.0 * W/WX$$

$$(5.7) \qquad \qquad \qquad (-0.5)$$

$$\bar{R}^2 = .71$$

Period of fit: 1961 to 1976

The sign of the coefficient on W/WX is incorrect, since by a priori reasoning it should be positive. Furthermore, it is statistically insignificant at any reasonable level. It was, therefore, set equal to zero. We then have $\beta_1 = -\beta_4 = .914 * 10^{-6}$, $\beta_6 = 0$, and $\beta_1, \beta_3, \beta_5, \beta_7$, and β_8 as originally estimated. Further, $c_1 = 9.14 * 10^{-7} = -c_2$.

Given these parameter values, solution of [13] yields $p_a = 1.71 * 10^{-6}$. Substitution into [11"] yields

$$X_1 = (1.71 - .914)/(1.71 - .914)$$

$$\text{or } X_1 = 1.0$$

Similarly, $X_2 = 1.0$

The model is stable. However, now suppose $\beta_6 > 0$, as in Reaume (9), and Seiver (10). In particular let $\beta_6 = 493$, a change of approximately one standard deviation from the fitted value in [2'']. In this case, $p_a = 1.715 * 10^{-6}$; $p_b = 0.914 * 10^{-6}$; $X_1 = 1.0$; and $X_2 = 8.08$. The model is now explosive since $X_2 > 1.0$. Again, a change of one standard deviation in one migration parameter converts the model from stability to explosive growth.

DATA PROBLEMS

It has been demonstrated that relatively minor (a priori) changes in specification, or relatively small variations in key migration parameters can markedly change this model's behavior. A reasonable conjecture is that the same is very likely true for other models. If for some reason the parameters of the net migration equation can be shown to vary greatly with normal data error or with the period of fit, then the case is closed. It will have been shown that (i) the net migration equation is of critical importance in determining a model's behavior; (ii) relatively small changes in the migration equation's parameters produce marked differences in model behavior; and (iii) point estimates of the migration parameters cannot be held in much confidence. The implication is that policy prescriptions based on simulations of regional econometric models (particularly long run simulations) should be formulated with even greater care than one might normally presume is prudent.

DATA ERROR

Adequate time series data on gross migration flows are not available for most states and local areas. For this reason, net migration is the usual regression variable and is typically defined as a residual using the identity

$$NMIG = N - N(-1) - NBD$$

[1A]

Now annual net births and deaths (NBD) is (presumably) measured fairly accurately in most developed areas, with the numbers taken by count from birth certificates and death certificates. If so, a relatively small percentage error in estimating the year-to-year change in N can produce a much larger percentage error in NMIG. To see this let the true values of N, NMIG and NBD be asterisked. Then

$$\begin{aligned} \text{NMIG}^* &= N^* - N^*(-1) - \text{NBD}^* \\ &= \alpha_1 \cdot (N^* - N^*(-1)) \end{aligned} \quad [24]$$

$$\text{where } \alpha_1 = 1 - \text{NBD}^*/(N^* - N^*(-1))$$

$$\text{Suppose } N - N(-1) = \alpha_2 \cdot (N^* - N^*(-1)) \quad [25]$$

Then from [1A] and the above

$$\text{NMIG} = (\alpha_2/\alpha_1) \cdot \text{NMIG}^* - \text{NBD} \quad [26]$$

$$\text{Suppose } \text{NBD} = \alpha_3 \cdot \text{NBD}^* \quad [27]$$

Since $\text{NBD}^* = N^* - N^*(-1) - \text{NMIG}^*$, it follows from [24], [26], and [27] that

$$\text{NMIG} = (\alpha_3 + (\alpha_2 - \alpha_3)/\alpha_1) \cdot \text{NMIG}^* \quad [28]$$

In the special case where $\alpha_3 = 1.0$ (no error in NBD) the fact $\alpha_1 < 1.0$ assures that the percentage error in NMIG will be greater than that in $N - N(-1)$.

A numerical example will help order magnitudes. For this example, let $\alpha_3 = 1.0$, $\alpha_2 = 1.01$, and $\alpha_1 = 0.5$. In this case, NBD is measured without error and accounts for one-half the true year-to-year change in population. Then $NMIG = 1.02 \cdot NMIG^*$. The percentage error in NMIG is double that of $N - N(-1)$. If $\alpha_1 = 0.2$, $NMIG = 1.05 \cdot NMIG^*$.

Classical large sample errors-in-variables analysis suggests that measurement error in a dependent variable can be subsumed in the equation's random error term. If the measurement error is well behaved, the standard Gauss-Markov assumptions apply, if they did in the absence of measurement error. If the measurement error causes the Gauss-Markov assumptions to be violated, standard remedies such as Generalized Least Squares or some form of instrumental variables technique can be applied.¹

If the sample is small, however, the problem is not so easily brushed off. In the case of annual net migration equations, sample sizes larger than thirty or forty are not often used. When they are, the problem of modeling structural change over long time periods enters the picture. In Alaska, net migration equations based on as few as fourteen annual observations are regularly used for forecasting and for policy simulation.² Given

1. This is discussed in most econometric textbooks. See, for example, Johnston (4) or Malinvaud (7).

2. See Kresge and Siever (5), Reaume (9) and Siever (10).

such small samples, even relatively accurate estimates of population for inter-censal years can lead to major errors of measurement in net migration and highly misleading and unreliable econometric migration equations.¹

ANOTHER ECONOMETRIC PROBLEM

The practice of using net migration as a dependent variable brings with it a problem other than measurement error. As Vanderkamp (12) has pointed out, the time period covered by the regression can have a significant influence on the estimates of the coefficients if the proportion of return migrants in the total varies over time. Vanderkamp emphasized simultaneity bias as the source of this problem. In brief, his point was that the existence of return migrants (people who had left the region and now are returning) can produce a net migration equation with variable coefficients.²

At this writing, the question of the proper choice of dependent variable in migration models is still being debated. At the very least, however, there is good reason to doubt the accuracy of coefficients estimated from a regression of net migration on its specified determinants.³

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1. It is well known that errors-in-variables can be particularly troublesome in small sample situations where the sample weight on aberrant observations is relatively large.
 2. This problem can be solved in principle by modeling the coefficient structure or, if the variability is random, by using one of the methods of estimation discussed in Raj (8). To my knowledge, such steps have never been taken with respect to the net migration equation in regional models.
 3. On this, see also Kriesberg E.M. and Vining D.R., Jr. (6).

CONCLUSION

The central role played by the net migration equation in a regional econometric model and the unfortunate lack of time series data on gross migration flows, combine to dramatically lower the confidence one can have in individual simulations and forecasts.

Some, possibly most, regional models implicitly model migration by subsuming net migration and natural increase into a single regression of population on its determinants. While I have not explicitly considered that case here, it is clear that solving out for net migration in the population identity, [1], amounts to the same thing. The analysis here applies, therefore, to all regional models with endogenous population equations.

The cost of obtaining direct annual estimates of inter-regional gross migration flows would appear to be prohibitive. The Social Security Continuous Work History Sample (11) covers only job holders. A careful mingling of cross section results and time series regressions may prove to be the most cost effective solution to the problem. It may be possible to impose reasonable constraints on regional time series migration models after careful analysis of census and longitudinal data.

Whatever steps are taken it is clear that before policy prescriptions are offered, a range of sensitivity tests are called for. If simulation results are particularly sensitive to what can reasonably be judged to be minor changes in key parameters, then policy prescriptions should be