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ESTIMATING THE ECONOMIC IMPACTS OF GEOTHERMAL RESOURCE DEVELOPMENT

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Abstract—Development of geothermal plants, as all other energy facilities, may have significant economic impacts on local and regional economies. Often the magnitudes of these impacts will be of great interest to both environmental and economic development planners. Because of their availability and relative ease of use, input–output models are often used to estimate selected economic impacts arising from resource development. This paper demonstrates the methodology for two case studies of potential development of geothermal facilities of 100 MW average capacity in the United States Pacific Northwest, in order to highlight the effects of different local economic structures. Results indicate that geothermal development can lead to significant economic impacts at the local level.

Key words: geothermal plants, economic impact, economic modeling.

INTRODUCTION

Development of geothermal facilities may have numerous socio-economic impacts on local areas. Besides the potential for environmental impacts, such as increased air and water pollution, development may also affect local and regional economies. In economically distressed areas, development may have beneficial impacts by providing jobs to area inhabitants who might otherwise be unemployed or underemployed, and by providing tax revenues for improvements in area infrastructure. Some larger projects, however, may have "boom town" effects resulting in a rapid increase in the demand for locally provided services such as housing, utilities, and schools. Once those projects are completed, demand for these services can fall rapidly, placing further strain on local economies. In addition to determining the cost-effectiveness of geothermal plant development, developers and planners may wish to have estimates of the overall economic impacts of plant development. While the economic impacts associated with a single plant may be quite small in comparison with the economy of a region, those impacts may nevertheless provide significant economic contributions.

The purpose of this paper is to demonstrate an input–output (I/O) modeling framework for calculating certain economic impacts associated with geothermal plant development, although the framework is equally applicable to other types of energy resources. To accomplish this demonstration, the economic impacts arising from development of a hypothetical geothermal facility with an *average* capacity of 100 megawatts (MW) are estimated for two alternative sites in the U.S. Pacific Northwest: the first in northern Washington State, near Mt Baker, and the second in southern Washington State, near Mt Adams. The specific input–output model used is a non-survey based model developed by the United States Forest Service (USFS), called Micro-IMPLAN.

The justification for use of an I/O approach to modeling economic impacts in general, and Micro-IMPLAN in particular, is presented in the following section. The section on **Estimates of Local Costs and Revenues** develops the direct final demand change estimates necessary to use the I/O model. Modeling of the overall economic impacts from plant development through operation, and the results of the analysis are presented in **Modeling Overall Economic Impacts**. The final section provides general conclusions and limitations associated with modeling economic impacts of geothermal and other energy resources.

INPUT–OUTPUT MODELING

Input–output analysis is the name given to an analytical framework developed by Professor Vassily Leontief in the late 1930s. In its most basic form, an input–output model consists of a system of linear equations, each one of which describes the distribution of the product of an industry throughout the economy (Miller and Blair, 1985). The basic Leontief model is usually constructed from observed economic data for a specific country or region. The primary focus is industries which both produce goods and services (outputs) while simultaneously consuming goods and services from other industries (inputs). This basic information from which an (I/O) model is developed can be found in the inter-industry transactions table. From the information in the transactions table, economic relationships about the linkages between industries can be developed. In addition, input–output models incorporate the additional economic interactions associated with consumers, government spending, exports, and imports into an economy. The I/O framework allows the determination of "multipliers" that translate direct impacts into overall impacts (Miller and Blair, 1985).

There are three types of economic impacts that are commonly discussed: direct, indirect, and induced impacts.

Direct impacts. The initial purchases made within an economy as a result of the activities of a project are termed the direct impacts. Thus, the direct impacts of geothermal development will include all of the expenditures associated with construction and maintenance of the plants. Examples of direct purchases include concrete, steam pipe, sheet metal, electric turbines, and wire during the construction phase, and special lubricants during the operational phase.

Indirect impacts. The production and sale of goods and services that result in direct impacts require inputs from other business sectors. For example, to produce the electric turbines used by the generating plants requires the purchase of many different inputs (e.g. steel, wire, sheet metal, etc.) from other industries. This second level of activity is the source of indirect impacts, so called because purchase of the direct impacts will have an indirect impact on demand for goods and services produced by these other industries.

Induced impacts. Industries that experience both direct and indirect impacts will often change their employment levels to meet the new level of demand. These employment changes induce changes in income that are spent in the region to purchase consumer goods and services. This income effect is the source of induced impacts. For example, some portion of the wages paid to local construction workers will be spent on food, housing, and other consumer goods within the counties themselves. Local spending of this additional income is the basis of an induced effect. Induced impacts lead to further rounds of indirect and induced impacts, as the increased demand for goods and services purchased by workers leads to further increases in output in other industries.

The *total* economic impact is found by summing all three levels of impact for each sector of the local economy. The larger the magnitude of local purchases, the larger will be the total economic impact. The amount spent outside the region does not affect the local economy. These expenditures outside the local economy are called *leakages*. With each round of spending, some portion usually leaks outside the local economy. Leakages of successive rounds of spending eventually reduce further rounds of respending to zero. The larger the region, the more slowly leakages are likely to occur and, therefore, the larger will be the total economic impacts.

As a result of the rounds of indirect and induced impacts, the initial direct impacts will be multiplied, resulting in a total impact larger than the initial direct impact. This so-called *multiplier* shows the relationship of direct impacts to total impacts. In a general sense, the multiplier can be estimated as the ratio of total impacts to direct impacts. This ratio holds true whether the impacts are measured in dollars from changes in income, or whether the impacts are measured in other units such as jobs created. If, for example, the direct impact is U.S.$1000 and the total measured impact is U.S.$2000, then the multiplier equals U.S.$2000/1000 = 2.

The main strength of an I/O model is its level of detail, which allows for estimates of industry specific impacts. This level of detail will be different for each model, depending on the resources available to construct the model and the requirements of policy makers. This level of detail is generally far beyond that which can be provided by econometric models of an economy, or by simple economic base studies.

One potential weakness of I/O analysis is the static nature of the model. I/O analysis assumes that the inter-industry sales from industry I to industry J depend entirely on the output in sector J and that the ratio of these sales is fixed. In other words, for industry J to produce its output, it requires fixed (and non-changing) amounts of inputs from all of the other industries. There have also been extensions of I/O models that incorporate a simulation module that adjusts the basic sales ratios, so that the model can be used as a robust dynamic simulation model (Conway, 1990). Despite this static nature, however, the I/O model can be used as a baseline for projections of future economic activity as long as the underlying production relationships within an economy are not expected to change significantly over the production period (Chase *et al.*, 1993).

While I/O models can provide a great level of industry detail, that detail requires a great deal of data collection. The Washington State Input–Output Model (Chase *et al.*, 1993), which was developed using surveys of state industries, cost several hundred thousand dollars and took several years to produce, yet breaks the economy into only 62 distinct industry sectors. As a result, non-survey models such as Micro-IMPLAN have been developed. Non-survey models are relatively inexpensive to develop and are considered to be reasonably accurate (Bruckner *et al.*, 1987). Micro-IMPLAN includes a data base of information from secondary sources (e.g. County Business Patterns, Census of Manufacturers, etc.) and software that allows regional models to be constructed down to the individual county level. While such models are far less costly to develop, they can pay a price in accuracy, since the underlying data may not correspond to actual conditions within the economy of a given region. A viable solution to this accuracy problem, which is used in the analysis to be described below, was the updating of the Micro-IMPLAN model with actual employment and earnings data in the two counties studied. In this way, greater accuracy of the estimates, even at a local county level where economic leakages may be significant, can be achieved.

ESTIMATION OF LOCAL COSTS AND REVENUES

Estimating local economic impacts due to geothermal development will depend on characteristics of the plant site, size of plant constructed, labor-force, and materials availability. For this analysis, two alternative sites in Washington state were evaluated: in southern Washington State, near Mt Adams, and in the northern part of the state, near Mt Baker. The site locations are shown in Fig. 1. For each site, we determine the overall economic impacts on the local counties, in this case Skamania and Whatcom Counties, respectively, from development of a hypothetical 100 MW geothermal facility. These impacts are evaluated based on the direct

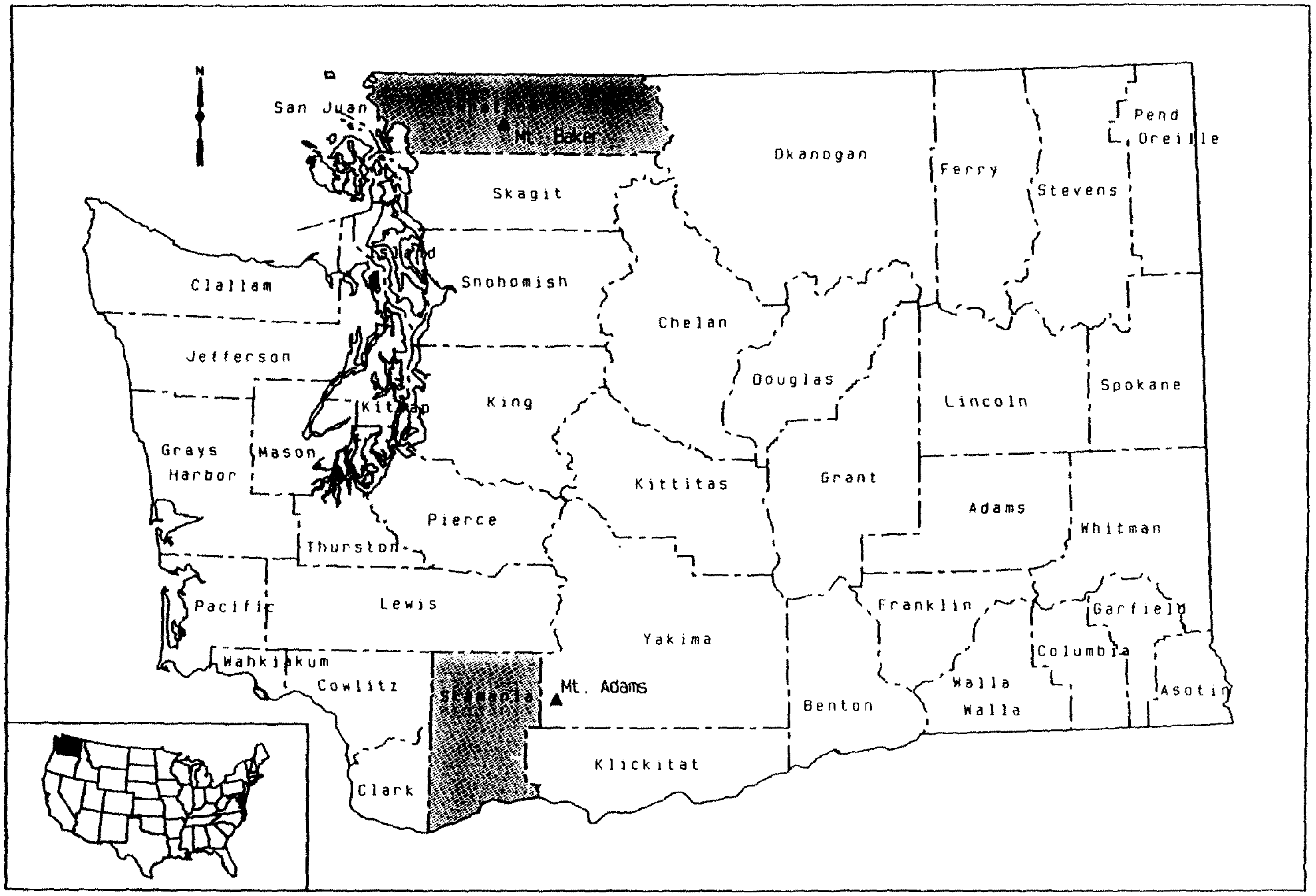

Fig. 1. Location of Skamania and Whatcom Counties, Washington State.

development, construction, and operations and maintenance costs of the facilities; the prevailing economic conditions in the counties; and the estimated revenues that would accrue to the counties from royalty payments and tax collections.

The accuracy of the ultimate estimates of total economic impacts will depend critically on the development of direct impact estimates. Thus, it is important to determine as accurately as possible the likely construction, and operations and maintenance costs associated with a facility. This will also require careful consideration of the direct employment impacts associated with the facility, since these estimates will determine the overall economic impacts determined by the derived multipliers from the model. (However, the fixed coefficient nature of I/O models allows sensitivity analyses of the estimates of economic impacts to be calculated in a straightforward manner.)

In this section, estimates for plant capital costs, labor requirements, and local work force requirements are developed. These estimates are then used in the Micro-IMPLAN model to determine the total economic impacts resulting from property tax and royalty payments, and wages respent by local workers.

Construction costs

The cost of constructing a geothermal plant will vary widely depending on the location and size. Costs will depend on the accessibility of the site, depth of drilling required for wells, the number of wells required for a given plant capacity, and the prevailing wages of engineering and construction personnel. Overall estimates of plant construction costs for both sites ranged from U.S.$2700 to U.S.$3100 per net kW (McClain, 1990; Yueh, 1990), on the assumption that the plant would consist of four 25 MW modular units to achieve the overall 100 MW goal. These cost estimates are consistent with prior studies that have shown a range of costs from U.S.$1550 to U.S.$3778 per net kilowatt for recently built plants (Bloomquist *et al.*, 1989; OESI *et al.*, 1991).

Estimated construction time is about 3 years, including site development and generating plant construction (Yueh, 1990). Typically, the costs of development in a more mountainous site, such as those under consideration, would be expected to cost more than desert sites such as those previously developed in Nevada and southern California.

The costs for more remote plants, or those which are more efficient, will likely fall in the higher end of the range. Due to the relative remoteness of the site considered in this study, as well as the existing uncertainty about the quality of the steam field, it was assumed that well field development costs would be about U.S.$1100/kW, while actual plant construction costs would be about $1700/kW (McClain, 1990). Pollution control costs for geothermal plants should be similar to other types of power plants.

Construction costs would also include engineering, administrative, and environmental costs. Engineering costs would include the costs of conceptual and contract design, as well as field engineering. Administrative costs would incorporate the costs of project management, legal support, and securing of project financing. Environmental costs would include costs associated with baseline studies, environmental impact statements, siting, permits, and compliance costs. Lastly, construction costs should also incorporate the costs of building a transmission line to connect the plant to the regional grid. For the purposes of this study, a 10 mile transmission line was chosen as representative. Total costs for such a line were estimated to be about U.S.$2.6 million, of which about U.S.$1.1 million was for materials (wood poles, insulators, conductor, and miscellaneous construction materials) and U.S.$1.5 million for labor (Hubsky, 1990).

Work force estimates

Work force estimates can be determined based on the separate development steps of the geothermal plant and well field, as well as estimates of operation and maintenance requirements. In this section, the work force requirements for the development and operation phases are first reviewed, and a range of estimates is developed from which to base total economic impacts on a low and high basis.

Development of geothermal energy usually begins with passive exploration, including geologic field surveys, mapping, and geochemical and geophysical analysis to reduce the size of the prospect area. This is followed by exploratory drilling to determine the location, quantity, and quality of underground steam or hot water.

Generally, geothermal development companies maintain a small local office to manage local operations. Staff size in local offices depends on the amount of leased land, the extent of development activities, and the level of subcontracted work.

Developers also maintain both office and field staff. Office staff may include clerical workers, administrative managers, professionals such as geologists and other earth scientists, land agents, and workers involved in securing necessary environmental permits. Field staff will include drilling supervisors, field engineers, and geologists. Some staff may perform both office and field duties, as well as manage a number of subcontractor activities, such as preparation of well pads and access roads, and exploration and well drilling. The majority of these workers will probably be located outside the local county.

Local office employees tend to be long-term residents of the local area (Matthews, 1983). This makes sense, given the relatively long time between resource leasing and initial electricity production. In addition, many of the skills required for local office work will be available in the local work force, since these jobs require much less specialization than field work-related positions.

Steam field development

Given the current uncertainty of Pacific Northwest steam resource characteristics, this report uses an estimate of 20–30 wells to provide power for a 100 MW development. For the purposes of this study, a total of 25 wells is assumed. Because well performance tends to decline over time, an additional 20–30 wells would be drilled to maintain the necessary steam supply over the assumed 30 year lifetime of the plant.

Development of each steam well normally takes between 30 and 90 days, with drilling crews working around the clock. The actual time will depend on the depth required and the difficulty of working at the site. For the purposes of this study, a 60 day drilling period per well is assumed. A typical drill rig is operated by four crews of 5–6 persons during each 24 hour period (Matthews, 1983). Overseeing each drill rig is a drilling superintendent employed by the geothermal developer. With four drilling crews and the drilling superintendent, the work force associated with each drilling rig is assumed to be between 20 and 25 persons. Since two drilling rigs are assumed to operate at the site, a total of 40–50 drilling-related workers is assumed.

In addition, periodically throughout the lifetime of the facility, the steam wells supplying the generating plant require re-drilling to clear obstructions or to regain full steam flow potential. Occasionally, new wells must be drilled if an existing supply well cannot maintain required output.

For the purposes of this analysis, therefore, it is assumed that, on average, between 40 and 50 drilling-related workers will be employed for the project through the end of 1998, when the last unit is assumed to come on-line.

Steam gathering systems

The number of workers constructing steam gathering systems for each power plant varies with the design of the routing and interconnection plan for the pipelines. The work force may be as few as 4 or as many as 50, and the construction period may last anywhere from several weeks to several months. The work force involved in the construction of the seam gathering system is less likely to be composed of long-term residents of the area, since the duration of the work is short and months may elapse between jobs (Matthews, 1983). Peak steam field plant and gathering system workers for the 27 MW West Ford plant completed in 1988 were estimated at 35 (Nolte and Associates, 1987). For this study, it is assumed that construction of the steam gathering system will not commence until 1995, and will employ between 10 and 40 workers for 6 months of each year, for an annual average of between 5 and 20 workers.

Plant construction

Actual construction time for 55–110 MW geothermal plants in The Geysers has been about 28–30 months (Matthews, 1983). However, site clearance and preparation or other construction activities involving earth movement cannot occur during the rainy season (generally November through March). Thus, the actual construction period could extend up to 36 months or more, depending on realized weather conditions. Newer plants at The Geysers have shortened the construction period considerably. The Bear Canyon, plant, for example, was built in 20 months, instead of the projected 24 months (Phair, 1989). The West Ford plant came on-line only 8 months after groundbreaking (Urbank, 1989). Other plants in California, Nevada, and Utah, had construction periods of less than 2 years due to significant fabrication of similar or standard "off-the-shelf" units.

The snow season in the Mt Adams and Mt Baker areas are analogous to the rainy season in The Geysers area. For the purposes of this report, a 36 month construction period for the first 25 MW module is therefore assumed. Construction periods for the subsequent modules would likely take less time, perhaps only 24 months. These construction periods are assumed to overlap such that one module comes on-line per year beginning in 1996.

Many of the work tasks throughout the construction period are of relatively short duration, ranging between several weeks and months. Some of the craft skills required are specialized, and the number of workers in the entire state, let alone a small county like Skamania, who are qualified to perform the work is likely to be small. However, a worker with a wide range of abilities and a high degree of skill in those various areas could maintain relatively continuous employment on a progression of geothermal plants.

Information supplied to the California Energy Commission (CEC) by geothermal developers indicated that the maximum number of construction workers for a 110 MW plant would range between 75 and 205 workers (Matthews, 1983; CEC, 1985). This is equivalent to 0.68 to 1.86 workers per MW. The maximum number of workers at the 27 MW West Ford Flat plant in California was estimated to be only 40 (Nolte and Associates, 1987), equivalent to 1.48 workers per MW. Unfortunately, a direct correlation between number of workers per MW and size of the plant cannot be made, due to economies of scale. There may be a wide disparity in total workers required for construction due to different characteristics of individual plants. However, modular designed plants will, in general, require fewer construction workers than strictly site-designed facilities.

During power plant construction, the peak force is active on site after the foundations and pads are set and the work begins on installation of the generating units. The majority of the work force during this period will be composed of electricians and pipe fitters who are usually dispatched through union hiring halls. The number of electrical workers during the peak period usually ranges between 5 and 35, but has been as high as 55 for a single project (Matthews, 1983). The number of pipe fitters active during the peak period may range between 6 and 50, and has been as high as 110 for a single project. The peak construction period generally lasts for 1 year, with the largest number of workers needed for 6 to 8 months (Matthews, 1983).

For the purposes of this study, it is assumed that construction will require between 15 and 70 workers, commencing in 1994 and continuing until the end of 1998. Thus, combining the steam field development, gathering, and plant construction tasks, the total number of construction-related workers is assumed to be between 60 and 140 during the peak construction period of 1995–1998.

Steam field maintenance

Once a geothermal power plant comes on line, it will most likely operate at full capacity unless there are technical or mechanical problems. Alternatively, plants may be operated to follow the daily electric loads placed on a utility. The size of the work force necessary to maintain adequate steam supplies for each well field and power plant is similar to that required during the steam field development phase. For example, the California Division of Oil and Gas (CDOG) estimated that the number of drilling rigs required over the lifetime of generating plants that are part of The Geysers development will remain relatively constant (Matthews, 1983).

For the purposes of this study, it is assumed that one drilling rig would be required to redrill wells. However, this drilling rig would only be required about 3 months of the year. Thus, while the drilling rig would employ 25 persons when operating, over the year there would be only about 6 full time equivalents (FTEs).

It is assumed that one drilling rig would be operated on a relatively continuous basis, employing 5–6 persons. In addition, it is assumed that 2 office staff would be required, for a total of 7–8 personnel devoted to steam field maintenance.

Power plant operation and maintenance

In the final months of the construction phase for each unit, personnel from the plant developer–operator begin testing equipment and systems in the new generating facility. These personnel may include power plant operators, plant engineers and electricians, instrument repairmen, and maintenance workers. Once the power plant comes on line, the permanent operation and maintenance work force maintains routine operations. Periodically, this work force may be supplemented by additional outside workers for facility overhaul and maintenance activities.

The numbers of workers involved in the operation and maintenance of the generating plant and related facilities varies with the operator. Pacific Gas and Electric's (PG&E) operation and maintenance work force in 1981 for 17 Geysers plants, for example, was about 130. Since the units are relatively close to one another, PG&E operates various units by remote control from a single point. Periodic checking of daily operations is performed by roving crews (Matthews, 1983).

In the last decade, other developers have begun operating plants in The Geysers. Some of these developers have estimated that they will need an initial operation and maintenance work force of 10–20 workers per plant. Few workers would be required to operate subsequent plants, since the basic work force would already be involved in their initial operation. This workforce economy of scale holds true at the recently built Bear Canyon and West Ford Flat plants built by Calpine Corporation. Approximately 12 plant staff operate and maintain these plants (49 MW total), for an average of 0.24 employees per MW (Sifford, 1991). There are an additional 8 field staff at this facility, raising total employment to about 0.41 employees per MW. The recently completed Coso complex uses an average of 90 employees in plant operations and 170 people total (Sifford, 1991) for the entire 240 MW plant complex. This translates to about 0.38 operations workers per MW and 0.73 total employees per MW. Using this range of employment estimates, a 25 MW facility will require between 10 and 20 workers. For the purposes of this study, it is assumed that this number of workers will be required whether only one or all four generating units are on-line, owing to the modular nature of the development. This range is expected to remain constant over the lifetime of the plants.

Local work force assumptions

Using the previous assumptions, geothermal plant development will be assumed to take place over a period of 6 years, beginning in 1993. By the end of 1998, four 25 MW units will be assumed to be operational. Drilling the well field will commence in 1993, with construction of the first generating unit beginning 1 year later. The first unit will be assumed to be on-line at the beginning of 1996, after a 36 month construction period. Subsequent units will come on-line in one year intervals until the full 100 MW complex is completed. Operation and maintenance employment will begin in the latter half of 1995, as workers begin training to operate the first completed unit.

Local employment impacts are important to consider, since not all of the workers required to build and maintain the plants will live within the counties. It is likely that many workers will commute from neighboring counties and metropolitan areas. The fraction of workers commuting or choosing to become long-term residents of the counties will depend on the work tasks involved, and the existing economic structure of the counties.

Because Whatcom County has a far larger economic base than Skamania County (WSED, 1989, 1990a,b), local work force assumptions for the two counties are different. In Skamania County, for example, it is assumed that for steam field gathering, 60% of the work force will be local; for well drilling, 20% of the work force will be local; and for actual plant construction, 75% of the work force will be local. In Whatcom County, on the other hand, it is assumed that for steam field gathering, 80% of the work force will be local; for well drilling, 40% of the work force will be local; while for actual plant construction, the same 75% of the work force will be local. These assumptions can be easily adjusted so as to develop a range of overall employment impacts.

The differences in the local employment percentages for the different job classifications stem from the degree of specialized training required to perform the tasks. It is unlikely, for example, that many local workers will have previous well drilling experience. On the other hand, a relatively large percentage of plant construction workers are assumed to arise from the local work force, since the skills required to construct a geothermal facility are similar to other construction projects. Because Whatcom County has a larger economic base than Skamania County, it is more likely that workers with the necessary job skills can be found locally.

For operations and maintenance (O&M), it is assumed that 50% of both the plant and well field O&M workers will be local for Skamania County, and 75% local in Whatcom County. These assumptions are meant to be conservative. The actual fraction of workers choosing to become residents of a county would depend on local economic conditions, the strength of the overall economy, whether similar development was taking place in nearby regions, and other factors.

Using the estimates of the local employment fractions, the total number of additional direct local workers can be estimates. These estimates are summarized in Figs 2 and 3.

Wage rate estimates

The additional local workers hired to construct, operate, and maintain the facilities will also spend some fraction of their wages in the local economies. This spending will lead to further induced employment and income impacts. Thus, it is important to estimate wage rates for the different classes of workers that will be hired.

Using data from cost estimation handbooks (Cleveland *et al.*, 1990; Kiley and Moselle, 1990), covered employee wage rate averages (WESD, 1990b), and published current plant operator

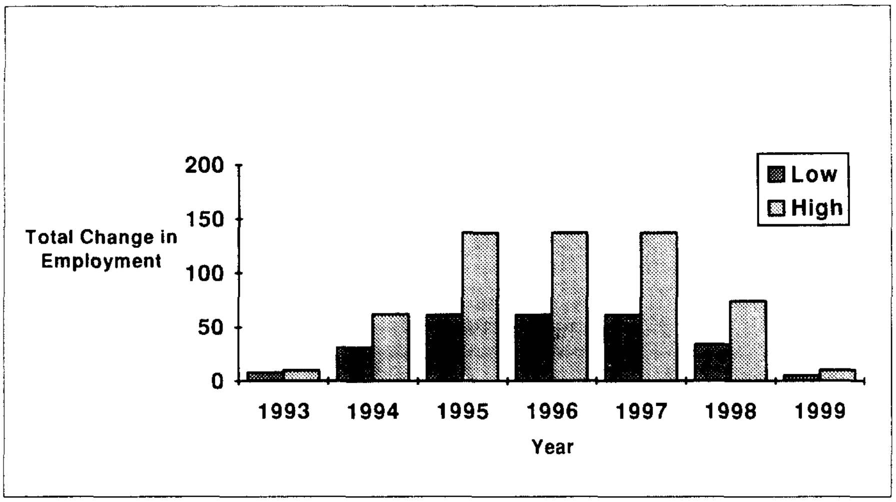

Fig. 2. Range of annual increases in direct employment: Skamania County.

wages at federal facilities (BPA, 1988), average annual wages for well field, plant construction, and plant and well field O&M were determined for the 1993–2000 period. Overall average well field construction wages were estimated at U.S.$34,000 per job in 1991, while average plant construction wages were estimated to be U.S.$40,000 per job. Plant O&M wages were estimated to be U.S.$35,000 per job in 1991, while steam field O&M wages were estimated to be U.S.$40,000 per job. It was assumed that wages would remain constant in real (after-inflation) terms for the duration of the study period. Using the assumed local employment percentages, the range of local employment estimates discussed above, and the 1991 wage assumptions, the direct local wage impacts for both counties can be determined. These are shown in Figs 4 and 5.

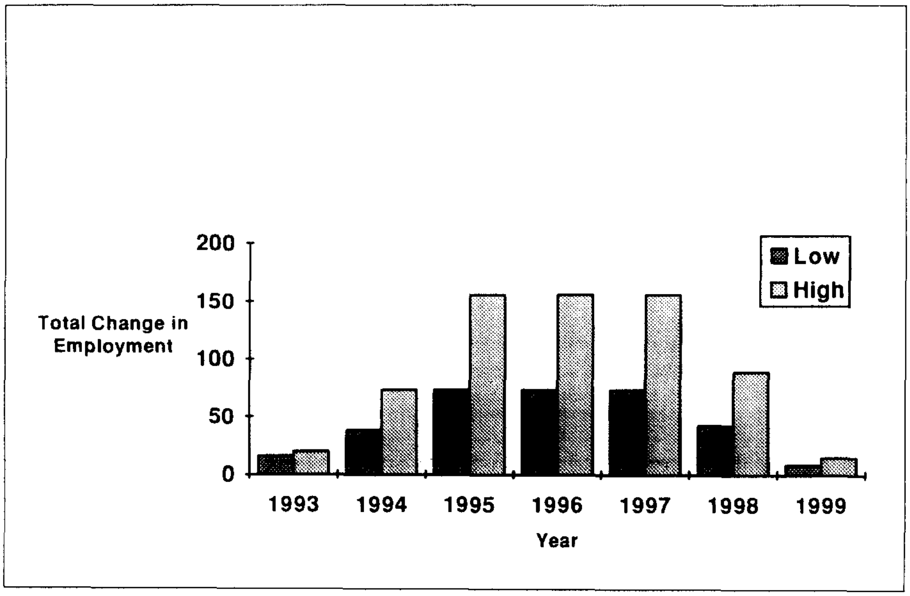

Fig. 3. Range of annual increase in direct employment: Whatcom County.

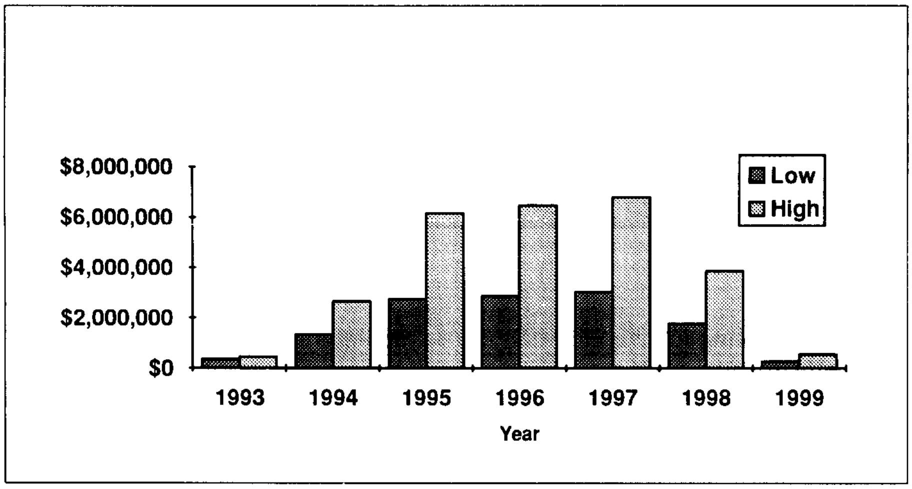

Fig. 4. Range of direct wage impacts: Skamania County.

Local wage impacts would rise rapidly after 1993 and peak in 1998. Once plant construction was completed, local wage impacts would drop down to a long-term level of about U.S.$550,000 in Skamania County, and U.S.$820,000 in Whatcom County. These wage rates would presumably increase with the rate of inflation.

Operation assumptions

The operating efficiency of the generating plant will have an important impact on total royalty payments collected and distributed to the counties. Consistent with operating data from existing plants, the actual output from each 25 MW unit is assumed to be 90% of capacity. Thus, each unit will produce about 200,000 MWh of electricity annually.

Total royalty payments to the federal government will be determined by the efficiency with which the generators utilize steam. Steam cost values are estimated from two-party contractual data. A power plant steam utilization rate of 14 lbs/kWh, consistent with one of the most

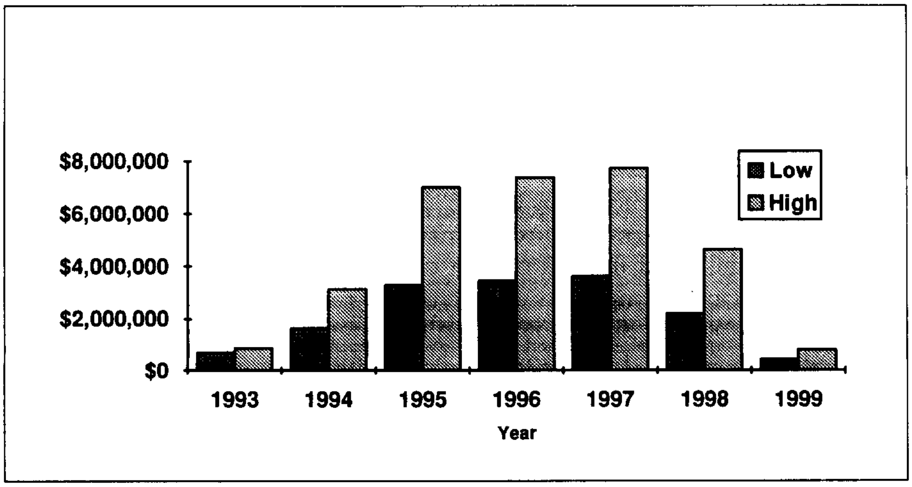

Fig. 5. Range of direct wage impacts: Whatcom County.

Table 1. State and local projected revenues per project (1991 U.S.$)

Source	Skamania County	Whatcom County
Federal royalties	U.S.$335,500	U.S.$335,500
Property tax collections	U.S.$3,100,000	U.S.$3,750,000
Total	U.S.$3,435,500	U.S.$4,085,500
Existing timber receipts*	U.S.$8,613,236	U.S.$1,753,400
Existing property tax collections*	U.S.$2,429,367	U.S.$58,716,523

*Received in 1990.

efficient plants operating in The Geysers, is also assumed in order to provide a conservative estimate of total royalty payments. Lastly, a 1991 steam value of U.S.$1.52/1000 lbs, also consistent with payments made by generators to steam suppliers in California, is assumed (Bloomquist *et al.*, 1989). The net result is a value of steam of about U.S.$0.02/kWh. Less efficient plants may be built for slightly lower capital costs, but will experience higher operations and maintenance, and royalty costs.

Under the Geothermal Steam Act of 1970, royalty payments to the federal government are equal to 10% of the steam value. Of the total collected by the federal government, 50% is returned to the state where development occurs. Existing Washington State law then provides that 40% of the royalties returned to the state are distributed to the specific county of origin, as prescribed in Washington State law. Based on these assumptions, total steam royalties returning to both Skamania and Whatcom Counties would equal U.S.$84,000 (1991$) for each 25 MW unit. Thus, royalty payments to the county are assumed to increase to about U.S.$335,500 beginning in 1999, when all four 25 MW units are completed.

Lastly, after the plant is operating, it will be required to pay property taxes to the county. In 1991, property tax rates near the Mt Adams area were U.S.$11.08/1000 of assessed value. In the Mt Baker area property taxes were U.S.$13.39/1000 of assessed value. Using the book value construction cost estimate as a basis for calculating property taxes, the complete 100 MW facility will have an assessed value of U.S.$280 million 1991 dollars. This translates to an annual property tax bill of about U.S.$3.1 million (1991 U.S.$) in Skamania County and U.S.$3.7 million (1991 U.S.$) in Whatcom County. Total state and county revenues from the fully operational plants are summarized in Table 1.

MODELING OVERALL ECONOMIC IMPACTS

Impact analysis is commonly used in regional policy making to predict the economic changes that may result from a project. These changes, or impacts, are realized as increases or decreases in the magnitudes of selected economic components, such as employment, industrial output, income, or value added. To estimate the overall economic impacts from geothermal development, it is necessary to first assess the direct impacts that will occur within each county due to local purchases of inputs used in construction of the geothermal facility. A review of the industrial structure and major employers of each county reveals that Skamania County has few major employers that would be directly impacted from purchases of goods and services for the project (WESD, 1989, 1990b). For example, none of the pipe needed for the steam field is manufactured within the county, nor are there sheet metal or concrete industries within the county. Only one sand and gravel dealer has been identified within the county, and the size of that firm is quite small.

In Whatcom County, on the other hand, a similar review indicates several employers that would be directly affected by purchases of goods and services for the project, including concrete products, sand and gravel producers, and sheet metal firms (WESD, 1989, 1990a). Many of the major specialized components, however, would still be purchased outside the county.

Because it was not possible to obtain the precise "recipe" for a geothermal plant, several conservative assumptions were made. First, for Skamania County, it was assumed that none of the direct industry purchases will be made locally, with the exception of locally-hired construction and operation and maintenance workers. As a result, there were assumed to be no *indirect* impacts from inter-industry purchases. The only economic impacts that would occur were assumed to result from the wage payments of the additional local employees being spent and respent within the economy. Thus, in Skamania County, economic impacts associated with plant construction and operation were focused solely on the *induced* impacts from increased income within the county, whether in the form of wage payments or revenues accruing to the county government.

Due to the larger size of the Whatcom County economy, it was assumed that 20% of the direct industry purchases (with the exception of the aforementioned assumptions about locally-hired construction and operation and maintenance workers) would be made locally. It was also assumed that these products would constitute a total of 10% of the plant costs of a geothermal facility. Thus, since the assumed plant cost is U.S.$1700/kW, total expenditures for these products would be U.S.$170/kW. If 20% of these expenditures are purchased from local firms, this will equal U.S.$34/kW, or a total of U.S.$3.4 million (1990 U.S.$). Thus, in addition to the induced impacts from wage payments to workers and revenues accruing to the county government, there would also be direct, indirect, and induced impacts due to inter-industry purchases.

Lastly, for both counties, there will be two separate impacts during the operations phase: impacts due to wage payments being spent and respent within the local economy; and impacts from expenditures of royalty and property tax payments to the counties. As Table 1 shows, predicted revenues accruing to Skamania County from geothermal plant development, over U.S.$3.4 million annually, would exceed total existing property tax payments of about U.S.$2.4 million annually. Property taxes and royalties would be exceeded only by timber receipts from logging of federal lands. That revenue source, however, is expected to decrease as logging restrictions—arising from environmental concerns—increase. Owing to the much larger economic base in Whatcom County, geothermal plant revenues would only increase existing county revenues by about 5%. While this is relatively small, it is quite large relative to the employment impacts of the plant.

Data from IMPLAN was used to develop expenditure patterns and local expenditure fractions for Whatcom County, which were then used to analyze the overall economic impacts from plant development. It was assumed that some portion of local wages paid to both construction and O&M workers would be spent within the county. Wage income was reduced by 25% to account for the effects of federal income and social security taxes. The remainder of wage income was then shared out on an industry basis to local industries. Based on the IMPLAN database, about one-third of disposable wages would be spent locally within the county. A similar expenditure pattern was developed for state and local government expenditures resulting from the royalty payments and additional property tax collections. It was also assumed that these additional revenues would be used to purchase additional goods and services for the county.

To better estimate county level impacts, unsuppressed 1989 covered employment and wage data were used to update the IMPLAN database. (Covered employment and wages refers to employees who are covered under Washington State unemployment insurance program.) The benefit of using this data is that it provides more accurate estimates of employment and income in each county than is otherwise possible using the non-survey approach. These data were

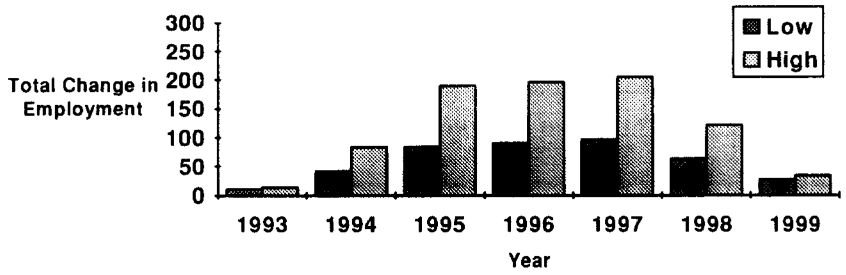

Fig. 6. Annual increase in direct, indirect, and induced employment: Skamania County.

combined with data on total earnings and employment from the Bureau of Economic Analysis (BEA) to develop a more accurate database for the IMPLAN model. The BEA data include sole proprietors and other non-covered employment and establishments. Based on the IMPLAN database, it was determined that about one-third of disposable wages would be spent locally within Skamania County, while about one-half of disposable wages would be spent within Whatcom County.

Total economic impacts for both counties are summarized in Figs 6–9, which show the range of income and employment impacts from 1993, when development would be assumed to begin, to the end of 1999, when the facilities would be fully operational. Results of the analysis show that employment and income impacts in both counties are relatively modest, though not insignificant. In the long-run, the majority of the employment and income impacts are predicted

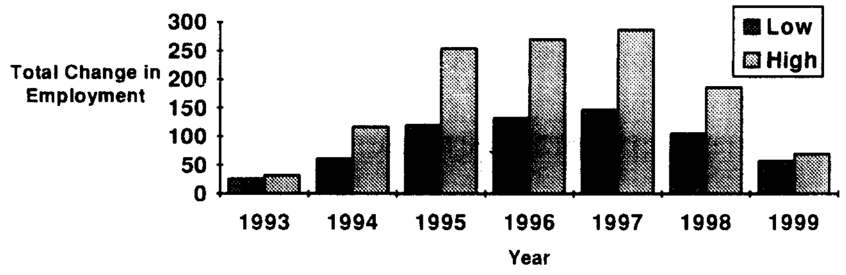

Fig. 7. Annual increase in direct, indirect, and induced employment: Whatcom County.

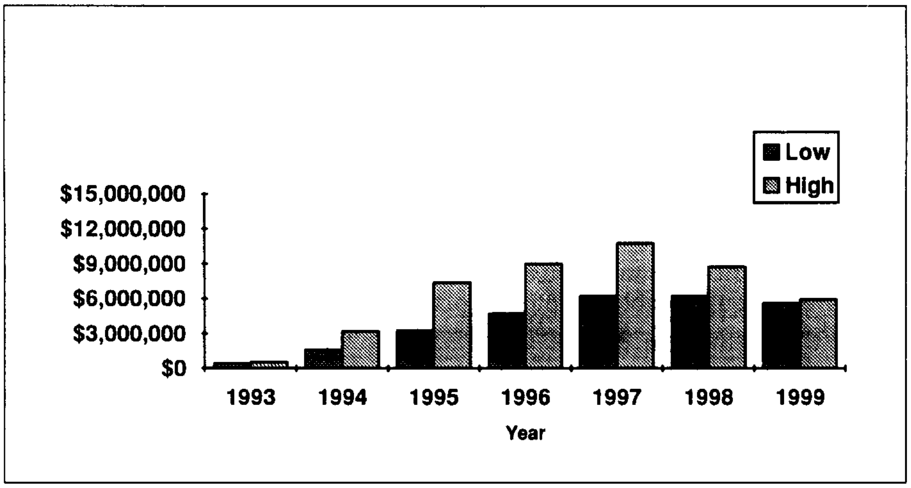

Fig. 8. Annual increase in direct, indirect, and induced income: Skamania County.

to arise due to expenditures of royalty and property tax income accruing to the counties. Those impacts far overshadow impacts arising from operation and maintenance at the plants.

One reason that the inter-industry impacts estimated are small in both counties is the lack of geothermal industry structure within the counties. If, however, major geothermal resource development were to occur over time, it is more likely that this infrastructure would develop. In that case, more of the materials and employees for development would likely come from local sources, resulting in larger economic impacts.

CONCLUSIONS

This paper has presented estimates of the economic impacts of geothermal development in Skamania and Whatcom Counties. However, the results should not be confused with a true benefit–cost analysis of geothermal development. Potentially adverse environmental impacts

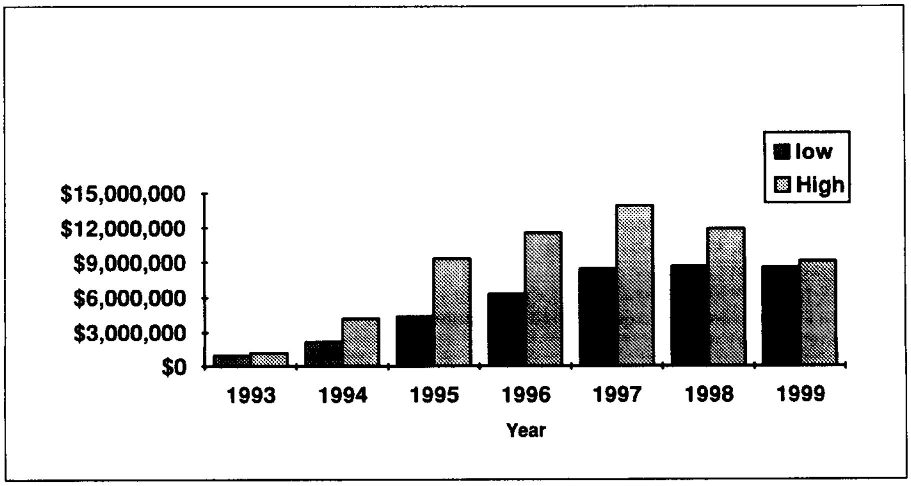

Fig. 9. Annual increase in direct, indirect, and induced income: Whatcom County.

that might accompany development, for example, were not estimated. Nor was an attempt made to estimate the potential for "adverse" economic impacts due to development, such as reductions in tourism expenditures as a result of plant development, or the costs associated with "boom-town" impacts on the local infrastructure. Development might be accompanied by a corresponding need to increase public services in the county (e.g. schools, highways, medical services, etc.). While these would register as economic impacts, it is not clear whether they would be counted as benefits or costs.

No attempt was made to formally assess the value of plant development in comparison with other types of electric resources, whether efficiency or generation resources, nor was an attempt made to compare the quantifiable benefits of plant development with the quantifiable costs. Such an analysis would be quite complex and time consuming, and is beyond the scope of this paper.

Lastly, economic impacts estimated may differ significantly from actual impacts, depending on the actual nature of the plant constructed, the presence of similar development in other areas of the state or region, and the health of the county economies. The input–output methodology used in this study also assumes a static economy. Estimating economic impacts over time would ideally use a dynamic specification that preserved the detail available with the input–output framework. Unfortunately, development of dynamic input–output models is extremely complex, and requires further estimates of future county and state economic conditions (Conway, 1990; Beaumont, 1990). Despite these limitations, use of the input–output methodology can provide useful information about future economic impacts to energy and environmental planners. The detail with which this information can be provided is unlikely to be available from any other type of model, especially at costs that are not prohibitive.

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