APPLYING BENEFIT TRANSFER TO GEOTHERMAL ENERGY IN INDONESIA

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Abstract: *The government of Indonesia plans to exploit non exportable energy sources to meet increasing domestic energy demand without decreasing energy exports. Geothermal energy, which is considered "renewable," may be a more environmentally-friendly alternative than conventional sources (Sven-Olof Ryding, 1992). However, geothermal does have environmental impacts throughout its life cycle which need to be evaluated. Direct evaluation of these impacts can be quite difficult and expensive in a developing country with little experience of geothermal electricity. Therefore I will apply benefit transfer techniques to evaluating air pollution health impacts of developing and using a geothermal site in Dieng, Central Java, Indonesia from a study site in Hualien, Taiwan. A benefit transfer is the application of monetary values obtained from one nonmarket goods analysis study site to another. Benefit transfer is currently quite popular, specifically in the developing countries, since it saves time and money in developing data. These impacts along with production costs will be used to cost geothermal energy.*

I. INTRODUCTION

Government policy in Indonesia calls for using coal and geothermal resources for electricity generation in order to save oil for the export market. Indonesia, which is on the Pacific "rim of fire", has abundant geothermal resources with an estimated potential magnitude of 16,000 megawatts (MW) (Partowidagdo and Isyna, 1992). Although considered a relatively clean fuel, geothermal does have external costs arising from the health impacts of air pollution generated over its life cycle. In this study I will apply benefit transfer techniques to estimate these costs.

Part 2 of the paper covers geothermal energy from an engineering point of view, the geothermal fuel cycle and environmental impacts of geothermal. Part 3 reviews the literature on valuing of nonmarket goods and services and benefit transfer. Part 4 presents the particulars of the policy site and part 5 presents the empirical results of applying benefit transfer to a geothermal field in Indonesia.

2. GEOTHERMAL ENERGY AND FUEL CYCLE

Geothermal energy is the heat contained below the Earth's crust. This heat is brought to the surface as steam or hot water created when water flows through heated, permeable rock and is used directly for space heating in homes and buildings or can be converted to electricity (NREL, 1994). Hydrothermal energy reservoirs are large pools of steam or hot water trapped in porous rock. To create electricity, the steam or hot water is pumped to the Earth's surface where it drives a turbine that spins an electric generator. Because steam resources are rare, hot water is used in most geothermal power plants. In Dieng there are both types of geothermal field: vapor dominated and water dominated (Himpurna, 1997).

Steam and hot water power plants use different power production technologies. Dry steam is routed directly to the turbines, eliminating the need for the boilers used by conventional natural gas and coal plants. Water at high temperatures above 200°C (392°F) is sprayed into a low-pressure tank, where it vaporizes to steam and is routed to the turbines. Water below 200°C (392°F) is used to vaporize a secondary working fluid, which then drives the turbine.

In valuing externalities of geothermal energy we need to consider the total fuel cycle, which includes exploration, development, production (electricity generation, transmission, end-use,)and the post operational phase (waste disposal and decomissioning) (National Renewable Energy Laboratory, 1994)

The exploration stage consists of general information, land leasing and permitting, geology, geochemistry, geophysics, land acquisition, licenses and permits, transportation of materials to support the facilities, exploration drilling, development drilling and production (extraction). The most intensive environmental impacts at this stage are the surface disturbances and vegetation clearing during development drilling with construction of the production well pad, power plant, and pipe lines.

The production of a geothermal well could be steam, hot brine water, or both. The geothermal power plant is run by steam: therefore, if the production of a geothermal well is both steam and hot water, they are separated with the brine water reinjected into the formation through an injection well. The steam is further processed before it goes into the turbine. Steam pressure is stabilized before it goes into the turbine. The equipment and facilities must be constructed to support steam production and consumption throughout the fuel cycle. Storage is required in several of the fuel cycle stages, including the operation and maintenance of facilities for storing materials, parts and equipment, and other items or commodities required for generating electricity.

Electric generation is done at the power plant. The refined high pressure steam which comes from the well goes into the power plant, expands, and rotates the turbine. A generator converts the mechanical energy of the turbine into electrical energy. The geothermal power plant includes systems to control gaseous, liquid, and solid wastes. If the steam still contains a lot of hydrogen sulfide and sulfur dioxide, flue-gas desulfurization will control the emissions.

Transmission systems transmit electricity to the consumer. Transmission lines produce electromagnetic fields (EMF). Though not proven, some believe that these fields may cause cancer, leukemia, and infertility. As a result the price of the land close to transmission lines is usually lower than land further out. (Dadang Purnama 1994). End uses for electricity include the use of electric consuming products such as light bulbs, air condition, and heating equipment, industry’s machinery, etc.

Waste disposal occurs in every stage of the geothermal fuel cycle. Drilling mud and cuttings in the exploration and development stage have the protential to pollute both land and water depending on their disposal method. Sulfur dioxide is emitted from wells during exploration, development and production. Combustion from equipment being used produces carbon dioxide and monoxide, nitrous oxides, lead and sulfer dioxide. It seems that the biggest part of the waste disposal in a geothermal field is from the reinjection wells. Since liquid used for generating electricity is recycled or reinjected into the well, no geothermal liquids enter the waterways, and this reuse of the liquids prolongs the life of the geothermal field. Waste recycling includes the collecting and reprocessing of raw materials and the recycling of parts and equipment.

In the geothermal fuel cycle, decommissioning is not a major environmental issue. Because of high capital costs, the current trend is to prolong the lifetime of the field and power plants. ` et al. (1992).

III. LITERATURE REVIEW VALUING EXTENALITIES AND BENEFITS TRANSFER

Since a geothermal project emits gas into the atmosphere, people who live around the geothermal field get respiratory diseases and visibility decreases. There is an externality because property rights for the air are poorly defined and the geothermal company does not bear the true cost of the air pollution. Electricity cost will be lower than if the pollutant cost is included. In order to measure the true or social costs of electricity we need to quantify this loss in air quality.

Measures of environmental quality can be expressed either in terms of willingness to pay (WTP) or willingness to accept (WTA). According to Freeman (1993) the WTP and WTA can be defined as follows: Suppose the property rights of a section of a river are owned by individual A who also owns a fishing industry in this river. If this river is polluted by individual B who owns a geothermal field and power plant located by the river, the WTP is the maximum sum of money that individual B would be willing to pay to pollute the river the WTA is the maximum sum of money that individual A would be willing to accept as compensation for accepting the pollution in the river. The WTP is constrained by the individual’s income but the WTA is not.

Economists have devised various ways to measure WTP and WTA for changes in an economic environment. For example, we can measure the change in welfare from a change in price for a market good with four alternative measures: the change in ordinary consumer’s surplus (CS), compensating variation (CV), equivalent variation (EV). We can illustrate these concepts in figure 1. The horizontal axis in panel A shows the quantity of electricity production and the vertical axis shows the other good. The individual has two indifference curves, the initial indifference curve is U_o and the other indifference curve is U_1 where U_1 is higher than U_o. Suppose that there is a decrease in electricity price from p_o to p_1. The price reduction makes the electricity output (budget constraint) increase from (I/p_o) to (I/p_1) (where I is the individual income) and the individual shifts from consumption bundle A at utility U_o to the consumption bundle C at the new utility U_1. Based on panel A we could derive panel B which shows the Marshallian demand curve (uncompensated or ordinary demand curve, q^M), and the Hicksian demand curve (compensated demand curve) for CV (q^h_{CV}) and for EV (q^h_{EV}). The Hicksian demand curve is a demand curve where the income effect of a price change has been taken out so that along the demand curve real income is held constant. Unlike the Marshallian demand curve where both income and substitution effect are included, the Hicksian demand curve includes only the substitution effect.

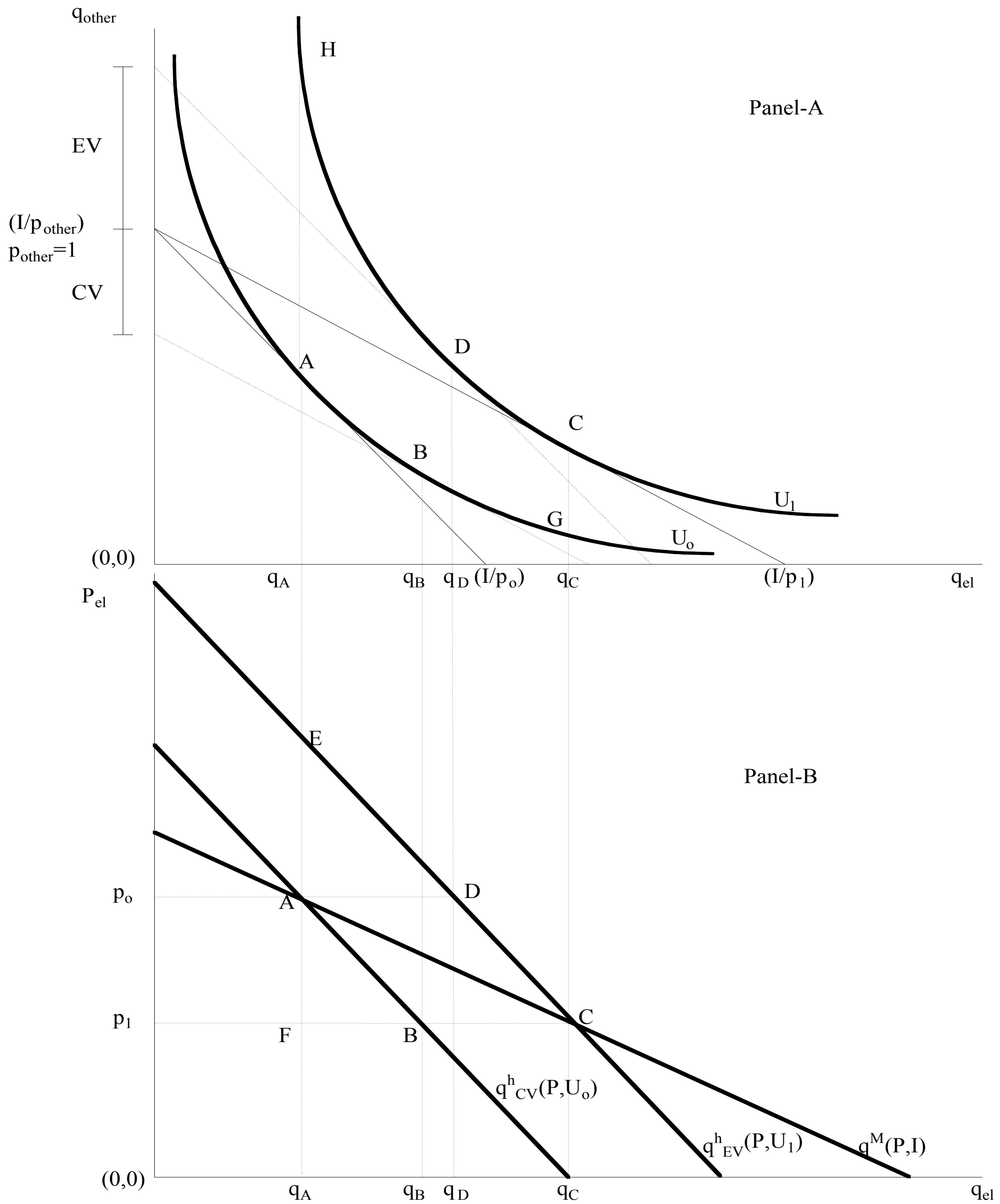

Figure 2 - Consumer Surplus, Compensating Variation, Equivalent Variation, Hicksian and Marshallian Demand Curves

The Hicksian demand curve for normal goods is steeper than the Marshallian demand curve for normal goods. I will define three welfare measures that can be defined in terms of the other good (the vertical axis), that is taken to be the numeraire. The units of the other good q_{other} are chosen so that the price of q_{other} is equal to one. So, q_{other} can be taken as the representative of income.

1. Consumer Surplus (CS) is a consumer's benefit measurement. It is the difference between what a consumer is willing to pay for a good and what the consumer actually pays.and is the area under the Marshallian demand curve (q^M) between price p_o and p_1 (area p_oACp_1). In mathematical form it can be expressed as

$$\Delta CS = \int_{p_1}^{p_0} q^M (P, I) dp \tag{1}$$

The Marshallian consumer surplus does not really measure any of the theoretical definitions of welfare change but is good as an "approximation" in welfare change measurement since it lies between CV and EV.

2. Compensating Variation (CV) asks what income change at the new price would be necessary to compensate the consumer for the price change (Varian, 1992). This is a measure of compensating payment that is needed to make the individual indifferent between the original utility (point A) and the new price set. Given the new price set with consumption at point C the individual's income could be reduced by the amount CV and the individual would still be as well off at point B as at point A with the original price set and money income. In the case of electricity (panel A and B), the CV can be interpreted as the individual's maximum willingness to pay for the opportunity to consume at the new price set. In mathematical form it can be expressed as

$$\Delta CV = [e(p_0, U_0) - e(p_1, U_0)] = \int_{p_1}^{p_0} q^h_{CV} (P, U_0) dp \tag{2}$$

Where $e(p_i, U_j)$ is the expenditure required to acquire utility j at price i.

3. Equivalent Variation (EV) variation asks what income change at the current prices would be equivalent a proposed change price change in terms of utility (Varian, 1992). As it is shown in the panel A, given the current price, the individual may reach a higher utility level of U_1 at point D with an income increase equal to EV. Thus, as Freeman (1993) pointed out, EV is the monetary equivalent of a price change. In mathematical form it can be expressed as

$$\Delta EV = [e(p_0, U_1) - e(p_1, U_1) = \int_{p_1}^{p_0} q^h_{EV} (P, U_1) dp \tag{3}$$

The EV and CV measurement would be the same as consumer surplus if the elasticity of the income of demand for electricity were equal to zero.

For nonmarket goods there are two approaches in measuring welfare changes, the expressed preference approach or the direct approach and the revealed preference approach or the indirect approach. Figure 2 illustrates these two approaches. The two most commonly used indirect approaches are the Travel Cost Method (TCM) and the Hedonic Pricing Method (HPM). What the TCM and HPM do is to estimate the relationship between the pollution and the non-monetary effect (people get sicker, for example). Therefore the indirect methods do not try to find the WTP for environmental benefit or WTA as compensation for environmental damage (Pearce and Turner, 1990). The uncompensated (Marshallian) demand curve can be developed from TCM or HPM, and based on this demand curve the consumer surplus welfare can be estimated (measured).

The direct approach is the contingent valuation (or survey) method (CVM). The income compensated (Hicksian) demand curve can be developed from the CVM approach and based on this demand curve the welfare measurement can be estimated.

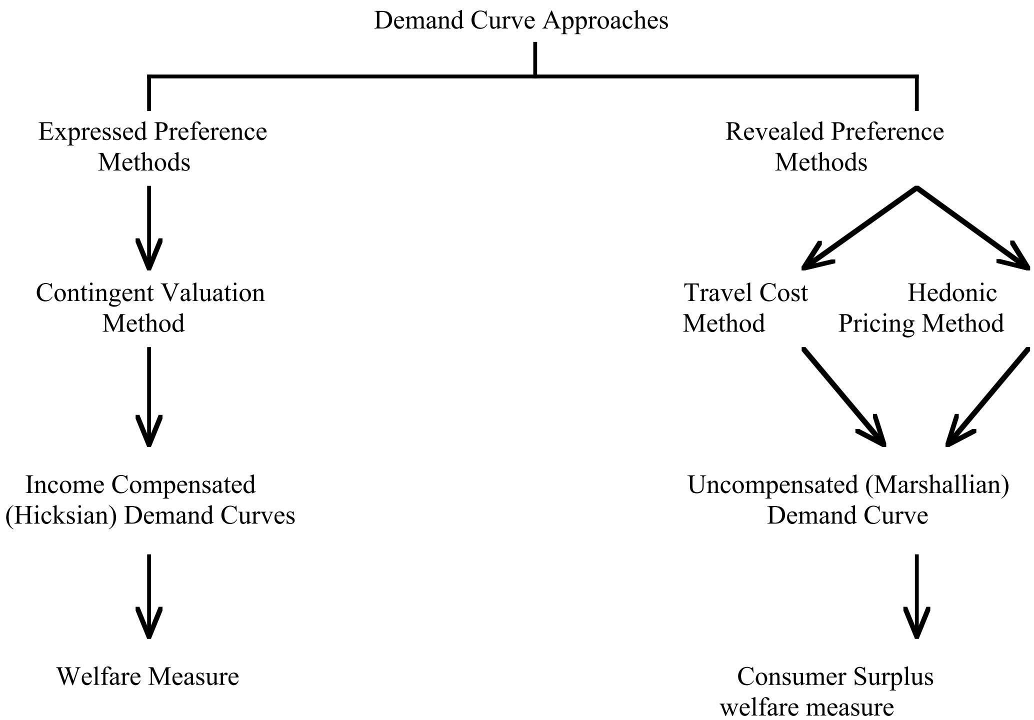

Figure 3 - Methods for the Monetary Evaluation of the Environment through Demand Curve Approaches. (Adapted partially from Turner et al. 1993)

<u>The Indirect Approach. The Travel Cost Method (TCM)</u> is frequently used to estimate social values for facilities like national and state parks and other recreational areas. The underlying assumption of the TCM is that the incurred site visiting's costs (e.g., gasoline costs) reflect the recreational value of that site. Suppose that the local government is going to know the value that individuals place on a trip to a national park, a beautiful mountain with geysers in it, that lies right next to the geothermal field and geothermal power plant that is currently under construction. An individual who wants to visit this national park will incur several costs. The individual's trip costs will include public transportation fees (if the individual owns a car, the monetary costs will be the gasoline and wear-and-tear), food, travel time costs, admission fee to the park, and the time costs spent inside the park. The individual's monetary valuation can be estimated by using questionnaires, and from their responses the travel costs can be estimated. A demand for visits per year can be developed.

Even though the recreational values are related to the travel cost, the TCM has some problems such as time costs, multiple visit journeys, substitute sites, house purchase decision, and non-paying visitors (Turner et al., 1993).

1) Time costs - A simple TCM assumes that the only travel cost is the gasoline expense to visit the park. In fact, the travelling time spent is also valuable to the individual who visits the park. Thus, there is a value of time that should be added to the travel cost. The value of time could be in dollars per hour spent in the car. There have been many attempts to estimate a value of time, but no real consensus has yet been achieved. The time costs problem is complicated because many people enjoy travelling and do not consider travelling to a recreational park as a cost.

2) Multiple Visit Journeys. Sometime an individual visits more than one site during a single day's journey and he is asked to answer the TCM questionnaire for one of the sites. It is difficult to apportion the travel costs of the visitors. Sometimes the analyst asks the respondent to set the percentage of the day's total travel costs, but the error margin is uncertain in this context.

3) Substitute Sites. If the recreational site is the only one in the area, an individual may be happy to travel for 30 miles to visit the site, another individual travelling the same distance but from another direction, may not be as happy since there is no other choice of site. The simple TCM approach gives the result that both visitors would like to hold the same recreational value for the park site, which is clearly not correct. To alleviate this problem, some analysts ask the individual to name substitute sites, but that technique is statistically complex and open to error.

4) House Purchase Decision. Some individuals who highly value the recreational site will buy houses, located close to the site. In this case they will incur relatively low travel costs visiting the site. This TCM result will underestimate the recreational value. Recently analysts have attempted to include this factor in their questionnaires.

5) Non-paying Visitors. Often TCM studies omit the visitors who walk to the site, thus incurring no travel costs. Though these visitors may highly value the site, they are not counted, which again undervalues the site.

<u>The Indirect Approach -The Hedonic Pricing Method (HPM)</u>. Goods such as air quality that do not have a market price, can influence the price of a market good such as houses. The HPM tries to evaluate the influence of the nonmarket good such as environmental services on the price of a market good such as property price. Houses located near industrial plants, for example, tend to sell at a lower price compared to houses located in a cleaner air area. Houses located on the beach, for example, have a higher price than houses located in the downtown. Those two examples show that differences in values can be attributed to differences in the characteristics of goods. One way to measure the contribution to the value of the different characteristic of a good is through HPM.

Data are taken from a sample of similar residential properties over a period of years (time-series analysis), or on a bigger set of properties that are not similar at a given point in time (cross-sectional analysis), or a mixture of both types of data (pooled analysis). These data are used to identify differences in property price caused by differences in environmental quality. The cross-sectional approach is used more often than is the time series approach since it is difficult to control for all of the variables that may affect property prices over time.

When we use appropriate statistical techniques, the hedonic approach will a) identify how much of the property price differential is the result of particular environmental differences among properties, and b) infer how much people are willing to pay for an improvement and what the social value is of the improvement (Pearce and Turner, 1990). House price is a function of variables such as property (the size of the house, total number of rooms, back and front yard, etc.), neighborhood (income and education level of neighbors), accessibility (near school, grocery, warehouse, theater, etc.), and environmental (air quality, proximity to airport, etc.). This can be written in linear form as

$$HP=\beta_0+\beta_1 PROP+\beta_2 NHOOD+\beta_3 ACCESS+\beta_4 ENV+\varepsilon$$

The value of β_1 will tell us by how much the house price will change if we alter or increase the value of the property variables by one unit, holding the other variables constant. The same interpretation also applies to β_2, β_3 and β_4. The value of β_4 which will tell us by how much the house price will change if we alter or increase the value of environmental variables by one unit holding the other variables constant. So we can relate the property price to willingness to pay in order to solve the problem of valuing environmental damage or environmental improvement.

Even though the HPM approach seems to be reasonably robust, it still has some problems. 1) Developing a relationship between house price and environmental quality requires a high degree of statistical skill to separate out the other influences on house price such as property, neighborhood, and accessibility variables. 2) There is an income effect on the individual decision in selecting the combination of house features. ?Yohan I don't understand the problem in 2)

<u>The Direct Approach -The Contingent Valuation Method (CVM)</u>. The foundation of the contingent valuation method is to ask people what they are willing to pay for a benefit or are willing to accept as compensation to tolerate a loss. Unlike the hedonic and travel cost models which are applied only for the valuation of property and recreation and scenic areas, the contingent valuation method is applicable to most environmental amenities. The major advantages of the contingent valuation approach is that it can be designed for situations before they take place. (ORNL and RFF, Report No. 1, 1992).

The indirect approach is able to measure only use values. The direct method in the form of the contingent valuation method (CVM) can measure use values and nonuse values. Where use values comes from utilizing a good such as a national park. Nonuse values comes from enjoying the national park not by using it but by reading or knowing about the park.

There are two approaches that can be taken in valuing illness. The first is to ask the respondents to describe the illness that is to be valued (Rowe and Chestnut, 1985 in Alberini et al., 1996) and the second one is to describe for the respondents the symptoms that the respondents are to value. For example, the respondent is asked to value a symptom such as a minor head congestion or eye, ear, or throat irritation. Minor here means that the individual still could continue with daily activities with little change. The second approach has been used more often than the first. The advantage of the second approach is the respondent knows the commodity (the described symptom) he is asked to value, so the commodity is well defined.

Based on the theory, there are three components in the individual's WTP to avoid sickness: the value of feeling discomfort (disutility) while the individual is sick, the value of time lost during sick time, and the amount the individual needs to spend (expenditure) to relieve the discomfort (Harrington and Portney, 1987). The individual will consider those three components of WTP. The individual may be asked how much time he missed from work and the resulting income loss, and what kind of activities were undertaken in order to relieve his symptoms (taking over-the-counter medicine, eating more vegetables, fruits, and juices, and visiting a doctor or a hospital). If any of these activities were undertaken, the individual needs to be asked if any of the activities were effective and how much money was spent on them. After the individual has described his illness in detail, the individual is asked hypothetical questions.

According to Kopp and Smith (1993) there are some disadvantages of the direct method. First, values that are obtained are hypothetical, so, one has to ask how big the biases are between hypothetical values and actual market values, and under what situations do significant biases occur? Second, the direct method has the unfortunate tendency for uninformed researchers to consider themselves experts in survey design. Some natural biases also may be present in the contingent valuation method: strategic bias, design bias, hypothetical bias, and operational bias.

1) Strategic Bias comes from the supposed problem of getting individuals to reveal their true preferences in the sense that by not telling the truth the individuals will have a benefit in excess of the costs that they have to pay. One example is if people are told that a service (for example, to gain better environmental quality) will be provided by the government if (a) the provision costs are less than their aggregated total willingness to pay, and (b) each person will be charged a price equal to their maximum willingness to pay. This kind of strategy can result in an individual understating his or her true demand. Freeman (1993) argued that this strategic bias problem can probably be minimized by careful design of the survey instrument.

2) The Design Bias comes in three forms.: the starting point bias, the vehicle bias, and the information bias. The starting point bias results from the interviewer's starting point bid. If the starting point bid is too low, the respondent may be willing to pay that amount but no more. Starting point bias can be minimized by careful survey design. The vehicle bias means that the vehicle or the instrument of payment used in the approach can influence the respondent. The respondent may give a different answer depending on the instrument of payment such as payment in local taxes instead of a surcharge on electric bills. Information bias occurs when the information cannot be understood by the respondent because the problem is not familiar. For example, if the questionnaire asks about the willingness to pay if the concentration of sulfur dioxide is reduced from 0.08 ppm to 0.03 ppm, the respondents may not understand the meaning of ppm (parts per million), so they may not be able to give an informed answer. If the questionnaire is

changed, so that the respondent understands the health risk consequences of lowering concentrations from 0.08 ppm to 0.03 ppm the respondent will give a more informed answer.

3) Hypothetical Bias can exist because the basic idea of the contingent valuation method is to elicit hypothetical bids that should be the same as actual bids if only actual markets exist. In actual markets, respondents (or consumers) become annoyed when they have paid too much. But in the hypothetical market, respondents may act more generously when expressing willingness to make payments than when committing themselves to actually do so.

4) Operational Bias arises from the contingent valuation survey that is not close to actual market conditions. This bias could happen if the individuals are unfamiliar with the good to be valued. Operational bias can be a problem for CVM estimates on nonuse values.

Cummings et al. (1986) suggest the following reference operating conditions should help make the CVM valuations close to the actual market valuations or unbiased. Individuals have to understand and have experience in valuing the commodity. There has to be little uncertainty in valuing the commodity and the estimation of commodity value must come from willingness to pay, not from willingness to accept.

Benefits Transfer applies the monetary values obtained from one nonmarket goods analysis site to another policy site (Brookshire and Neill, 1992). Three such applications of benefit transfer are 1) expert opinion estimation, 2) observed behavior estimation, and 3) preference elicitation mechanisms estimation.

1) Expert opinion uses the judgement of an expert to approximate WTP for avoiding health problems, for example. A unit-day approach values a day of coughing or other sickness avoided (ORNL & RFF, Report 1, 1992). In the proxy approach researchers use alternative values from related goods. For example, in valuing how many sick leave days an individual will take when he catches cough and cold, the proxy chosen was three days based on the doctor requirement official letter to the employer to give three days rest to the individual.

2) Observed behavior estimation is an observation on behavior (own price, substitute price, income, education, etc.) between the study site and the policy site. Conceptually, the observed behavior approach is sounder than the expert opinion approach. It is estimation based upon the characteristics and behavior between the commodity in the study site and policy site. Loomis (1992) and Atkinson et al. (1992) illustrated the utilization of observed behavior data for benefit transfer applications.

3) Preference elicitation estimation is through a contingent valuation study. Many contingent valuation studies are good candidates for applying the benefit transfer (Brookshire and Neill, 1992). For example a contingent valuation study could give the willingness to pay function (Hicksian demand function) of a nonmarket good commodity in a study site, and this demand function could be transferred into the policy site. Empirical results indicate that benefit transfer of the whole benefit function is more accurate than transfer of only average site benefits. According to Kirchhoff et al., (1997)

there continues to be a scientific debate over benefit transfer and many issues are still unresolved even though benefit transfers are currently being used in decision making. Inspite of the criticisms, benefit transfer is being used more and more often because of costs and time demands for primary data collection conducted on a site-by-site basis and the demand for valuation research is increasing in developing countries. (Brookshire & Neill, 1992 and Boyle & Bergstrom, 1992). Further Alberini et al. (1996) found a direct CV survey in Taiwan yielded similar results to the benefit transfer from the U.S. These Taiwan results suggest that benefit transfer works fairly well and justifies a similar benefit transfer for Indonesia.

To do my benefit transfer I first discuss the air pollution affects that I will be evaluating. Air Pollutants and Physical Health Effects. Many chemical substances find their way into the air. Some are in small amounts that do not cause a health concern, but others build up and become a human health hazard. Exposure to air pollution causes mild changes in health (watery eyes, nose, mouth, throat irritation, and coughing and sneezing) up to serious illnesses such as lung diseases (asthma, bronchitis and emphysema) (Dockery and Pope, 1994). The U. S. Environmental Protection Agency has classified six major air pollutants: carbon monoxide, ozone, nitrogen dioxide, sulfur dioxide, particulate matter, and lead. The following indicates how these chemicals are formed and the health impacts of each.

Carbon Monoxide (CO) is an odorless, colorless, and poisonous gas, which is the byproduct of incomplete combustion. It comes from motor vehicle and other combustion exhaust. **Health effects**: When CO is inhaled into the lungs it binds with hemoglobin, which reduces the ability of this protein to carry oxygen. The reduced oxygen reaching the heart, brain and other tissues causes headaches, fatigue, queasiness, poor vision and concentration, and heart pain. It is particularly dangerous for an individual who has heart disease, and for pregnant women and their fetuses. At very high levels of concentration, it causes death.

Ozone (O_3) is a colorless and odorless gas. It includes harmful ozone in the lower atmosphere and beneficial ozone in the upper atmosphere that protects the world from ultraviolet radiation. Ozone, not directly emitted into the air but produced in the atmosphere when hydrocarbon gases combine with nitrogen oxide compounds in the presence of sunlight, is the major harmful ingredient in smog. **Health effects**: Ozone can inflame the breathing passages causing coughing and chest pains. U.S. studies show that low levels of ozone pollution are related to hospital admissions and emergency room visits for respiratory problems. Individuals who exercise also suffer from its effects.

Nitrogen Dioxide (NO_2) is formed when the heat from combustion causes the nitrogen and oxygen in the air to combine to form nitrogen dioxide and related nitrogen oxides (NO_x). The compounds of the nitrogen oxides contribute to health problems and ozone formation. In the atmosphere NO_2 can change to acidic particles and liquid nitric acid through photochemical or catalytic oxidation. **Health effects**: It is an irritating gas that can increase the susceptibility to infection and may constrict the airways of asthmatics.

Sulfur dioxide (SO_2) is formed from burning sulfur-containing fuel. Diesel engines in drilling rigs contribute to the sulfur dioxide formation. Sulfur dioxide can change into acidic particles and sulfuric acid in the atmosphere through photochemical or catalytic oxidation. **Health effects**: A brief exposure to low level sulfur dioxide constricts the air passages and can cause asthma attacks. Children exposed to sulfur dioxide will experience respiratory tract infections and healthy people may experience sore throats and coughing.

Particulate Matter (PM) includes tiny liquid and solid particles that float in the air. These particles come from industry, burning fuels, motor vehicles, and dust from activities such as construction, drilling, mining, landfills, and agriculture. A particle of 10 microns in diameter or smaller is called PM10, which is about the size of one-seventh thickness of a human hair. It can be inhaled into the deepest parts of the lung. The PM10 is a mixture of materials including metals, acids, salt, soot, dust, and smoke. (Dockery and Pope, 1994). **Health effects**: PM10 can bypass the body's natural filtering system going deep inside the lung's air passage. Trapped there, it degrades the respiratory system's natural defenses increasing the number and severity of asthma attacks, aggravating bronchitis and other lung diseases and threatening the body's immune system. PM10 is considered the greatest health threat among these six pollutants.

Lead (Pb) is a poisonous substance that comes from lead smelters, lead battery incineration, leaded gasoline used in vehicles that service geothermal field (Indonesia still uses leaded gasoline) and from burning lead-contaminated waste oil that comes from field incinerators. **Health effects**: Lead cannot be eliminated from the body and accumulates in the blood. Exposure to low levels of lead can result in impaired mental functioning and development in children and higher blood pressure for middle aged men. At relatively low levels, lead exposure can result in a permanent decrease in the IQ of children. At higher levels, anemia can occur in both adults and children.

Benefits transfer will be used as the basic methodology for valuing the environmental externality of air pollution from geothermal power, which cannot be estimated at the policy site.

Brookshire (1992) also made a simplified benefits transfer framework as follows:

$$V^{ss} = \beta_0^{ss} + \beta_1^{ss} X_s^{ss} + \beta_2^{ss} X_g^{ss} + \beta_3^{ss} X_m^{ss} \quad (4)$$

$$V^{ps} = \beta_0^{ss} + \beta_1^{ss} X_s^{ps} + \beta_2^{ss} X_g^{ps} + \beta_3^{ss} X_m^{ps} \quad (5)$$

where

V^{ss}= individual valuation regarding study site.

V^{ps}= individual valuation regarding policy site, based on the $\beta_s^{'}$ of study site.

X_s= vector of socioeconomic characteristics at the study and policy site (income, age, education, cultural, etc.)

X_g= vector of characteristics of the commodity (physical - quality and quantity and economic relevant notions (such as complement's, substitute's uniqueness)) at the study and policy site, in this case study the commodity is the air pollutants.

X_m= vector of market conditions (size and composition) at the study and policy site.

β_i^{ss}= study site regression coefficients.

If we have β_i^{ss} from the study site and we have the X_s, X_g, and X_m from the policy site, we can calculate the individual valuation in the policy site (V^{ps}).

I will estimate (by using benefit transfer) the health effects caused by air pollution which come from developing a geothermal power plant, using a modification of the Kask and Shogren (1994) model. They recommended a four-stage approach for a transfer analysis for valuing reduction of public health risk from improved water quality. Stage 1 defines the purpose of the benefit estimates. Stage 2 develops the proposed transfer protocol, such as commodity characteristics - (a) response/causal agent, (b) risk definition, (c) temporal dimensions, (d) voluntary and involuntary dimension, (e) exposure pathway, and (f) exposure level and site and sample characteristics include socioeconomic, location and temporal characteristics. The socioeconomic characteristics include income, age, education, risk awareness, baseline health, and baseline risk. It is important to find a well-developed study site valuation model that matches the policy site as closely as possible and Stage 3 is to identify an existing benefit study or studies that agree with the transfer protocol. Stage 4 is to select and to decide the appropriate transfer method using mean value, adjusted mean values, or complete demand functions.

Stage 1 or my purpose is to estimate the net social benefits of air pollution that comes from developing and using the geothermal field and power plant. The cost estimates are made from transferring the costs from a study site where the estimation has been made into the policy site.

The policy site is a geothermal field being developed , which has its power plant in Dieng plateau, Central Java, Indonesia. This area is not a pristine area; it already has many people living there, most of whom are potato and vegetables farmers. A foreign investor is currently developing this field, and one of the power plant sites, Unit-I, a 55 net MW facility has been operating since March 1998. Developing a geothermal field and power plant will probably increase atmospheric pollutants. The diesel engine, vehicles and other machines in the field emit carbon monoxide and dioxide, nitrogen dioxide, sulfur dioxide, lead, and particulate matter (PM). The wells emit sulfur dioxide.

The commodity specification for this study is the human health impacts from air pollution that comes from geothermal development and operation. Response/Causal Agent will be specified as a particular set of symptoms such as increased days of disease beginning from failure of the immune system to fight colds, flu, and other common light illness up to the risk of chronic illness. This can be represented as days of work loss and restricted activity days.

Risk definition. The health effects caused by exposure to the mixture of air pollutants can range from low probability of premature mortality to a high probability of morbidity. The development of a geothermal power plant will increase the health risk caused by the additional air pollutants that come from the geothermal field and power plant project.

Temporal definition: Health impacts from environmental air pollution range from acute immediate effects to chronic effects. The dimension of time of the health effects includes time between exposure and occurrence of the illness or death and also length of time of the illness. The temporal dimensions of the health effects between the policy site and the study site (with similar environmental air pollution) is assumed to be similar.

Voluntary and Involuntary dimension: Environmental air pollution that causes adverse health effects are typically involuntary as compared to health effects from driving, smoking, and drinking. In this case study the exposure to the air pollution is considered voluntary (the geothermal field worker) and involuntary for the inhabitants surrounding the geothermal field and power plant.

Exposure pathway: The exposure pathway for the air pollutants is through inhalation. This pathway may affect consumer value because of the consumers ability to avoid the hazard by self-protection and/or self-insurance. For example the consumer will perceive more control over the air quality by wearing a mask while working or being active outdoors.

Exposure level: The location where the geothermal field and power plant site is being developed has been exposed to some concentrations of nitrogen oxide, sulfur oxide, carbon monoxide, hydrogen sulfide, ozone, methane hydrocarbon, lead and particulate matter. In general the air pollutants concentration are still below the Indonesian ambient air quality standards (Decree of Minister of Population and Environment, No.: KEP. 02/MENKLH/1/1988).

Potato and vegetable farms are located in the geothermal area; the farmers use a lot of decomposing chicken dirt, which is one of the reasons why this area has high concentrations of nitrogen oxide. The source of emission of sulfur dioxide come from vehicle emissions, through a photochemical activity, the sulfur dioxide could be changed into sulfuric acid aerosol. The carbon monoxide comes from vehicle emissions and biomass oxidation. The source of hydrogen sulfide comes from volcano activity, fumarole, and organic (food and leaf waste) decomposition. The geothermal field and power plant development could increase the risk by incrementing ambient air quality concentrations, especially of hydrogen sulfide, sulfur dioxide, carbon monoxide, and particulate matter.

My benefit transfer study is Alberini et al. (1996), who studied the health effects of air pollution in a developing country, Taiwan. They conducted a contingent valuation study on the willingness to pay (WTP) to reduce acute illnesses, primarily acute respiratory illnesses, such as colds or the flu. It is assumed that air pollutants cause colds and flu. The study was conducted in three locations in Taiwan: From these three I choose Hualien, an unpolluted city on the east coast of Taiwan as the most appropriate match for the study site since both are less industrial areas.

In the Hualien survey, respondents were asked to describe the most recent acute illness episode they had experienced. After describing the episode and their efforts to alleviate the symptoms, each respondent was asked whether he would pay a certain amount of money to have avoided the episode altogether. A WTP function was developed from the data collected from the survey as in equation (4). The regression results for their study are in Table 1

Table 1: Willingness To Pay Equation

Regressor	Mean of Regressor	Estimated Regression Coefficient (β_s)	t-value
Intercept	5.3064	3.7606	7.095
Log(duration)	2.2255	0.1730	1.736
Log(# of symptoms)	0.6948	0.2572	2.009
Cold	0.2537	-0.4457	-2.781
Restricted daily activities	0.2083	0.3215	1.972
# of workdays lost	0.3051	0.0906	1.740
drug	0.5368	0.3314	2.112
doctor visit	58249	0.6153	4.157
log(household income/month)	11.1131	0.3377	2.643
(NT$/month)	0.1690	0.0537	2.723
years of education	0.0233	0.0856	-1.010
Hualien resident	0.3297	1.6048	3.361
Ground water	0.3669	0.5553	3.309
Bottled water	1.2718	0.3423	2.257
air filter	0.2598	0.0377	2.296
# of sick leave days	0.1311	0.2965	1.904
lungs problem		0.3323	1.587
chronic illness			

I use the above benefit transfer function with the following inputs for Dieng

1. Cost of Illness in Taiwan (US$14.69) is calculated by using the formula [Taiwan's mean of WTP(US$)/1.77], and it is based on the concentration of PM10 at 145$\mu g/m^3$.

2. Duration in policy site are 5 days, and sick leave are 3 days (expert opinion, asthma and allergy specialist, Dr. Widjaja M.).

3. Mean of cold at policy site is the mean average from year 1980, 1986, and 1995 of HDRI.

4. Mean of doctor visit at policy site is taken from HDRI 1992.

5. Mean of over-the-counter drugs purchased is taken from HDRI 1980.

6. Policy site's years of education and household income are taken from Himpurna 1997.

7. Labor wage is Rp.3000.00/day without meals, adjusted to year 1992 (Final Report on Environmental Management and Monitoring Efforts, Drilling & Production Tests Wells, Dieng Geothermal Exploration, 1995).

8. Cost of Illness (COI) value in policy site is calculated as {[(Rp.150/strip of drugX2 types of drug)X5days of duration]+[(Rp.3000/(1.1)^3)X3days of sickleave]}/Rp.2062 = US$4.01

9. COI with doctor visit (Rp.5000/visit) is US$6.43.

This yields the costs in Table 1.

Table 1 The Externality Costs (mills/KWh) based on Alberini et al.

on 55MW power plant at Dieng. (in 1992 price)

	Function
Individual WTP (US$)	70.75
Total WTP (US$)	795,938
Externality Cost (mills/KWh)	0.1080

Note: 1.) Total WTP is calculated for the total population of 11,250 individual surrounding geothermal field and power plant (radius 4-5 km.). 2)Externality costs in mills/KWh = [(Total WTP in mills)/(Electricity production within 15 years in KWh)]. *) Individual WTP = Policy Site Individual WTP at 1985 inflated to 1992 with the average annual inflation rate 3.5%.

I find the cost per person to be $70.75. Distributing this cost over the whole population and production I find that the external costs for air pollution are 10.8 mills per kwh as the social costs of air pollution for geothermal electricity. These costs are added to the private costs of production to get an indicator for the social costs of geothermal electricity generation. Since I had difficulties in obtaining total private costs from the geothermal company, I took proxy costs from Wahyuputro et al., 1990. The following is the calculation of the Average Total Full Private Cost from Dieng in mills per kilowatt-hour at the 55 MW power plant.

Investment Costs (Million of US$)	43.2
Operating and Maintenance Costs (million of US$)	13.7
Total Costs (Million of US$)	56.9
Electricity production within 15 years in Gwh	7,371.5
Average Total Private Costs (mills per Kwh)	18.5

Note: Geothermal Capacity Factor = 85%, Discount Rate = 10%, Project Economic Life = 25 years.

Total cost per kilowatt hour including private costs and social costs of air pollution are 18.5 + 10.8 = 29.3 mills per kwh. Since this does not include all of the negative externalities, this would be a lower bound on true social costs. Further work could be done to quantify the other negative externalities associated with geothermal electricity production.

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