Market and Non-Market Values of Water Resources and Non-Market Values of Hydropower Associated With Glen Canyon Dam: A Theoretical Framework and Literature Review

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1. **This study has been conducted with initial direction provided by Dr. David Garrett. This document has been significantly improved thanks to comments from three anonymous peer reviewers. However, the views expressed are solely those of the author, who is responsible for any errors or omission.**
2. This analysis does not necessarily reflect the opinions of the Department of Agricultural and Resource Economics nor Colorado State University.

Executive Summary

Theory Section

Hydropower: All sources of electricity have their costs and benefits, and hydropower is no different. This report provides a theoretical framework in which one can conceptualize the possible non market benefits associated with generating a given amount of electricity using hydropower rather than fossil fuel (primarily coal). The report then provides a review of the existing international empirical literature on magnitude of these benefits in terms of:

- reduced health effects from air pollution
- increased visibility at national parks
- reduction in CO_2 emissions
- increased reliance on renewable energy

I assess the relevance of the existing literature values to Glen Canyon dam operations.

The resulting gaps in the empirical literature with respect to Glen Canyon dam operations and insights gained from the theoretical framework helps to motivate future research needs to allow a more complete assessment of the potential environmental benefits relying on hydropower rather than fossil fuels for an incremental or marginal change in electricity production.

Water: This report also investigates the market and non market values of water in the Colorado and Green River systems, particularly an incremental or marginal change in the quantity of water. In particular we provide an equivalent theoretical framework for evaluating the market and non market benefits of water supply. This is followed by a review of the international empirical literature on:

- market values of irrigation water and municipal water
- non market values of irrigation water
- non market values of water based recreation

We then investigate what these existing empirical studies can tell us about the incremental or marginal values of water in the Colorado River system.

The resulting gaps in the empirical literature with respect to Glen Canyon dam operations and insights gained from the theoretical framework helps to motivate future research needs to allow a more complete assessment of the potential market and non market benefits of any incremental changes in water supply.

Summary of Theory Results

The theoretical framework suggests there can be non-market benefits for many of the positive environmental aspects of hydropower such as air quality, reduced CO_2 emissions and being renewable energy. In particular, some of the principles derived from economic theory suggest:

- The economic efficiency benefits of market, non-market use and non-use values is measured by what a person a person would pay for them, i.e., willingness to pay.
- The magnitude and geographic extent of non-use values is an empirical matter.
- Due to non-rejectability of public goods, not all public goods will be valued by all people.
- The more substitutes there are for a resource the less likely non-use value will be significant.
- Altruism toward others only generates non market values that can be included in an economic efficiency or benefit-cost analysis if the source of altruism is paternalistic—a concern that other individuals consume the specific public goods. The rationale is explained in the theory section.
- Distributional concerns about the general well being of others or employment should be

displayed separately as an economic impact of the project or policy and not included in a Benefit-Cost Analysis (BCA) .

Hydropower Empirical Results

This study reports monetary values for improved health and visibility benefits from the literature, as well as monetary values for reducing CO2 emissions. While the benefits of renewable power in general, and wind power and solar in particular have been empirically measured, it has not been specifically measured for hydropower. This is a gap in the literature that could be investigated by future research.

One of the more definitive findings is for coal. The costs per megawatt hour of air pollution (SO2, NOX and PM) and Carbon Dioxide amount to $.95 and $4.64, respectively per MWh. Willingness to pay for renewable power (in the form of wind power in NM) is $.27 per MWh. Care must be taken in using these values not to double count the value of renewable power and the value of air pollution avoided, as some of the reasons for valuing renewable power is to avoid air pollution affects from fossil fuels.

Water Value Empirical Results

Market values of water provide one indicator of value of irrigation water**.** Market values of water in irrigation in Arizona range from $33-$68 per acre foot for one year lease, to about $700 per acre foot for purchase of water rights. For residential water use in Phoenix, the net willingness to pay per acre foot is about $200 an acre foot each year. In California as a whole the average one year irrigation lease rate is between $83 and $119, but one transaction in Southern California involved a one year lease rate of $258 per acre foot. Purchase prices for water rights on average in all of California are between $700-$900 per acre foot. I could not locate any Southern California specific water right purchases.

For water, the theoretical framework suggests there can be non market benefits for many of the positive environmental aspects of water. Non market values of water are most evident in the use values of water-based recreation in the Colorado and Green River systems. These recreation use values are dominated by the value of water based recreation at Glen Canyon Dam (e.g., Lake Powell). However, many of the recreation value studies, particularly of rafting and fishing below Glen Canyon Dam are more than two decades old, which limits their applicability for making current trade-offs for dam operations today. Updating these studies is an important avenue for future economic analysis.

Beyond the many studies of water based recreation there has been just one published study on the public's non market value for irrigated agriculture in the western U.S., the results of which are not disaggregated to the state level. Thus attempting to estimate the non market values of irrigated agriculture at the state level is an important area for future research.

Native American Values

The existing literature stresses only valuing incremental changes in access to Native American's for their cultural and natural resources and not attempting to measure their total value. There are only two studies on the economic values that Native Americans hold toward natural resources. There is no research in the U.S. (and only one study in Australia) on the general public's willingness to pay to provide natural resources to native people's.

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Section V. Literature Gaps and Important Areas for Future Research

Introduction

This study was initiated at the request of water and hydropower associations affiliated with the Colorado and Green River systems to assess if there are non market values associated with changes in the availability of these resources in general, and in the Colorado and Green River systems, in particular. The policy setting for this study is potential changes to Glen Canyon dam operations that involve changing flow release patterns from the dam. Some of the possible changes in flow patterns could involve reducing the amount of peaking power produced, and hence the need replace this power during times of peak demand. Some of this replacement power will likely come from fossil fuels such as coal and natural gas. While the timing of water flow releases could change when water is available to downstream users, it is not likely to change the total amount of water released over a year, or over a ten year period due to Colorado River Compact requirements.

The **first objective** of this study is to provide a general theoretical framework (Section I) incorporating market and non-market aspects of water and hydropower into the standard utility maximization framework used for economic valuation.

The **second objective** is to review what the existing literature has to say about the empirical evidence of these market and non market aspects of water and hydropower. The literature review was literally to be global in scope, looking at not just studies in the western U.S., but also internationally.

The **third objective** is to determine the applicability of the empirical values reported in the literature values to potential incremental changes in power production and water releases from Glen Canyon Dam operations.

The **fourth objective** recognized that there might be several gaps between theory, the existing empirical literature and finally the Colorado and Green River systems. Therefore this fourth objective addresses what new empirical research studies should be undertaken to fill the gaps between the theory and existing empirical studies in relation to the market and non market values of water and hydropower in the Colorado and Green River systems.

This study reflects the spirit of an increasingly interconnected planet in which management of large coupled human-environmental systems requires us to confront the weighing of local impacts (many of which may be non-market in nature) against contributions to regional and even global impacts and trends (many of which may also be non-market in nature).[1]

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[1] I thank Robert Berrens, Department of Economics, University of New Mexico for this insight.

There is almost no externality-free electricity supply (NRC, 2010), perhaps with the exception of conservation and roof top solar. Renewable energy sources (hydropower, wind, large scale commercial solar, geothermal) and non-renewable energy sources (coal, natural gas) all have external environmental costs to geographic regions where the production takes place, and in the case of carbon dioxide, to the entire world. Thus mitigating regional impacts of one power source may increase pressure in regional electricity generation grids and markets to use another power source. The primary objective of this study is to contribute to an assessment of the incremental external benefits of incremental changes in availability of water and hydropower while trying not to minimize the importance of the external costs of these two resources. Others have studied the external environmental costs of irrigation projects (Moore, et al. 1996), and external environmental and social costs of dams (World Commission on Dams, 2001). However, per the objectives of the statement of work these other effects will not be investigated in any detail, beyond simply to acknowledge them where appropriate in the report. Finally, given the focus in the statement of work, the well known fuel cost savings of hydropower, and its flexibility in meeting electricity demand are not studied in this report either.

SECTION I
THEORETICAL FRAMEWORK FOR MARKET AND NON MARKET VALUES OF HYDROPOWER & WATER

1. General theoretical framework

1a. Definitions of types of goods: Private and Public Goods

Some of the goods produced by Glen Canyon Dam are **private goods** (e.g., consumption of electricity by households) and some are **public goods** (e.g., air quality). The two primary characteristics that distinguish private goods from public goods are the following: (a) Private goods are rival in consumption (one person's use precludes another person's use of the same unit of a private good (e.g., a hamburger)). (b) Suppliers of private goods can also exclude people from consuming the private good via the market, i.e., if the person does not pay the market price, they are denied access to the private good. "The most common definitions of public goods stress two attributes of such goods: nonexclusivity and nonrivalness (Nichloson, 1992:756). Non-rival in consumption means that one person's use or enjoyment of a public good does not "use up that unit of the good". Therefore another person (or for that matters thousands or millions of other people) can simultaneously use or enjoy that same unit of a public good. Non-exclusivity means that once the public good is provided to one person, there is no economically efficient way to prevent others from consuming it. However, the third characteristic of a public good, non-rejectability, means everyone gets the same quantity of the public good, whether they obtain utility or not from it. For most cases (improved air quality, water quality) everyone will receive benefits. However, non-rejectability can result in a case where some public good (e.g., silvery minnow in the Rio Grande River) may be of value to some people, but others might have no value for it at all.

Consumption of private goods primarily has use values to the person consuming them. This consumer is able to choose how much of the good to consume to maximize their utility subject to their income and the price of the good. In the United States and many developed countries private goods are provided by markets. Profit maximizing firms provide many of the private goods. Some private goods are provided by government agencies or quasi government organizations, rural cooperatives, non- governmental organizations, etc. Hydropower from Glen Canyon is an example of a private good (electricity) provided by a government agency.

In contrast to private goods, the individual consumer cannot usually choose the quantity of public goods available to them, as there is only one quantity provided to everyone residing in a particular location. Depending on the nature of the public good, this may be a city (e.g. local urban drinking water quality), a multi-state region (e.g., protecting air quality over national parks in the desert southwest—see Schulze and Brookshire 1983), or globally (protecting a unique species found only in the Amazon). Usually collective action of some form (e.g., referendum voting, voting by elected officials or government agency decisions—e.g., EIS) can increase or decrease the amount of public goods available in that area.

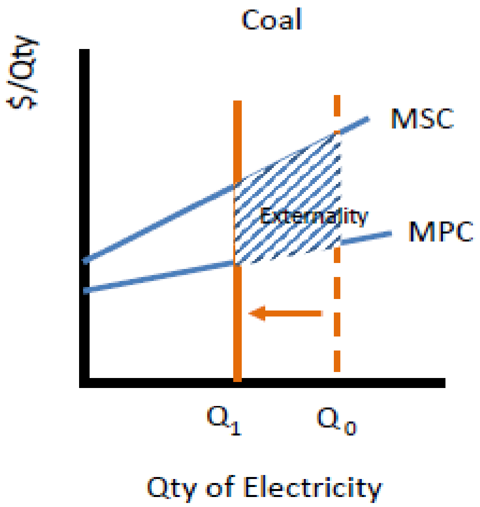
Public goods can be combined with private goods to produce non-market ***use*** goods (e.g., recreation, improved health) that provide enjoyment or utility to people. Public goods may also provide benefits to some people who do not directly use the public good on site. These off site values are referred in the literature as ***passive use values or non-use values***. The components of passive use values include the enjoyment from just knowing the public good exists for its own sake or the use by others (altruism) and knowing that preservation today can provide this public good to future generations.

1b. Externalities in Production of Private Goods and Public Goods from Environmental Quality

For markets to provide a socially optimum amount of a private good, all the costs of production must be reflected in the price paid by consumers. In the case of coal fired powerplants providing electricity, some of the health and visibility costs of electricity production arising from air pollution caused by the plant are not fully reflected in the cost of production and hence the price of the electricity to the consumer. These health and visibility costs are costs external to the market (they are not paid for by the firm). Air pollution is a non market costs of coal fired electricity production. These external costs are called negative externalities by economists. Hydropower generates no air pollution externalities (but there are downstream externalities to endangered species, for example). Hence in some sense replacing 10 megawatts of coal fired electricity with hydropower provides a non market benefit in the form of avoiding the air pollution externality on those units of production. Improved air quality from replacing some electricity production from a coal fired powerplant with hydropower has characteristics of a public good.

Figure 1 illustrates this example of air pollution externality from a coal fired powerplant. Figure 1 shows the negative externality is the difference between the Marginal Private Cost (MPC) and Marginal Social Cost (MSC). The shaded polygon in between Q1 and Qo is the quantity of coal generated electricity. For simplicity, assume that this is the residual externality after efforts to reduce the magnitude of the externality has been performed, e.g., scrubbers are in place. If hydropower generation can provide Qo-Q1 worth of electricity, this reduces the magnitude of the externality. This would be a non market benefit of the hydropower. The avoided externality is a public good since many people can ***potentially*** benefit from the reduced air pollution, or in other words the improved air quality. Some of these that benefit from the improved air quality will be visitors to the region (a non market use value). Some of these will be those that reside downwind from the power plant (a non market health benefit). Some of these people will be people not directly affected by the reduced air pollution but received non market benefits from knowing the air quality is improved over other regions (a non market non use value). Some of this would be benefits of reducing climate change from reduced CO_2 emissions.

Figure 1. Negative Externalities from Electricity Produced from Coal.



As noted above all forms of electricity production have negative externalities, they just take on different forms and magnitudes. Thus in Figure 1, it is equally plausible to replace the word “Coal” with natural gas, wind generated electricity or large scale commercial solar facilities favored by some large utilities. With wind turbines, bats and bird deaths have been well documented (Eveleth, 2013; Barclay, et al. 2007). Covering significant areas of land with solar panels will reduce wildlife habitat. In this report we focus more on coal because it is the most financially cost effective of alternative electricity sources (Harpman, 2006: 11) to replace incremental amounts of hydropower that may need to be made up at certain times of day, days of the week or months of the year due to any changes in operation of Glen Canyon dam. Of course the economics of electricity production are changing all the time, with falling natural gas prices and falling prices for photovaltaics, coal may not always be the financially cheapest power source in the future.

So now the question is how does one, in principle, measure these non market use and non use benefits. It is to the theoretical underpinnings of the empirical measurement of these values we now explore.

1c. General Utility function incorporating private and public goods.

Both Carson, et al. (1999) and Freeman (2003) provide a general formulation of utility with market use, non market use and Passive Use/Non-use Values. A simple utility function is:

$$\text{(1) Utility= function }((g(X_1..X_n, PG_1\ldots PG_n)).$$

Utility (U) is a function of all the private goods a person consumes ($X_1\ldots Xn$) and all the Public Goods ($PG_1..PGn$) available to them such as water quality, air quality, rare species, etc. (Public goods such as National Defense, Space program, etc. will be suppressed for notational simplicity).
Some public goods will enter the Use portion of the utility function since they serve as inputs to the individual in producing non market ***use*** values such as health and recreation. For example, some rare species (e.g., whooping cranes) provide both viewing use values for some individuals and passive use values to users and non-users (see Stoll and Johnson, 1984 for empirical evidence). Freeman (2003: 142) notes that there is no logical reason why an individual could not simultaneously receive utility from use and passive use values (PUV) from the same public good.

A slightly different form of the utility function given in equation (1) is often given as an example of a utility function with the properties that a person receives both use and non-use value from a given public good (Carson, et al. 1999; Freeman, 2003). Equation (2) presents this variation of the utility function.

$$\text{(2) Utility= function}((g(\mathbf{Xm, PG), PG}))).$$

In words utility is an overall function of private goods (**Xm**) represented by a vector of private goods ($X_1\ldots Xn$) and a vector of public goods ($PG_1\ldots PGn$). The slight, but important difference between equation (1) and equation (2) is that a subset of the public goods produces non market *use* values in combination with *some* of the private goods (e.g., boats and fishing poles) and non use values. In particular, some of the public goods may produce both use (g function) and PUV. However, some public goods may produce only PUV because no private goods are needed to receive enjoyment from the public good (e.g., utility gained from an endangered species in a remote location where no visitor access is allowed).

This utility function in equation (2) is weakly separable between the function g that combines some private and some public goods (PG) to produce non market use values and the PG by itself which has non-use value. By weakly separable economists mean that decisions about how much X1 and PG1 to combine to increase utility due, say, to improved health does not affect the marginal utility from the public good PG itself (Nicholson, 1992: 187-188—Also see Layard and Walters, 1978:165-167).

2. Some Principles of Non Market Use and Non-Use Values from Equation (2)

Irreversibility versus Reversibility: With the aid of this general formulation we can also discuss several principles of non-use value. First, a reduction in the quantity or quality of PG may bring about a reduction in non-use value even if the change is reversible, i.e., not irreversible (Carson, et al. 1999: 119; Freeman, 2003: 149-150; Randall and Stoll, 1983: 268). Irreversible changes may result in larger non-use value, however. A reduction in non-use value can also arise from a reduction in PG that does not result in complete extinction or elimination of PG (Carson, et al. 1999: 119; Freeman, 2003: 149-150).

Uniqueness of the Public Good: The public good (PG) need not be unique to generate non-use value (Carson, et al. 1999: 119; Randall and Stoll, 1983: 268), but the more unique, i.e., the fewer substitutes the resource has the greater the non-use value is likely to be. The change in non-use value from a change in quantity or quality of a reproducible resource with many close substitutes would likely not generate much change in non-use value, but how small a change in non-use value is an empirical question that may be addressed through survey research. However, a change in a reproducible public good with many substitutes may generate local non market use value in the form of local recreation.

The Role of Altruism in Non-Market Valuation and Non-Use Values

There is evidence all around us of people making sacrifices to help other people, i.e., they are altruistic toward others. Economics have long discussed whether altruism should be counted in benefit-cost analysis (Flores, 2002:294; Bergstrom, 2004) and non-market valuation—especially non-use value (McConnell, 1997, Freeman, 2003). In studying this area economists have made distinctions between pure altruism and paternalistic altruism.

- Pure altruism toward others stems from a general concern for the general well being of others or their overall level of utility, regardless of what increases that level of utility (e.g., more food, better education, more parks, better medical attention).
- Paternalistic altruism is a concern that others have a specific public good.

Of particular interest here is that a potential source of non-use value arises from paternalistic altruism toward others of the same or future generations (Freeman, 2003: 150-151). If my utility depends on the utility derived from the availability of a specific public good to myself and to current or future generations then this paternalistic altruism may be a source of existence and bequest to me (McConnell, 1997; Lazo, et al. 1997). For example, if I want future generations to have a self sustaining viable population of condors, this is often referred to as bequest value to me (Lazo, et al., 1997). The non-use value arising from paternalistic altruism toward wanting others to have a specific public good is valid to include in economic benefit calculations of that public good (Freeman, 2003: 151; McConnell, 1997). However, if my altruism toward others stems from a general concern for their well being, i.e., is non-paternalistic or pure altruism, then in most circumstances it is not valid to include this as an economic value (Freeman, 2003: 150)[2]. Thus, if I care about the well being of farmers in general, then providing them money (as is done in the Farm Bill) is pure altruism and would not count as an additive economic efficiency non market value. The reason is that in order to raise the income of farmers there is a dollar per dollar cost of this transfer. That is, one dollar of increased well being to a farmer, costs myself and others collectively one dollar. As can be seen there is no net gain. Another example might be providing subsidized electricity to rural families to improve their general well being in a non-paternalistic way (e.g., I don't care if they use the additional electricity to raise their thermostat or play video games longer—anything that makes them better off, makes me better off). Providing this subsidy has a dollar per dollar opportunity cost to the supplier, and if provided by a government or quasi government agency, foregone tax revenue not available to all citizens. Thus, as in the example of the farmer, a gain to one group is exactly offset by a cost to others, for no net gain. Further, unlike the public good case described immediately below, providing the electricity to one group, means that quantity of electricity is not available to another group, i.e., electricity is a rival private good which mean some other group is deprived of subsidized electricity. While society might care about the distribution of the subsidy this seems to be a distributional issue not an economic efficiency issue (a point suggested by Carol Silva at our December 6, 2013 meeting).

In contrast, an intuitive explanation for paternalistic altruism is: besides getting utility from my own consumption of an existing public good I also get utility from your consumption of the same public good (Flores, 2002: 293). In this case the benefits are additive. Being a public good, the marginal cost of allowing another person to consume the existing public good is zero. Thus, there is no additional cost to the recipient of providing public good. Thus there is a net gain to society if people exhibit paternalistic altruism toward others with regard to the specific public good. However, as Flores (2002: 304) points out if the benefit-cost analysis is evaluating provision of the public good or

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[2] Bergstrom (2004) is not so definitive on this point, but his theoretical set up is rather restrictive requiring the initial allocation of resources be distributionally efficient (p348), an assumption at odds with the real world.

an increase in quantity or quality of an existing public good for which the direct cost to the government or opportunity cost of providing the public good is positive then who pays the added cost matters. As discussed more below in addressing the implications of altruism in stated preference surveys, how the public good is financed matters.

The theoretical underpinnings for this dichotomy between paternalistic and non-paternalistic altruism is spelled out in some detail by McConnell (1997) and Lazo, et al. (1997) and summarized by Freeman (2003: 150-151). Flores (2002) and Bergstrom (2004) provides a more recent theoretical discussion but one not as definitive as McConnell (1997).

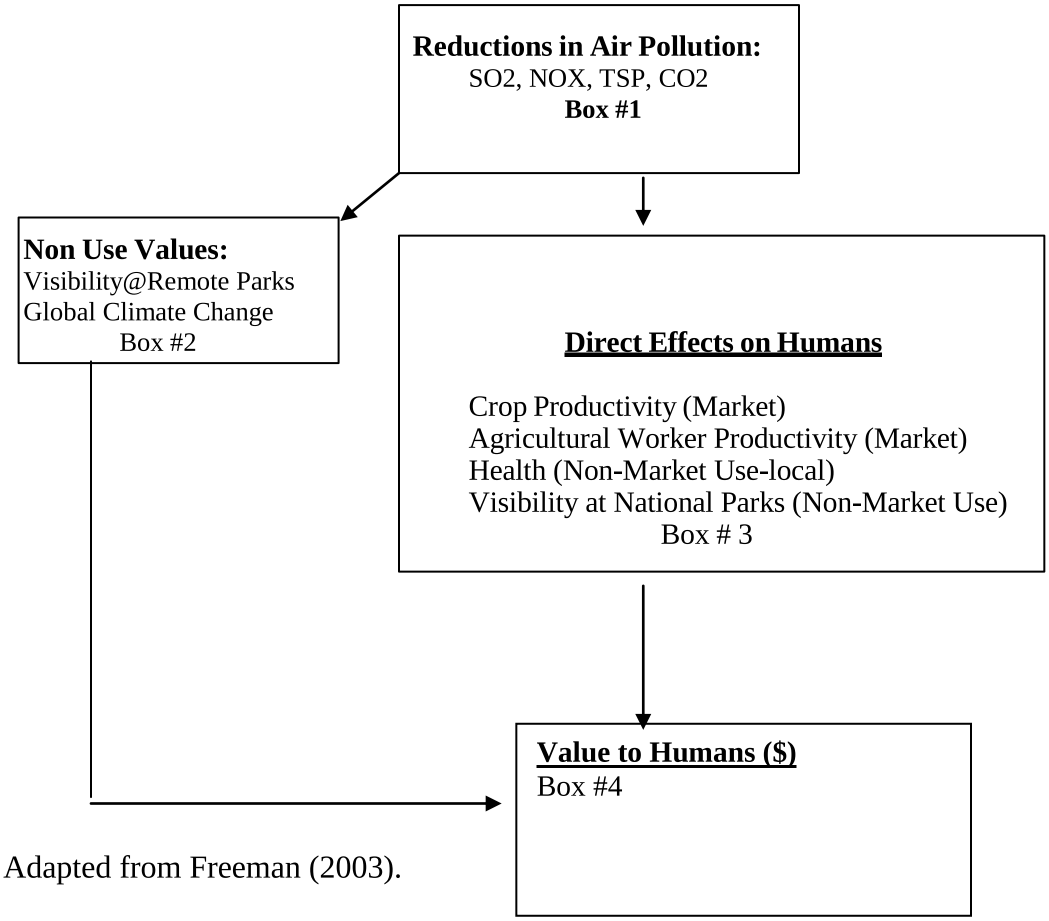
Based on my interpretation this literature and the above authors' examples in their articles as well as their guidance on Stated Preference (Contingent Valuation) surveys there are some general principles for designing CVM surveys if one want to incorporate paternalistic altruism. This next section draws directly from Lazo, et al. (1997: 369), McConnell (1997:36) and Flores (2002: 304). To guard against eliciting non paternalistic or pure altruism, (and what both Lazo, et al. (1997) and McConnell (1997) warn could be double counting of benefits and Bergstrom (2004) would claim as overstating benefits), these authors provide some guidance on the form of the CVM WTP question. According to Flores (2002: 304) " *…benefit-cost analysis with altruism cannot simply be conducted independent of who pays. This result is particular important for studies using stated preference techniques. If researchers are eliciting values for public goods, they need to make clear the cost to others in order to minimize measurement error*". Thus, if funding to provide the public good will actually result in a mandatory payment by others (e.g., taxes or utility bills—as suggested by Carson and Groves), then this needs to be communicated to respondents. In this case, one would follow Lazo, et al.'s guidance to choose a payment vehicle applicable to all households and reinforce this with the (usual) statement that all households must pay for the good if it is provided. A voter referendum format where a majority votes to provide the good, all households will pay a broad based tax would seem to be the best fit. This suggestion is also consistent with Bergstrom (2004: 348) that CVM questions emphasize payment vehicles such as taxes that all would have to pay in order to explicitly get respondents to consider that not only will they have to pay the costs, but there will be costs to others. The theory is that with this payment vehicle if the respondent only cares about the general welfare of others (i.e., pure altruism), then the respondent would not include benefits to others as there would also be costs to others. However, if the respondent gains utility from the other person having a particular public good, and there is no cost to the other person (e.g., it is funded by voluntary donations perhaps via a voluntary check off on state income tax or voluntary check off on utility bills, or a tax affecting only a small portion of the most wealthy—capital gains tax), then the respondent should include the utility the respondent would get from such a paternalistic gain in others utility. As shown in a lab experiment by Messer, et al. (2013), this is a challenging task. As one can see, qualitative research with focus groups early in any survey design process will be needed to probe respondents' reasons for voting in favor or against provision of the public good to determine if the payment vehicle is getting this point across to the respondent. It is a delicate balancing act in survey design to allow for paternalistic altruism while avoiding the respondent including any pure altruism.

Lazo, et al. also suggest that the payment vehicle have a short time frame (they suggest ten years), so that only the current generation pays, but not future generations pay. This ensures that there would be no double counting in the bequest value toward future generations. McConnell's suggestions are a little more cumbersome to implement, but help to distinguish respondents based on their type of altruism. Questions would be designed to ascertain if the respondent receives any benefits from providing the particular public good to the household or whether any benefits arise from the respondent's view that the public good would raise the other household's general level of well being. As can be seen, this would be a difficult question to ask a respondent as it involves a relatively subtle, but important distinction.

Role of Non-Rejectability of a Public Good: In part because a public good is non excludable everyone receives this good, whether they want it or not (e.g., national defense, wolves in Yellowstone, flood control if you are living below a dam). Thus it is worth mentioning again that only a subset of people who receive a PG may have a non-market use or non-use value for it. Given the non-rejectability characteristic of a public good, everyone receives the current level PGo. Much like market goods, where not everyone values all private and public goods (e.g., many people do not value tofu or cauliflower even though it is available in the grocery store at a fairly low price), not everyone receives non-market use or non-use values from a particular public good. For example, if I do not go recreational fishing, even changes in *native* trout may *not* have a non-market use value. If the native trout is rare enough (e.g., greenback cutthroat trout), a person might have a non-use value. However, there may be some people who simply don't care about native trout, and receive no non-use value either. Not everyone has paternalistic altruism toward the current generation or future generations. Rather some people may have non-paternalistic altruism, where they care about the overall wellbeing of others of the current and future generation but it does not matter to them whether the increase in wellbeing of others is from native trout, or better schools, better air quality, or better health care. Further, the proportion of the population that may receive non market use value and non-use value is an empirical question that may be addressed through empirical research. The extent of the “market” for non market use values and non-use values may also vary depending on the uniqueness of PG (i.e., if there are no substitutes within a 1,000 miles of where the person lives, then non-use values for some people may extend out as much as a 1,000 miles). See Loomis (2000) for empirical examples of the extent of non-use values for rare and endangered species.

Figure 2 conceptually illustrates an application of equation (2) to reduction in air pollution from some management action (e.g., replacing fossil fuel with renewable energy). The reduction in air pollution in Box #1 has two effects: (a) Box #2—increase in non-use values for the improvement in air quality (AQ1) at Park X, and possibly globally from reductions in CO2 if these reductions are substantial enough, (b) Box #3—improvements in agricultural productivity from reduced air pollution reducing crop yield (Westenbarger and Frisvold, 1995) and improving farm worker productivity (Graff Zivin and Neidell, 2011), both market effects; improvement of human health (a non market use value) and scenic visibility of local residents and visitors to Park X (additional non market use values). These gains in market, non-market use and non-use values have some increase in utility, which as noted below, can be expressed in monetary terms (Box #4).

Figure 2. Production of Use and Non Use Values from Improved Air Quality



Adapted from Freeman (2003).

3. Tailoring the Utility Function to Air Quality Benefits of Hydropower

To illustrate how the concepts underlying equation (2) and Figure 1 might be adapted to the case of reduced air pollution associated with the increased use hydroelectric plant generated electricity in lieu of an equivalent amount of coal fired power plant electricity production, consider equation (3):

(3) $U= \text{func}((g(X_1 \ldots X_{n-1}, X_{elec}, EQ_1 \ldots EQ_{n-1}, AQ_{local}, AQ_{regional})$

Where:

$X_1 \ldots X_{n-1}$ are private goods consumed (e.g., bread, meat, cars, clothing, etc.)

X_{elec} is electricity consumed, a private good

$EQ_1 \ldots EQ_{n-1}$ is Environmental quality of other public goods in the region where they live such as water quality for drinking (EQ_1), water based recreation (EQ_2), forest recreation (EQ_3)--both non market use values to national or global (e.g., T&E species or Amazonian rainforests), etc., these examples would potentially have non-use values.

AQ_{local} is Air quality where the person lives and affects their own health and local visibility—a non market use value.

$AQ_{regional}$ is air quality in other regions where the person does not live but cares about (e.g., a national park, wilderness area) either because they visit (non-market use value) or nationally/globally (a potential non-use value).

There could also be interactions between AQ_{local}*EQ2 and AQ_{local}*EQ3 which would represent the interaction of local air quality on water quality (e.g., lake acidification, nitrogen deposition fueling algal growth and hence lower dissolved oxygen, and changes in composition of fish species) and forest health for recreation (e.g., acid rain effects on forests).

As noted above, not every person will receive benefits from each $EQ_1 \ldots EQ_{n-1}$, $AQ_{regional.}$

Equation (3) provides a menu of potential benefits that some individuals may receive from replacing Y# of kW hours of electricity production from fossil fuel plants. Whether these all of these benefits are realized by a given individual may depend on one or more particulars of the powerplant.

To illustrate and show the application of equation (3) consider the following example. A windfarm replaces an aging coal fired powerplant. The powerplant is nearby a National Monument and Wilderness Area which have Class I air quality, but not any major city (i.e., located in a fairly remote region in the intermountain west). Thus there would be benefits from improving air quality at these two natural areas to visitors (non market use value) and to many non-visitors (passive use public good). There would be a reduction in CO2 emissions, a global public good. Closer to home, there would be a small number of people for whom air quality improved, and they would have a non-market use value from improved air quality related health (e.g., fewer cases of bronchitis). There may be improvements in forest health or water quality if the powerplant's emissions resulted in significant acidification of soils or acid rain, as well as improved water quality from less deposition of airborne nitrogen into lakes. Both of these would be a non market recreation use value. If the powerplant was large enough that it was a significant contribution to CO2 emissions in the region, then there would be a non-use public good benefit of contributing to combating climate change.

However, this example is based on several assumptions, the first assumption would likely be about where the fossil fuel plant is relative to where a person lives and the direction of the wind. Whether local Air Quality is improved sufficiently to affect the health or local visibility will depend on whether a particular city is near and downwind from the coal-fired plant whose production is being reduced. Likewise whether the air pollution from the power plant would be significant enough to cause acidification of lakes and forests would depend on the sulphur content of the coal and the pollution control devices on the powerplants that would be used more to replace any reduction in hydropower.

However, it is likely that Air Quality regionally or nationally would be improved from the substitution of hydroelectricity for an equivalent amount coal fired electricity. Whether that matters to individuals, by how much it matters, and how many individuals it matters to is an empirical question that may be resolvable with survey research. As before, whether these environmental concerns matter to individuals, by how much it matters, and how many individuals it matters is an empirical question that may be resolvable with survey research.

G. Tailoring the Utility Function to Water

To illustrate how equation (2) might be adapted to the case of a change (gain or loss) in water supply coming from a river or reservoir consider equation (4).

(4) $U= f(g(X_1 \ldots X_{n-1}, X_{muni}, EQ_1 \ldots EQ_{n-4}, W_{local\ lakes,} W_{local\ rivers}, OS_{local}(Land, X_{IR}), Farmers_{local}(X_{IR})), W_{regional\text{-}global\ lakes}, W_{regional\text{-}global\ rivers,} Farmers_{regional\text{-}national}(X_{IR})$

Where:

X1…Xn-1 are private goods consumed (e.g., cars, clothing, books, computers, etc.)

Xmuni, municipal water the household consumes (e,g., cooking, bathing, lawns, etc.), a private good

$EQ_1 \ldots EQ_{n-4}$, is Environmental quality of other public goods (this can be local to global such as T&E species in other countries, Amazonian rainforests). Local would likely be non-market use values and non-use values for non-visitors.

Wregional lakes, quantity of water in lakes (e.g., water levels in lakes) in the geographic region where they live. Wregional rivers, quantity of water rivers (e.g., instream flows) in the geographic region where they live.
If both of these water resources have public access then these would have non market use values for visitors to these water resources.
OSlocal-region(Land, XIR): amount of open space in the local or regional area where they live. This may potentially have non market use values if publically accessible, if not they may have incidental non market use values (Freeman, 2003) as when someone drives by on their way to work or the airport. It may also have some local non-use value if inaccessible and not viewable.

Farmerslocal(XIR)) availability and timing of irrigation water influencing the profitability of local farmers for purposes other than open space such as paternalistic altruism toward farmers. This would be considered a non- use value.

Wnational-global lakes, quantity of water in lakes (e.g., water levels in lakes) nationally or globally

Wnational-global rivers, quantity of water rivers (e.g., instream flows) nationally or globally.

These would be potentially non market use values if a person visited, and non-use value to non visitors.

$\text{Farmers}_{\text{regional-national}}(X_{IR})$ availability and timing of irrigation water influencing the profitability of regional and national farmers for purposes other than open space such as paternalistic altruism toward farmers in the state or US. This would be considered a non-use value.

Numerous reservoirs provide several of these types of benefits listed above in equation 4. For many reservoirs this is almost by design. They were designed as ***multiple-purpose*** reservoirs to provide water storage for urban and agricultural uses, to provide water based recreation, and in some cases hydroelectricity and flood control.

To illustrate these concepts and equation (4) consider Chatfield Reservoir, a large reservoir adjacent to Denver, Colorado. This reservoir provides irrigation water to farmers that maintains thousands of acres of farmland near the outskirts of Denver. In the absence of this reservoir providing surface irrigation water, some of this land would not be profitable to farm. The portion of this land near existing subdivsions would likely be converted to suburban uses reducing the amount of open space to existing surburban residents (a loss in non market use value). However, some of this land may be located so far from any urban or suburban areas, that it may simply remain idle, providing very similar open space services as the previous irrigated agricultural land did to the few residents living in those remote areas. It should be noted that the reservoir itself provides valuable water based recreation (e.g., water and jet skiing) near Denver to several million people (a non-market recreation use value). The reservoir also provides a significant amount of drinking water to suburban Denver cities and towns (a private good use value).

5. **Transitioning from Utility to Willingness to Pay**

This utility-theoretic framework provides the foundation for economic efficiency analysis of benefits and costs of projects and policies. The definition of economic benefits in economic efficiency analysis is usually maximum willingness to pay (WTP), but depending on what is considered the status quo and the assignment of property rights, it can be minimum willingness to accept (WTA). There are what is called four Hicksian welfare measures of WTP and WTA. These are Compensating Variation, Compensating Surplus, Equivalent Variation and Equivalent Surplus. Because we are dealing with unpriced public goods and non marketed goods, the Surplus measures are relevant since they are quantity based rather than price based. Here we look at two of the most commonly used in empirical analysis of public goods, as these are the most relevant:

1. Compensating Surplus: is the maximum amount of money a person would pay for a gain in the quantity or quality of a public good. Specifically, it is the maximum amount of money that a person would pay and make the person indifferent between their current utility level (Uo) with the current amount of the public good (PGo) and the new level of utility (U1) with an increase in the public good (PG1), where PG1>PGo. Compensating Surplus is what economists call an exact measure of WTP. If in fact the change being evaluated would make the person worse off, then a compensating measure could also be a willingness to accept measure (WTA). This would be the minimum amount of compensation they would take to accept the reduction in the public good and remain at their current level of utility (Uo).

2. Equivalent Surplus: is the maximum amount of money a person would pay to avoid a loss in the current quantity or quality of a public good. Specifically it is the maximum amount of money that a person would pay and make the person indifferent between their current utility level (U1) with the PG1 amount of the public good and Uo with PGo amount of the public good. Equivalent Surplus defined in this way is appropriate if the individual does not have any right to have the currently higher level of the public good (PG1). For example, when air quality is 4 times better than required by the Clean Air Act, reductions in air quality to 2 times better than the Clean Air Act could be a situation where the individuals would have to pay to avoid the reduction in air quality.

However, if the individual has a legal right to the current level of air quality (e.g., current air quality is worse than the level required by the Clean Air Act), then the Equivalent Surplus measure would be the individual's minimum WTA in money the individual would accept in lieu of an improvement in air quality. WTA reflects the minimum amount of money a person would have to be paid to accept the new lower level of air quality and be no worse off than they are now with the higher level of air quality.

As noted whether WTP or WTA is the appropriate welfare measure depends on what is defined as the current situation (i.e., the status quo) and to whom the legal property rights are assigned. As suggested by a reviewer, the status quo be could defined as the situation that exists now, whereby households view the current amount of hydropower produced as the baseline level of air quality. Therefore a worsening in air quality from an incremental switch from hydropower to fossil fuel based power may require a minimum WTA measure for the reduction in air quality. Alternatively, a person might view the prior Congressional passage of the Grand Canyon Protection Act as setting a different baseline, and in this case it would be the WTP to maintain the maintain the current amount of hydropower and air quality associated with it.

Legal cases can and do change the assignment of property rights in some cases. The case of reducing Los Angeles' water right in order to protect Mono Lake under a broadening interpretation of the public trust doctrine transferred property rights to a portion of the water from Los Angeles to Mono Lake (National Audubon Society vs Superior Court, 1983, heard before the California Supreme Court). In theory, this would change the benefit measure from WTP for more water in Mono Lake to WTA to reduce the amount of water in Mono Lake.

However, in the case of water releases from Glen Canyon dam, the quantity of water is set by two laws. The overriding one is the Colorado River Compact which gives legal rights to downstream states to an average amount of water over a 10 year period. As such they are entitled to that water. This entitlement at the state level is further reinforced by individual water rights granted users under state water rights. It seems reasonable to take these as the status quo when performing an economic analysis. Thus in many cases it would be the water right holder's minimum WTA for leasing or selling some of their water. In water markets, the agreed upon price provides a starting point for estimating the WTA of the person for the quantity of leased or sold and likewise the WTP of the buyer for that quantity of water leased or bought.

The distinction between using WTP versus WTA would be of limited theoretical interest if not for the fact that economic benefits empirically quantified by the two measures can be significantly different. As such, there has been a great deal of academic debate in the journals over by how much of a difference between WTP and WTA values there are in theory versus practice. According to standard economic theory WTP and WTA should be fairly close for many public goods, where the change in WTP or WTA is a small part of income. Empirically there seems to be more of a difference than economic theory would suggest (Kahneman, et al. 1990; Horowitz and McConnell (2002, 2003) provide a comprehensive empirical review of the empirical studies as well as some possible explanations of the disparities). These divergences between WTP and WTA have been found in the lab experiences, many of which use real money. But the non lab experimental (e.g., field) comparisons have been fraught with difficulties in credibly measuring WTA, as most survey respondents are quite unfamiliar with offers by the government to pay people to forgo public goods.

Thus the general guidance for conducting non market valuation studies is to measure WTP (Arrow, et al. 1993; U.S. Water Resources Council, OMB, 2000, 2003, USEPA, 2010). Because of this guidance and the fact that a large majority of empirical studies measure WTP, we will emphasize that in our report. However, the reader should keep in mind, that in some cases minimum WTA might be the more appropriate measure of the change in economic well being for reductions in public goods, if the individual has a *legal right* to their current level of utility. The mere fact that an individual has historically enjoyed this level of public good, does not constitute a legal right that they are entitled to the current level of the public good. However, when conducting focus groups it is worthwhile to keep in mind that some respondents may feel they have a “right” to the current status quo, and hence should not be asked their WTP but rather their WTA.

Stated Preference methods such as the Contingent Valuation Method and Choice Experiments can measure Compensating or Equivalent Surplus directly. Most Revealed Preference methods (e.g., market demand, actual behavior based methods) measure Consumer Surplus. In most empirical applications a consumer surplus measure of WTP is a close approximation of Compensating Surplus (Vartia, 1983; Creel and Loomis, 1991). However, Revealed Preference methods such as site choice models based on the random utility model can also provide compensating measures. Some trip frequency Travel Cost Models (e.g., those based on count data models) may also provide compensating measures, while other specifications of the trip frequency model provide estimates of consumer surplus.

6. Addressing Whether Other Economic Effects are Non Market Values or Not

6.a Economic Efficiency Benefits and Benefit Cost Analysis

The use of WTP as a measure of the change in utility underlies what counts as a benefit or a cost in economic efficiency analysis or Benefit-Cost Analysis (BCA). The U.S. Bureau of Reclamation and

U.S. Army Corps of Engineers refer to their BCA as National Economic Development (NED) analysis (see U.S. Water Resources Council, 1983). Summary statistics for BCA or NED are the Benefit-Cost Ratio or Net Present Value (NPV). NPV is the present discounted (for timing) Benefits minus the present (discounted) Costs of the project or policy and on theoretical grounds, NPV is preferred to BCR as the appropriate measure of economic efficiency of a project (Gramlich, 1990: 41-42). Regardless of the measure used, the focus on net public benefits to the nation continues be the emphasis in the newer Draft Interagency Guidelines (2013: 19) that have accompanied the Principles and Requirements for Federal Investments in Water Resources (2013). More specifically, the Draft Interagency Guidelines (2013, 16) refer to OMB Circular A-4 which requires that benefits be measured by willingness to pay.

As the name National Economic Development implies, benefits and costs are treated from the view point of the nation as a whole. This is required by federal BCA and NED procedures (US Water Resources Council, OMB, 2003; USEPA, 2010). This also makes economic sense as the laws governing many of the projects (e.g., Endangered Species Act, Grand Canyon Protection Act), the agencies themselves (U.S. Bureau of Reclamation, U.S. National Park Service), and much of the taxpayer funds and revenues have a connection to the Federal government.

Effects on state level or multi-county economies is reflected in what the U.S. Bureau of Reclamation call Regional Economic Development. Development of water and power in one region has the potential to stimulate economic activity in both the short run and long run in that region. In the short run there is a gain *in that area* from more construction activity (e.g., hotels, restaurants, gasoline purchased locally). In the long run, there may be gains in employment in that area from the personnel needed to operate and maintain the facility. Regional economic models also calculate a multiplier effect in that local economy from the initial (direct) increase in expenditures. The IMPLAN input-output model is a commonly used approach for quantifying these multiplier effects on a county or multiple counties (MIG, 1997).

Generally speaking Office of Management and Budget (OMB, 2003) does not consider local employment gains or losses as national benefits or costs in conducting benefit cost analysis. In the OMB Circular A-4 costs are considered opportunity cost, which OMB also defines in terms of WTP to forgo a particular benefit. There is no discussion of multiplier effects or input-output models in their description of allowable benefits or costs.

OMB's reasoning for omission of employment considerations in benefit-cost analysis, is based on the longstanding and widley accepted principles of benefit-cost analysis (Gramlich, 1990: 63; Sassone and Schafer, 1978: 71). These books conclude that rarely would any gains in regional activity represents a net gain to the nation. In order for local gains to count as national benefits hinges primarily on whether there were unemployed resources available that could be employed in this project for the duration of the project. This in turn depends on the current and future state of the economy. If the country is in a prolonged recession, then during the time of the recession there would be less opportunity costs to the nation of employing workers in the construction and operation of the new development project. But the unemployed resources would either have to have the requisite skills or be capable of being trained to perform the needed type of work. If the country is not in a recession but the potential workforce is growing such that newly trained labor is entering the workforce, then these new projects may represent a net gain in output, *if* these workers would otherwise be unemployed. But if these conditions do not hold (i.e., there is reasonably full employment—defined by economists as an unemployment rate in the 4-5% range), then starting a new project in one location has an opportunity cost of reducing output where the labor is withdrawn from. Further, one question that must be asked is if there is limited funding for these projects, then the choice to build a project in County A may come at the expense of building the same or similar project in County B. In this case it is easy to see there would be no net gain to the national economy (Young, 2005). One county's gain in increase expenditures is perfectly offset by another counties loss in expenditures.

Finally, if there is a given amount of demand for a product, wherever a project is built to meet that demand, the project will generate economic activity there, but not somewhere else. This situation is illustrated by the decision of where to build a large coal fired powerplant, the Intermountain Power Project. Its original location was in Kane County, Utah, nearby Capital Reef National Park, and downwind of the powerplant was Arches and Canyonlands National Parks. As a result of concerns over air pollution violating the Class I air quality of these National Parks, the project was moved to Delta, Utah. In this case the employment to build and operate the plant was transferred from Kane County to Delta Utah, and from the State of Utah's perspective and that of the nation, there was not change in employment generated by the project.

Thus a gain in economic activity in one geographic location of the country due to inexpensive power in that area will come at the expense of a reduction in economic activity in other geographic areas. That is, if a rural county or particular area gains a new manufacturing plant, that means that plant is not built somewhere else. Thus the total amount of employment in the nation is the same, it is just a transfer of economic activity from one location to another. Therefore, most analysis of changes in employment are called economic impact analysis, to keep them distinct from economic efficiency analysis and Benefit-Cost Analysis.

6b. Distribution Does Matter in EIS's

However, the distribution of economic activity and other distributional issues based on race/ethnicity, low income, Native Americans, etc. do matter and are addressed in EIS's. In EIS's the local economic impacts of various alternatives are often calculated and displayed. Agencies are required to address Environmental Justice related to race/ethnicity, low income and Native Americans as required by Executive Order 12898. But again keep in mind, that a project in location A improves the well being of one group in location A means that this project is not able to improve the well being of people in location B.

Thus, a complete economic effects analysis should display these distributional economic consequences. However, general distributional concerns about the well being of others are not market nor non market values in the sense of economic efficiency. People may certainly care about the well being others. However, as noted in the Section 2, if Person A's concern is about the overall material wellbeing of others (e.g. food, shelter, access to medical services, etc.) then this non paternalistic altruism is *not* a non market value (Freeman, 2003; McConnell, 1998; Lazo, et al. 1997). Only if Person A receives utility from knowing Person B consumes the specific Public Good, then this paternalistic altruism would count as a non market value (Freeman, 2003; McConnell, 1998; Lazo, et al. 1997). Donating money to an elementary school general fund to pay help improve the school is a form of non-paternalistic altruism. This is in contrast to a donor that provides money with the condition that the money only be used for nature field trip to a state forest. Here the donor gets his/her utility from knowing the child is "consuming" nature. This is paternalistic altruism, as the utility is derived from ensuring that the recipient consumes a particular commodity or public good.

7. Conclusion

Based on our review of general economic theory, the theoretical literature on non market valuation, and its stylized application to hydroelectricity production and irrigation water several conclusions can be reached.

- Consistent with the principles of economics, an individual consumer receives utility/wellbeing from consuming a subset of private goods and public goods.
- Some public goods can produce non market **use** values when combined with private goods (e.g., fishing trips at public reservoirs and rivers).
- Some public goods provide non use or passive use values to some individuals.
- Depending on the location and wind direction, improved air quality can potentially have local non market use values and potentially non use values.
- The more substitutes there are for a resource the less likely non use value will be significant.
- The magnitude and geographic extent of non use values is an empirical matter.
- Not all public goods will be valued by all people.
- The economic efficiency benefits of market, non market use and non use values is usually measured empirically by what a person would pay for them, i.e., willingness to pay.
- Altruism toward others generates non market values if the source of altruism is paternalistic—a concern that other individual consume the specific public goods, not from a concern about their general material well being.
- Distributional concerns about the general well being of others are **not** economic efficiency benefits and hence should not be included in a Benefit-Cost Analysis (BCA) or National Economic Development (NED) account.

- Distributional concerns about employment should be displayed separately as an economic impact of the project or policy and not included in a NED or BCA.
- Depending on the location of where irrigation water goes (e.g., to fields adjacent to urban areas or along highways), *open space* maintained by profitable irrigated agriculture might produce non market use values associated with open space. This requires that if dryland agriculture is not profitable it might be developed for other uses. If it is not profitable to develop for suburban uses, then withdrawal of irrigation water will simply change the nature of the open space from irrigated to dryland, but not the fact it remains open space.

SECTION II
EMPIRICAL LITERATURE ON NON MARKET BENEFITS RELATED TO HYDROPOWER

As noted in the theoretical section, electricity produced from hydroelectric dams has both external non market costs to downstream fisheries as well as external non market benefits. The external non market benefits of hydropower over fossil fuel electricity production (primarily coal) include:

- Better air quality (health, scenic visibility)
- Reduced carbon dioxide emissions contributing to lessening of climate change
- Reliance on renewable energy

This empirical section of the report will review the empirical evidence on these values, and also help to identify gaps in the empirical literature. We will take the topics in order listed above.

A. Non Market Values of Air Quality

1. Health Costs of Fossil Fuel Based Electricity

It is widely acknowledged in the literature that emissions of SOx, NOx, and fine particulate matter from coal fired powerplants impose significant health effects (Rabl and Sapdaro; 2000; Krewitt, et al. 1999; NRC, 2010). These health effects range from premature mortality, which several authors quantify as life years lost, to hospitalization to asthma and bronchitis. Life years lost are valued using a "value of statistical life" which is calculated from both revealed and stated preference studies of the willingness to pay to reduce risk of premature death. Rabl and Sapdaro calculate that the health costs of coal are about three times that of natural gas. While these authors indicate that hydropower does not involve air emissions, they also note that there are ecological costs associated with hydropower.

The Clean Air Task force study performed by Abt Associates using standard EPA methodology found excessive death and hospitalizations associated with emissions from coal fired powerplants. What is of particular relevance to our analysis is that the health damages vary greatly depending on population density and proximity to the powerplants. The Task Force's map shows that the intermountain west and California have the lowest mortality effects from power plant emissions. Even the high end of their range of estimates is 5 premature deaths per 100,000 population as compared to upwards of 15-20 premature deaths per 100,000 population in the eastern U.S.

Turning to European studies of the environmental damage costs from fossil fuel electricity, Krewitt, et al.

reinforce the above point that damage costs per ton of pollution vary considerable depending on the site of the powerplant relative to population centers. Their study analyzes not only health effects (reduction in life expectancy, hospital emissions, etc.) but also materials damages from SO2 to metal and stone structures. They also include damages to crops in terms of reduced yield. Considering all these costs, they estimate an average damage in the European Union of 6.4 cents a Kwh and corresponding damages per ton of $6,000 for SO2, $5,000 a ton for NOx and $20,300 a ton for Particular Matter of 10 microns. Of course these estimates represent damages to a large number of people living in densely population areas, in some cases in close proximity to the powerplants. In Section 3 of this report we attempt to scale these to the intermountain west, by calculating damages per capita from the European Union study of Krewitt, et al and then scale back up using populations of the intermountain west.

Environmental Adders Approach to Include Social Costs of Fossil Fuel Electricity

A popular approach to empirically summarize all the external costs of fossil fuel electricity (mainly health but not limited to health) is called the Environmental Adders approach. Environmental adders reflect environmental costs of different electricity generation technologies. They were developed in the early 1990's to incorporate the differential negative externalities associated with different electricity generation methods. Thus, these adders consider environmental costs along with the more traditional capital and O&M cost. Environmental adders were adopted in 18 states as of 1990 (Ottinger, 1990), and were under study in an additional 8 states as of 1992 (Freeman, et al. 1992). Implementation of the environmental adder approach was slowed due to electricity deregulation (Keske, et al. 2012).

It should be noted that the general purpose of environmental adders is to provide a level playing field in evaluating new electricity generation (Keske, et al. 2012), not for application to existing projects.

There was some debate about how to calculate the magnitude of the adders in the face of existing regulation of criteria air pollution (Joskow, 1992; Freeman, et al. 1992). Nonetheless, seven states settled on monetary estimates of environmental adders (DOE, 1995). Wisconsin was focused primarily on CO2 and NOx. Other states such as Colorado, Oregon, Massachusetts, Nevada, New York and California adopted either point estimates or ranges of environmental adders for pollution such as NOx, SOX, PM10 as well so CO2.

Table 1a summarizes the specific externality values for different pollutants for California and Nevada. As can be seen the five main environmental adders are for SO2, NOx, and Total Suspended Particulates (or PM10), Volatile Organize Compounds (smog precursor) and Carbon Monoxide. These are the ones associated with the largest health effects. I have taken the values per ton and divided by the population of each state, to put damages per ton per million population. This facilitates transfer to the populations that would be affected by replacing a portion of the electricity produced from Glen Canyon Dam (GCD) with a coal fired power plant. Since these values are derived from studies that are nearly two decades old, it is likely that even adjusting for inflation does not result in precise estimates of current damages. This is likely due to the fact that the scientific understanding of the health effects of these pollutants has changed, and the preferences toward environmental quality and real incomes of the population may have changed as well. Thus as Boman et al. (2011) study indicates, estimates that are two decades old should be applied with some caution.

Table 1a. External Damages per Ton for Different Pollutants, by State

		Air Pollutant			
State	SO2	NOX	TSP	VOC	CO
California	$ 7,341	$ 14,925	$ 7,541	$ 6,932	N/A
CA/Million Pop	$ 229	$ 466	$ 236	$ 217	
Nevada	$ 2,808	$ 12,241	$ 7,525	$ 1,656	$ 1,656
NV/Million	$ 1,835	$ 8,001	$ 4,918	$ 1,082	$ 1,082
Avg/Million Pop	$ 1,032	$ 4,234	$ 2,577	$ 650	$ 541

State totals updated from 1992 dollars in Table 18 DOE 1995 report to 2012 dollars. Calculations of damages per million done by the author.

A 500 MW coal fired powerplant puts out 10,000 tons of SOX and NOX per year (Union of Concerned Scientists, 2013). So as one can see the damages per can be quite substantial even using the low end damages per million population from California.

Keske, et al. (2012) illustrates a comparative analysis of environmental costs and private costs for a variety of electricity generation sources. She finds that coal has an environmental cost per megawatt about twice what hydropower does (mostly ecological costs appear to be included consistent with Rabl and Sapdaro study that emphasize this point). Since Keske, et al case study focused on Colorado they have a more detailed report and spreadsheet calculator for Colorado environmental externalities. Keske, et al. (2012) approach of expressing the damages MWh facilitates more direct transfers to changes in production at GCD. Table 1b uses information from Keske, et al. to develop damages per MWh.

Table 1b. Air Quality Damages Per MWh per Million Population

	Tons per MWh		
	SO2	NOX	PM
Coal tons per MWh	0.000047	0.0002	0.00002
Average Damage per ton Per Million Population	$ 1,032	$ 4,234	$ 2,577
Damages per MWh per Million Population	$ 0.05	$ 0.85	$ 0.05

Tons per MWh from Keske, et al. 2012, damages per ton per million population from Table 1a.

This table should allow one to calculate the damages that might arise if a MWh of electricity from hydropower had to be replaced with a MWh of electricity from coal fired powerplant. To finalize the calculation the number of people downwind from the particular coal fire powerplant would need to be known. This may require some atmospheric modeling of where the emissions from the particular coal fired powerplant would travel to.

Below in the application of the empirical literature to the Glen Canyon area, we apply these results with respect to the Navajo Generating Station powerplant at Page, Arizona.

Abt Associates (2010) have one of the most detailed and well developed evaluation of particulate matter (PM2.5) health costs in the form of a Powerplant Impact Estimator. It includes health effects such as asthma, emergency room visits and hospital admissions. One of the key features of their software is that it facilitates accurate scaling up of the aggregate or total external health costs by the particular populations receiving the emissions from the particular powerplant. Their model accounts for air pollution emissions and dispersion so as to reflect the exposure of a county population to the location of a particular powerplant. This is a key point overlooked in most other environmental adder studies but mentioned in most of them as a note of caution: the magnitude or size of the environmental adder depends very much on the number of people affected in proximity to the power plant. This makes sense as pollution is essentially an environmental bad in the sense its damages are non rival. The more people affected, the greater the sum of the damages. Thus as previously noted in the report by the Clean Air Task Force report, many of the coal fired poweplants in the intermountain west are not by large population centers. Hence the environmental adders developed for places like California or other densely populated areas may significantly overstate the damages per ton occurring from intermountain west powerplants. Thus caution should be used when applying national estimates such as the NRC's (2010) average cost per kWh of 3.2 cents for coal and .16 cents per kWh for natural gas to the western U.S. These averages likely overstate the damages in the relatively sparsely population intermountain west (at least as compared to the densely populated east coast).

Environmental adders are perhaps most well developed and widespread in Europe. The European Union effort is known as ExternalE (Krewitt, 2002). Unlike the U.S. states which have assigned relatively low values to CO2, European Union has put larger emphasis on this pollutant. It is worthwhile pointing out this ExternalE effort made a preliminary investigation as to whether there were any external costs associated with depletion of fossil fuels such as coal, and found that depletion was almost too small to count (Krewitt, 2002). This is probably even more applicable to the U.S., where estimates of coal supplies stretch out more than a hundred years to as much as 250 years (Institute for Energy Research, 2013).

2. Improved Visibility at National Parks

There has been a long series of studies that have focused on improving air quality over National Parks, especially those in the desert southwest. These studies date back to the contingent valuation study of Schulze, et al.'s (1983) survey of households and Rae's (1983) contingent ranking valuation of air quality to visitors. Balson, et al. (1991) also conducted a study of the valuation of air quality over Grand Canyon in support of pollution control efforts at the Navajo Generating Station. A more recent study of WTP for air quality over desert southwest National Parks was performed by Industrial Economics (2013). Each of these is reviewed below.

Schulze, et al. (1983) applied the CVM to value an improvement in average visibility over just Grand Canyon National Park (GCNP) and then also for two other NP's Mesa Verde (MVNP) and Zion NP

(ZNP). Their in-person survey used photos of different levels of visibility over these areas. The payment vehicle was higher electricity bills. Residents in Denver, Los Angeles, Chicago and Albuquerque were interviewed. Their value elicitation method involved a precursor to the payment card where an individual circled their dollar amount they were willing to pay. Here we will focus on values of residents in the western U.S. Table 2 shows the values, updated from the 1980 survey to 2012 values using the consumer price index. What is evident is even in this early CVM study is that this study passed what is now referred to as a scope test, whereby WTP for the three National Parks exceeds the WTP for just Grand Canyon NP.

As can be seen in Table 2, the annual WTP values are significant for preserving the “current” (as of 1980) average air quality over these three NP’s from degradation. However, these values should be treated as indicative of the values not precise estimates of current day values, as the underlying studies are nearly 35 years old. In the last 35 years, preferences of the population toward values of air quality over national parks may have changed and household incomes have changed, possibly resulting in somewhat different values today (a general point raised by Boman, et al. 2011).

Table 2. Annual WTP per Household for Preserving the Current Average Air Quality ($2012)

Region	Annual WTP just for GCNP	Total Annual WTP for GCNP, MVNP & ZNP
Albuquerque	$137	$275
Denver	$124	$221
Los Angeles	$171	$322

(Source, Schulze, et al. 1983).

Rae (1983) conducted what is called a contingent ranking experiment to value avoiding an increase in moderate haze over Mesa Verde National Park. The contingent ranking method is an early version of the conjoint approach where respondents rank their combinations of visibility and cost to them from best to worst. This was a survey of visitors to the park. In the contingent ranking approach visitors sort cards that contain information on visibility and cost to them of higher entrance fees.

The benefit per vehicle for a guaranteed clear condition was $3 to $5 per vehicle in 1982 dollars (Rae, 1983: 225) or $8 to $14 in 2012 dollars. The range is due to which without improvement condition of air quality was told to the visitor. If the without payment scenario shown to the visitor was the current distribution of haze then WTP was $3 per vehicle for clear conditions. If the without payment picture had intense haze as the current air quality then WTP was $5 a vehicle for clear conditions. Thus the WTP amounts vary sensibly in that visitors are willing to pay more for larger improvements in air quality.

The Balson, et al (1991) study estimated the benefits of reducing air pollution over Grand Canyon National Park due to proposed improvements to reduce air pollution at the Navajo Generating Station in nearby Page, Arizona. A contingent valuation method study was employed. A variety of seasonal benefit estimates were made. These ranged from an improvement in the worst 10 winter days per year with an annual household WTP of $2.28 (with a median of zero), to upwards of $27 for improving visibility during both summer and winter. Winter only was valued substantially less at $6 per year.

Industrial Economics Inc (2013) conducted a choice experiment stated preference study to value different levels of visibility improvement in the four corner states. This region encompassed 15 Class I air quality areas. Class I is the strictest air quality level afforded National Parks and Wilderness areas. The authors used the choice experiment to isolate the value of the visibility improvement from other potential benefits of improving air quality such as health or ecosystem impacts. The visibility was illustrated using five photographs of air quality, and the number of days each year each level of air quality would be attained. The improvement in visibility was conveyed by an increase in the number of days of good visibility and correspondingly a reduction in the number of days of bad visibility throughout the year (365 days). The mail survey of 2,000 respondents in the main Four Corner cities (Albuquerque, Denver, Phoenix, and Salt Lake City) attained a response rate of 38.6%. The regression coefficient on cost is negative and statistically significant. This indicates internal validity, as the higher the dollar amount households were asked to pay, the less likely they were to pay. The annual WTP per household for a 5% improvement (progress to natural visibility) each year was worth $6. At the other end of the spectrum a 100% progress toward attainment of natural visibility was worth $88. This shows that respondents could distinguish between the distribution of visibility days across the years, and the choice experiment passed a scope test.

In sum, improving scenic visibility at National Parks and Wilderness areas has substantial value to households throughout the Four Corners region. This is apart from the value of the improved air quality to improving human health. Stated preference methods such as CVM and choice experiments are able to provide economically sensible results where larger improvements in air quality yield higher benefits than smaller increases in air quality. These values are not only held by visitors (Rae, 1983) but by households throughout the Four Corners states, even though the majority of them have not visited these National Parks, and are probably unlikely to visit all of them.

3. Benefits of Reducing Greenhouse Gas Emissions.

It is recognized that greater reliance on renewable energy to produce electricity will aid in efforts to slow climate change. Various sources of hydropower are an important part of the renewable energy sector (Kosnic, 2008). These include small or micro hydropower, adding turbines at existing dams and upgrading turbine efficiencies at existing hydropower dams (Kosnick, 2008).

There are several ways to determine the social benefits of reducing carbon emissions that would come from reliance on hydroelectricity as compared to coal fired power plants and to a lesser extent natural gas plants. These include: (1) the market value of a carbon emissions permit; (2) estimates of damages per ton of carbon; and (3) surveys of what the public would pay to reduce greenhouse gas emissions. In this section I review all three. In the application to Glen Canyon Dam section of the report (Section V) I will provide a comparison of the values derived from methods (1) and (2).

Description of the Carbon Markets/Carbon Auctions

Market purchase of carbon emissions permits or auctions of permits have become more common in the last decade. The European Union which adopted a mandatory cap and trade program was one of the first and most active. Companies must have sufficient number of emission permits to cover their CO2 emissions. California in 2012 has a CO2 emissions trading program associated with a phased-in reduction in industrial carbon emissions. The cap on each firm’s emissions gets tighter and tighter over time reducing about 2% each year and then 3% each year until it reaches a 15% reduction in 2020. Firms must have permits to cover their emissions, or face a penalty equivalent to buying four permits for every permit short they are to cover their emissions (Cal EPA, 2011). There is an active carbon exchanges in the Northeastern U.S. as well, although not legally binding as in California. On June of 2013 China launched its first pilot carbon trading program in one of its provinces (China Today, July 29, 2013).

Outside of California and the Northeast, and outside of Europe, the rest of the United States and the most of the world carbon markets (such as the Chicago Climate Exchange) involve transactions that are initiated voluntarily by companies/corporations. The motivations of the companies for doing this varies from being a good environmental steward (environmental corporate responsibility programs) or to begin "pre-compliance" with what companies believe will be forthcoming mandatory cap and trade programs. In the United States there are three such voluntary "trading areas": The Northeastern Regional Greenhouse Gas Initiative (RGGI), the Midwest, and the western US/western Canada. RGGI began its first formal auction in 2008 (Litz, 2008). RGGI describes itself as a mandatory, marketed based CO2 reduction program (see http://www.rggi.org/design). California began its in April of 2013 (Bosworth, 2013).

Allowable Projects to Generate Carbon Credits

Companies' demand for permits is related to their level of economic activity and their ability to internally reduce their emissions. The supply of permits can only come from approved projects designed to either offset carbon emissions (e.g., reliance on renewable energy projects) or from absorbing carbon, usually via planting forests. Which types of projects are allowable varies by the "rules" set by the organization capping emissions. For example in California only forestry projects, dairy digesters and destruction of ozone depleting substances are counted as generating allowable carbon reduction credits for sale (Cal EPA, 2011).

However, world-wide a far broader set of means of generating carbon emission reductions are allowable. Peters-Stanley and Yin (2013) found that in 2012 the main mechanisms of generating carbon offsets for sale were forestry (about one-third), wind and other renewable energy sources (about one-third), fuel switching from say coal to natural gas, and hydropower (at 12%) . Distinctions are frequently made within the hydropower sector between run of river hydropower and large hydropower projects (e.g., large hydroelectric dams). World-wide in 2012, these two different types of hydropower generated 5% and 7%, respectively of world wide carbon credits (Peters-Stanley and Yin (2013)). However in the U.S. the Federal Government (USDOE, 2008) and some states, only count new hydropower with preference given to run of river hydropower as generating renewable energy credits, not large hydroelectric dams. As discussed more in detail in the section on renewable energy credit, the rationale has been that there are external environmental costs imposed by large dams that may partially negate their CO2 reduction benefits. However, this emphasis on new generations is changing as several states are considering relaxing their state guidelines to allow large existing hydropower dams production to generate carbon credits.

Prices of Carbon Emissions Permits

World-wide Peters-Stanley and Yin (2013) found that in 2011 and 2012 that prices for permits allowing emissions of one ton of CO2 were between $5-6 a ton. However, there was a great deal of variability. In Europe the initial distribution of permits resulted in an oversupply and firms also found it less costly than expected to reduce their emissions internally. The result was lower emission permit prices driving down the average price as European purchasers represent about 50% of the transactions. The Chicago Climate Exchange had prices closer to $1 a ton in 2011/2012 (Peters-Stanley and Yin). U.S and Canada represent about one third of the transactions on the Chicago Climate Exchange. In contrast California's first auction with its legally binding carbon caps resulted in permit prices of $10 a ton (Bosworth, 2013). In China, the pilot project saw two companies (Petro China and Hanergy Holding Group) each buy 10,000 tons of carbon credits at $4.60 and $5 a ton (China Today, July 29, 2013).

Overall it appears the market value of reducing carbon emissions is between $5 and $10 a ton depending on whether: (1) the market is voluntary or mandatory, (2) the initial level of supply of permits; (3) the ease by which firms can reduce their own emissions to meet their or governments targets and (4) the particular market. At this point in time there is limited trading between carbon permit markets, especially between the California market and those outside of California, as the California market is focused on emission reductions in California, not elsewhere.

Estimates of the Social Damages from Carbon

Until the last 8 years there have been very few markets for carbon, especially in the U.S. Even with markets there have been limited number of transactions until recently. As noted in the previous section the prices for permits also reflect many of the institutional features of the markets themselves such as initial supply of permits provided and whether the market services areas where there are voluntary versus mandatory reductions. As such, the current market price for carbon may be an imperfect measure of the damages that another ton of carbon imposes on society. Therefore, economists have been estimating the damages that additional carbon emissions cause since the early 1990's (Ayres and Walter, 1991).

These damage estimates usually reflect damages of carbon emissions to agricultural productivity, human health, property damages from increased flood frequencies, and the reduction in the quantity and value of ecosystem services (USEPA, 2010; Interagency Working Group on Social Cost of Carbon, 2010). Many of these estimates come from published interdisciplinary research using what are called Integrated Assessment Models that combine projected increases in temperature with changes in precipitation, the resulting changes in the environment, and corresponding effects on economic sectors (USEPA, 2010).

Since a ton of carbon is relatively long lived in the atmosphere it causes the damages listed above for many years. As such the damage done by a ton of carbon is the present value or the sum of discounted annual costs over time. As is well known, the magnitude of the present value can be sensitive to the particular interest or discount rate used in the analysis. Thus EPA (2010) and the Interagency Working Group on Social Cost of Carbon (2010) provide a range of estimates that vary with the particular interest rate used. At the 5% discount rate (the highest one reported) the damage per ton of carbon in the near term is $5-6 a ton. However, at a lower interest rate of 3% the social cost of carbon becomes $21-$24 a ton. This is the range of values EPA and other federal agencies will be using in their benefit cost analyses of regulations that effect carbon emissions.

Since these estimates were based on the literature, they are within the range of damage estimates that Tol (2005) found based on his comprehensive evaluation of the published literature. A total of 28 published studies were found in the literature. These studies were authored by 18 independent research teams, and produced 103 distinct estimates of the social damages of carbon (Tol, 2005). His estimates reflect a median of $14 a ton and a mean of $16 at ton at a 3% discount rate. These estimates are in the same range as the estimates that USEPA and the Interagency Working Group on Social Costs of Carbon.

Thus it appears that a reasonable range of damage estimates from the literature would put the lower bound at $5 a ton, a middle range of $14-$16 a ton, and an upper range of $21-$24 a ton. As can be seen the lower range is similar to what many exchanges occur in the carbon markets.

Summary of Stated Preference Studies for Reducing Climate Change

Chronologically the first comprehensive survey of the U.S. adult population was conducted by Berrens, et al. (2004) and published in *Journal of Environmental Economics and Management*. Very large samples (over 2,000) were used in the analysis. Here the policy valued was one means of reducing climate change, via implementation of the Kyoto Protocol. In the full information treatment version of the web based survey, the respondent had access to 27 separate pages of summary information on topics concerning climate change. One of the sections was Consequences of Global Warming. Computer tracking of respondents indicated that about 2-3 pages of extra information were visited by the typical respondent. The household would pay for implementation of the Kyoto Protocol via higher gasoline and energy prices. The vote was an advisory referendum. The standard calculation of annual household WTP ranged from a low of $1280 to a high of $1760 per year (Berrens, et al, 2004: 357).

The next nationwide study was conducted by Lee and Cameron (2008) published in the journal *Environmental and Resource Economics*. They used a sample of 1,651 U.S. households to ask WTP for climate change mitigation programs. The with action on climate change program was keeping the climate as it is now and avoid climate change impacts. The household would pay primarily through higher energy taxes. The annual WTP to per household was to avoid "moderate harm" to Agriculture/Water and Oceans/Water, with the harm falling disproportionately on the poor, averaged $160 per year across Lee and Cameron's four scenarios. The annual WTP per household to avoid "substantial harm" averaged
$717 across the four scenarios, with a disproportionate effect on the poor. The fact that WTP changes substantially across going from moderate to substantial harm suggests the study passes an internal scope test and hence has some degree of internal validity. The four scenarios reflected whether income taxes as well as energy taxes were raised and whether other developing countries were asked to pay one-third of the costs of climate change mitigation. The primary limitation of the study was a low survey response rate (22%), but this was corrected for statistically by sample selection modeling.

Carlsson, et al. (2010) at Resources for the Future, a long time (50+ years) independent think tank in Washington DC, conducted a study of willingness to pay for mitigating the effects of climate change. This study (like Berrens, et al.) was conducted using an internet panel. As illustrated in their Table 1 (our Table 3), three scenarios were presented respondents.

Table 3, Carslon, et al. (2010) Stated Preference Study Valuation Scenario.

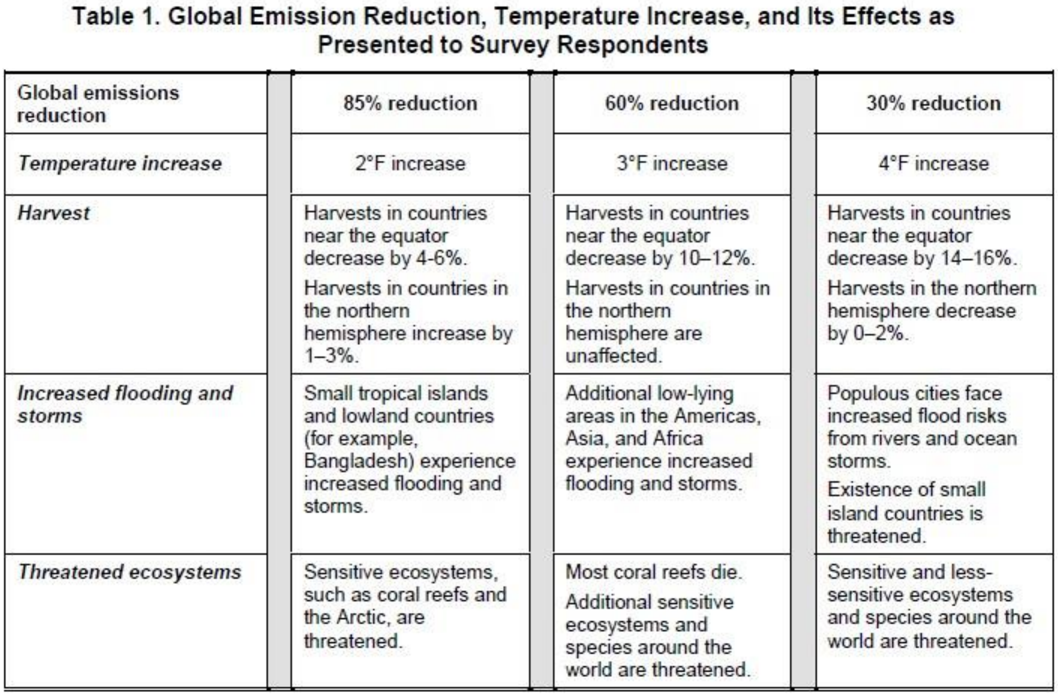


Table 1. Global Emission Reduction, Temperature Increase, and Its Effects as Presented to Survey Respondents

Global emissions reduction	85% reduction	60% reduction	30% reduction
Temperature increase	2°F increase	3°F increase	4°F increase
Harvest	Harvests in countries near the equator decrease by 4-6%. Harvests in countries in the northern hemisphere increase by 1–3%.	Harvests in countries near the equator decrease by 10–12%. Harvests in countries in the northern hemisphere are unaffected.	Harvests in countries near the equator decrease by 14–16%. Harvests in the northern hemisphere decrease by 0–2%.
Increased flooding and storms	Small tropical islands and lowland countries (for example, Bangladesh) experience increased flooding and storms.	Additional low-lying areas in the Americas, Asia, and Africa experience increased flooding and storms.	Populous cities face increased flood risks from rivers and ocean storms. Existence of small island countries is threatened.
Threatened ecosystems	Sensitive ecosystems, such as coral reefs and the Arctic, are threatened.	Most coral reefs die. Additional sensitive ecosystems and species around the world are threatened.	Sensitive and less-sensitive ecosystems and species around the world are threatened.

A payment card approach was used in which respondents circle their maximum WTP. Zero is one of the dollar amounts shown on the payment card. A monthly payment until 2050 was in the form of increased energy and gasoline prices. There were about 1,000 U.S. households in the sample.

About 25% of respondents were not willing to pay anything to reduce emissions and reduce impacts of climate change. U.S. monthly WTP for the smallest reduction in emissions and largest remaining impacts was $17 monthly ($204 annually). WTP for the moderate reductions, was $28 monthly ($336 annually). The WTP for the greatest (85%) reduction in emissions and avoidance of widespread large impacts except minor impacts to agriculture and to just the two most sensitive ecosystems (coral reefs and the Arctic), was $36 per month ($432 annually). The rank ordering of the increasing WTP for larger emission reductions and avoiding severe impacts suggests this study passes an internal scope test and hence has some internal validity.

Valuation of a smaller reduction in greenhouse gas emissions (17%) was studied by Kotchen, Boyle and Leiserowitz (2011) in a National Bureau of Economic Research working paper. Using a large sample (2,034 respondents), an internet panel survey was conducted. A dichotomous choice WTP question was asked for one of three climate reduction policies: (a) cap and trade program; (b) carbon tax; (c) Greenhouse gas regulation. Annual household WTP ranged from a conservative $58 to $79 for the cap and trade program as the means to achieve the 17% reduction in emissions. Annual household WTP ranged from $63 to $85 for the carbon tax, and was the highest for Greenhouse gas regulation at $70 to $90 per household.

Atker and Bennett performed an internet survey of 634 households in New South Wales, Australia, regarding their willingness to pay for a Carbon Pollution Reduction Scheme. Increased prices of goods and services were used as the means of payment. Respondents were asked what they expected the rise in temperature to be in Australia by 2100 with and without the Carbon Pollution Reduction Scheme. They were also asked about the major impacts that Australia may suffer in absence of the Carbon Pollution Reduction Scheme. The respondents perceived about a 1^{o}C (1.8^{o}F) reduction in temperatures with the implementation of the Carbon Pollution Reduction Scheme. A majority of responses indicated decreases in water supply and agricultural production as well as damage to the Great Barrier Reef (Atker and Bennett, 2011: 424). Four WTP estimates are presented across two logistic regression model specifications and two scenarios about global cooperation with Australia’s efforts. The range was a low from $16 to a high of $69 with an average of $44 AUD annual WTP per household, or $48 US dollars.

Table 4 summarizes the studies reviewed in order to provide an overview of the studies and evaluate patterns in the responses.

Table 4. Summary of Willingness to Pay to Reduce or Slow Climate Change

Authors	Year	Sample Size	Climate Scenario Valued	Annual WTP per household
Berrens, et al	2002	2,000+	Implement Kyoto Protocol	\$1280-\$1760
Lee & Cameron	2008	1,651	Avoid moderate harm	\$160
Lee & Cameron	2008	1,651	Avoid substantial harm	\$717
Carlsson, et al	2010	1,000	30% reduction in emissions, accept +4^{o}F & geographically widespread harm remains.	\$204
Carlsson, et al	2010	1,000	60% reduction in emissions, accept +3^{o}F & significant harm to some areas remains	\$336
Carlsson, et al	2010	1,000	85% reduction in emissions, accept +2^{o}F & harm to only limited geographic areas & a few natural resources	\$432
Kotchen, et al	2011	2,034	17% reduction in emissions	\$79-\$89
Atker & Bennett	2011	634	Australia; avoid +1.8^{o}F increase in temperature and adverse affects to agriculture, water & Great Barrier Reef	\$48

Overall, the general pattern of results shows that larger emissions reductions and avoidance of larger impacts results in higher WTP.

4. *Economic Effects of Air Quality on Agricultural Production, Agricultural Worker Productivity and Environmental Effects of Air Pollution on Water Quality*

4a. Air pollution on agriculture: Air pollution can cause market effects on agricultural production through reducing crop yields (Westenbarger and Frisvold) and on agricultural worker productivity (Graff Zivin and Neidell, 2011). Westenbarger and Frisvold (1995) found effects for soybeans and corn in the eastern U.S. Leung, et al. (1982) have found effects of air pollution on crops in Southern California including alfalfa, lettuce and tomatoes. Since these values are not expressed on a per acre basis it is difficult to develop per unit value estimates that can be transferred to other locations. Nonetheless, even just these two studies suggest significant market benefits from reducing air pollution, particularly from ozone precursors such as NOx.

4b. *Air pollution on worker productivity:* Related to reduction in crop yields, is the reduction in agricultural worker productivity from air pollution. In particular Graff Zivin and Neidll (2011) find that air pollution (particularly ozone) reduces agricultural field worker productivity in a statistically significant fashion in the Central Valley of California. Hence, the net value of crop production is reduced (in addition to the health effects borne by these workers).

4b. *Air pollution on water quality:* Nitrogen deposition from air pollution can result in increased nutrient concentrations in water bodies, especially lakes. The addition of this extra nutrients can kick off a cascade of related effects such as more algal growth. Besides the resulting change in lake color toward a more green tint and loss of water clarity, the increased nutrients can result in reduced dissolved oxygen with can reduce desirable fish species such as trout. Studies by CH2MHill (2013) for Utah indicate that households with recreation users would pay $36 a year to prevent a nutrient induced deterioration in water quality and $96 a year to improve water quality. Non user households would pay $24 a year to avoid deterioration of water quality from nutrients. This suggests significant non market recreation use values and non-use values for reducing nitrogen deposition from fossil fuel production.

5. *Hydropower as Renewable Energy*

Clearly, hydropower is a renewable energy source, as the water supply is replenished annually through the hydrologic cycle. States have increasingly adopted renewable energy portfolio standards that require a certain percentage of electricity be generated by from renewable sources. As Kosnick (2008) notes only

3 states had these standards in 2003, but by 2008 28 states had these standards. While hydropower is clearly a renewable energy source, what particular types of hydropower counts is a matter of regulatory definition.

What types of hydropower can be counted in meeting Renewable Energy Standards?

a. Federal Government

The federal government issued in 2008 (U.S. Department of Energy, 2008) Renewable Energy Requirement guidance that includes hydropower. For the federal government, only "new" capacity qualifies, and their definition of new is placed in service after January 1st 1999. This new capacity that qualifies is either from increased efficiency or addition of new capacity at an existing hydroelectric project. Thus any recent increases in Glen Canyon, Flaming Gorge or Hoover Dam efficiencies would qualify as contributing to meeting renewable energy requirements.

b. State Governments

While hydropower is considered a renewable energy source by nearly all the 30 states with a renewable portfolio standard or RPS (Stori, 2013), there are significant restrictions on the counting of credits from existing hydropower or from hydropower that is not from "run of the river" facilities (i.e., hydropower facilities that divert water out of the stream/river). As Stori (2013: 2-3) notes, "The predominant limiting factor to hydropower RPS inclusion is age. RPSs generally give the highest priority to new or recent renewable energy development, thereby excluding most hydroelectric facilities given that most were installed decades ago. In addition, because of concern over the ecological impacts of large dams, large hydropower (most frequently defined as greater than 30 megawatts (MW)) is limited in inclusion in state RPSs." However, there is currently some discussion about relaxing these restrictions in states such as those in New England and the Pacific Northwest (Stori, 2013: 3).

To the extent that hydropower is eligible under state and federal guidelines as a power source for meeting renewable energy standards then hydropower is eligible to supply Renewable Energy Credits/Certificates (RECs). There are two renewable energy credit markets. These are segmented into voluntary markets were firms can purchase these for any number of reasons (e.g., green marketing like some ski areas and other companies do) or compliance markets for utilities located in states with legislative or regulatory renewable energy standards. Interestingly enough in national voluntary markets

RECs have been selling for about $1 MWh (DOE, 2013) about the same price as in the compliance markets in the seven states currently with standards and that allow utilities to use RECs (DOE, 2013).

Role of Hydropower in Facilitating Other Forms of Renewable Energy

Even in states where large existing hydroelectric dams are not counted and hence do not generate renewable energy credits, EPRI (2013) suggests that hydropower still plays a role in facilitating great adoption of allowable renewable energy sources such as wind and solar. This is because wind and solar have short run variability in their generation of electricity due to wind patterns or amount of solar radiation. As such hydropower, with its low start up and shut down costs, can be used as a "backstop" or to fill the gap when there is a drop in wind and solar generation. This service of hydropower may be more valuable than the traditional value of hydropower when it is used to meet base load power needs (EPRI, 2013, xii). However, the authors note this value is "…not easy to quantify." (EPRI, 2013, xii). When the EPRI report talks about value, they are generally referring to profits, revenue or income, not non market values. As they suggest, utilities with growing wind and solar generation capacity would likely pay more for availability of hydro to fill the gap than they had in the past. Thus if financial models of the value of filling this gap in terms of increasing electricity supply reliability are developed the estimates would likely be reflected in market bids or transaction prices for hydropower.

Non Market Benefits of Renewable Energy

With increased interest in renewable energy has come efforts among environmental economists to quantify what households would pay for renewable energy, particularly renewable electricity. Here we describe the studies and provide a summary of the results. While none of these studies value of hydroelectricity as a renewable energy (an important empirical gap in the literature), these empirical studies have important implications for potential renewable energy benefits from hydropower.

Descriptions of the Studies: In the last decade there has been a series of stated preference studies on household willingness to pay (WTP) for renewable energy programs. Some of these studies simply value generic programs for green or renewable energy (Ethier, et al. 2000; Vossler, et al. 2003; Weiser, 2007; Brochers, et al. 2007). Mozumder, et al. (2011) emphasizes windpower primarily but also mentions solar in his study in New Mexico. Their value of $15 a month is for attaining 20% renewable energy in New Mexico (Mozumder, et al. (2011: 1125). They note that currently only 5% of NM's customers served by the largest utility (serving half the households in the state) voluntarily pays extra toward renewable energy (Mozumder, et al. 2011:1120). Others value the attributes of the green energy program such as reduced air pollution (Bergman, et al. 2006, 2008; Whitehead and Cherry, 2007; As noted later, this fact that survey respondents already include their values of reduced air pollution when answering CVM WTP questions for renewable requires caution to avoid double counting of the reduced air pollution benefits of when valuing hydropower.). Other surveys value a specific form of renewable energy such as wind energy (Champ, et al, 2001). In most cases households are told they will pay through higher monthly utility bills.

Summary of Results: First it should be noted that not all households would be willing to pay a higher utility bill for renewable energy. In particular, the stated preference studies from 2000 to 2009 show that between 50% to 80% would **not** pay anything additional on their utility bill for renewable or green energy. This is consistent with actual voluntary utility programs where only a fraction of households actually sign up for such programs when offered. While most of the recent data I could find is fairly old, dating from 2000, at that time between 1% and 13% of U.S. and other developed countries (e.g., European countries, Australia, Japan) residential customers actually signed up to pay higher utility bills for renewable energy (Bird, et al. 2002).

However, of the households that indicate they would pay or sign up, the WTP is significant. In particular the low end willingness to pay of those that would buy renewable electricity would pay $5-$8 per month (Longo, et al. 2008; Whitehead and Cherry, 2007; Either, et al. 2000) to $12 to $20 a month (Champ, et al. 2000; Mozumder, et al. 2011; Bergman, et al. 2006). The variation in WTP in part reflects what households were told about the environmental improvements they were "buying" through reliance on renewable energy. Table 5 summarizes the key findings from each of the studies.

Table 5. Summary of Stated Preference Study WTP Results for Renewable Energy

Study	% WTP>0	Average Monthly WTP per household of those WTP>0 ($2012)	Good Valued	Study Area
Bergman, et al (2006, 2008)	NA	$17	Reduced env impacts including reduced air pollution	Scotland
Champ, et al. (2001)	24%-43%[1]	$12	Wind Energy	Wisconsin
Ethier, et al. (2000)	20%-35%	$8	Green Energy	New York
Longo, et al. (2008)	NA	$5	Reduced CO2, power reliability	England
Mozumder, et al 2011	NA	$15	Renewable energy (primarily wind energy)	NM
Nomura, et al. 2004	NA	$23	Green Electricity	Japan
Whitehead & Cherry, 2007	55%-61%	$5	Improved air quality from green energy	NC
Wiser, et al. 2007	36%-49%[1]	NA	Renewable Energy	US
Yoo, et al. 2009	16%	$2-$2.51	Increase % of Green Energy	Korea

1. Ranges indicate different survey versions (e.g., Champ, et al) or different survey scenarios (e.g., Wiser, et al.).

Overall a significant portion of the general public indicates some positive willingness to pay a higher utility bill for renewable energy. However, combining households that will not pay any premium with the households whose WTP is lower than the minimum premium utilities require to sign up for green energy results in relatively low actual sign ups (with the top ten sign ups ranging from 2% to 7% during the 1999 to 2002 time period http://apps3.eere.energy.gov/greenpower/resources/pdfs/nrel_35618.pdf). By 2007, the median participation rate had increased to 8%, although none of these cities were in Arizona (http://apps3.eere.energy.gov/greenpower/resources/tables/topten1210.html. Some of these low signs up may be due to less awareness of the actual program by consumers, and the transactions costs of signing up for the actual program as compared to the survey setting. That is, the survey setting provides a description of the program and it was easy to indicate if you would sign up. Nonetheless, in some study areas there is a sizeable WTP in areas such as Wisconsin and New York. It should be noted that 860 utilities in the U.S. offer what DOE calls Green Pricing options to consumers to pay an additional amount on their utility bill to cover the incremental cost of the utility contracting for or investing in additional renewable energy (http://apps3.eere.energy.gov/greenpower/markets/pricing.shtml?page=0).

There are five Arizona utility companies that offer the green pricing program. At the low end, the extra cost per kWh ranges from .4 cents a kWh from Arizona Public Service to .8 cents kWh for Tri-State Generation and Transmission through Columbus Electric Cooperatives (where the renewables come from wind and hydropower). In 2007, Arizona Public Service also offered customers the opportunity to buy blocks of power for 1 cent a kWh premium (http://apps3.eere.energy.gov/greenpower/markets/pricing.shtml?page=2&companyid=44. At the high end is 3 cents a kWh from the Salt River Project (where renewables come from Photovolataics, wind, landfill gas, small hydro and geothermal). (See http://apps3.eere.energy.gov/greenpower/markets/pricing.shtml?page=1 for more details.)

In sum, a segment of consumers value renewable energy for its many positive attributes enough to sign up and pay a premium. The non market benefits of renewable energy are the health damages avoided and CO2 damages avoided from reliance on renewable energy instead of fossil fuels such as coal in particular. There has not been any willingness to pay studies for hydropower as a renewable energy source however.

A note of caution brought up by two reviewers regarding estimating household WTP for renewable energy in general, and hydropower in particular, is the potential for double counting. In particular, some (perhaps all) of the WTP by a household for renewable energy is probably due to avoiding the air pollution damages and CO2 emissions. If survey values value renewable energy, and then adds to it the damages avoided from relying on hydropower this would double count avoiding air pollution damages and CO2 emissions.

SECTION III.

NATIVE AMERICAN, ABORIGINAL AND INDIGENOUS RESOURCE VALUATION.

Two different perspectives can be taken here. The first is the values the native people have themselves for their natural and cultural resources. The second is the value of these Native American natural and cultural resources have to non-native (e.g., white, African American, Hispanic) Americans. In particular, as was discussed in the section on theory, non-native Americans may derive utility from paternalistic altruism toward others, and in this case Native Americans. Specifically, non-native Americans may get utility from providing Native Americans specific natural resources (e.g., irrigation water) in order for those tribes to continue to farm on their Reservation. This section will review and discus both of these sources of values of Native American resources.

However, it should be noted at the outset that no conceptual or empirical studies were found on Native American values for electricity or hydropower. So this summary is what is available on how they value their own resources and how non Native Americans value Native American resources. Since so little is done on this topic is an important area for future research.

Both Duffield, et al. (2002) and Hammer (2002) note there has been very little valuation work done on Native American’s values of their own resources or the public’s values for Native American’s resources. Even looking internationally there are only a few studies that we will review here.

We will start with Hammer, 2002 as she provides an overview of the challenges in economic valuation of Native American (NA) cultural resources. Many traditional tribal members hold strong religious and cultural beliefs about natural resources that often do not allow for trade-offs between money and the natural resources. If tribal members are unwilling to make trade-offs this would make economic valuation nearly impossible.

However, tribal members do consumptively use resources in the sense of hunting, fishing and timber harvests. But they attempt to balance their consumptive use with preservation of the resource stock (Hammer, 2002). Also, actions of many NA tribes and tribal members indicate they do make trade-offs between resources. Duffield in 1997 used the fact that tribal members trade off working in the market for a wage rate for spending more time (and in some cases all their work time) pursuing subsistence activities instead.

My tentative conclusion from Hammer's review and the empirical studies discussed below is that tribal valuation of ***incremental*** changes in natural and cultural resource availability may be possible with Tribal members. But the economists need to avoid attempting to estimate a total value of cultural and natural resources as this is not possible. It may very well be that while tribal members will trade off small gains or losses in natural and cultural resources for money, there is some minimum level needed for continued cultural and traditional practices for which they would not accept any amount of money. Once the resource diminishes to the point it endangers their ability to continue their important cultural practices and transmission of cultural traditions from one generation to the next then there is likely to be no acceptable trade off to tribal members (Duffield, et al. 2002). Attempts at valuation in such a situation may be unusually challenging. In addition, incremental values or the change in values "with vs without" some management action or impact is more relevant for decision making than estimating the total value of cultural and natural resources to Tribal members.

An example of a study that estimates the tribal values of natural resources and associated cultural practices from tribal members is Duffield, et al. (2002) for the Penobscot River in Maine. The river had been polluted with dioxin from a old paper mill that had contaminated fish to the point where they were unsafe to eat.

The purpose of his survey was to estimate the damages to the tribe from not being able to consume fish they would catch from the Penobscot River, and the associated loss of cultural practices surrounding a "fish meal" and related activities involving fish (Duffield, et al. 2002). Duffield et al. cast the loss of the traditional fish meal as having a use value in that alternative protein food sources had to be substituted for the fish meal. He conceptualized that the loss of traditional practices associated with fishing and the transmission of these traditions to the children was more of a passive use value that the Native Americans themselves hold.

Conducting a phone and mail contingent valuation survey of Penobscot Tribal members was plausible since the Tribe had twice in the recent past conducted actual referenda to decide upon important tribal issues involving monetary amounts. In particular a vote had recently taken place on whether to accept a given amount of money in exchange for relinquishing claims on certain lands the tribe viewed as Tribal land in Maine.

The design of the valuation question followed a referendum format were the tribal member was asked whether they would vote to ***accept*** a one time payment for slower natural restoration of the river from pollution (expected to take 30 years) versus not accept the money and receive an accelerated recovery in two years. In this case the fish would be safe to eat in two years instead of 30. Notice Duffield, et al. asked a minimum willingness to accept question rather than willingness to pay, since Duffield et al (and no doubt tribal members) believed they had property rights to an unpolluted Penobscot River for purposes of fishing.

The survey was done of all tribal members (about a thousand). Some tribal members were interviewed over the phone and others sent mail survey. Combining responses to both survey modes a very high response rate of 79% was attained.

The median lump sum payment needed to compensate for giving up the accelerated recovery of 2 years for natural recovery in 30 years was $14,000 per tribal member. Duffield also asked half the survey respondents their willingness to accept a lump sum to forgo a slower active recovery program that would only make fish safe to eat 20 years from now instead of natural recovery in 30 years. Given that this active recovery would only make fish consumption safe 10 years earlier than natural recovery, the lump sum WTA reflected that with a median value of $3,000 instead of $14,000 to forgo safe fish to eat in two years.

Duffield concluded that this CVM study was able to successfully obtain willingness to accept values from tribal members themselves because of the prior experience of the tribe with trading off tribal resources for money. I believe it is a testable hypothesis that one might be able to elicit economic behavior in a CVM referendum survey from tribal members if the Tribe routinely has a general election to a tribal council or other tribal governing body.

Gonzalez-Caban et al. (2007) used a multi-mode, phone- mail booklet and follow-up phone interview of the Kootenay-Salish tribe in Montana to find out their value for reducing the risk of wildfire on their reservation lands. In particular, a CVM survey asked Native American households what they would pay for prescribed burning and forest thinning to reduce the risk of wildfires. The research team worked with the locals in the area to develop the survey with a focus group on the survey to make sure it was sensible to tribal members. The means of payment in the survey was payment into a trust fund. The WTP question was framed as a voter referendum.

The response rate was 74%, a very good response rate made possible in part by coordination with and the buy in of the Tribal Council. In addition, there was low (less than 10%) protest responses to the WTP question by Tribal respondents. Protests were identified as those that would not pay even $1. The most often cited refusal to pay $1 for prescribed burning was "someone else should pay" and mistrust of government. For the mechanical fuel reduction (thinning) additional protest reasons included that "thinning was ecologically damaging" and "program won't work"(Gonzalez-Caban, et al. 2007: 57). The coefficient on the dollar amount the respondents were asked to pay was negative and statistically significant indicating that tribal members were using economic reasoning as the higher the dollar amount asked to pay the lower the probability they would pay.

The results indicate that Native American households would pay about $135 per year for a prescribed burning program, and about $305 per year for a mechanical forest thinning program. These values were similar to what the authors obtained from non Native American households in Montana for the same programs on non tribal forests in Montana (Gonzalez-Caban, et al. 2007). The authors felt the CVM study worked reasonably for Native Americans for this forest fire reduction program.

Rolfe and Windle (2003) look at the values of Aboriginal cultural heritage sites in Australia. In particular, they not only obtained the values for protecting aboriginal cultural sites for Aboriginals themselves, but also asked a willingness to pay question of non-Aboriginals in towns near the cultural heritage sites and those living far away in the city of Brisbane. Rolfe and Windle (2003:4) make the point that cultural heritage sites may have non use values to those living in distant cities.

As a result of the potential for non use values, Rolfe and Windle use a stated preference method called a choice experiment to value protection of (depending on the scenario) 25% to 55% of currently unprotected aboriginal cultural sites. The other attributes in the choice experiment was related to water and included: (a) condition of vegetation in the waterway; (b) kilometers of waterway in good ecological health; (c) amount of water that remains unallocated (and presumably available for instream flows). Due to several of the attributes being water related the payment vehicle was increased water rates or water bills.

A total of 63 Aboriginals participated in the survey, yielding a response rate of 56%. The sample for local towns was 100 (80% response rate) and city of Brisbane was 58 (response rate of 70%). Thus while the samples are relatively small, the reasonably high response rate would suggest they may be representative of the respective populations.

The choice experiment format involves respondents selecting one alternative that has, in the respondent's eyes, the best combination of percentage of aboriginal sites protected and km of streams protected for the money they are asked to pay. The results suggest that for aboriginals, each one percent increase in cultural sites protected was worth about \$3 per month. However responses by non aboriginal households suggested that on average they would not pay, and that each percentage increase in sites would require compensation of about \$2 a month. A similar relationship holds for city of Brisbane resident at \$1.78 per percentage point protected per household. However, by treating the percent sites protected as an attribute in the choice experiment involves estimating one coefficient and hence one marginal value. To allow for more flexible estimation of the marginal value of the attribute, the authors used what is called effects dummies for the different levels (high, medium, low) of percentage of aboriginal cultural sites protected. These results show that non aboriginal households do value low levels of additional protection, but still have negative values for large increases in the percentage of non aboriginal sites protected.

As can be seen there has not been any valuation work on Native American's natural and cultural resources to non native Americans (e.g., whites, Hispanics, African Americans). Given the large of number of non native households, even small values per household could result in potentially large values.

SECTION IV MARKET AND NON MARKET VALUES OF WATER

A. Market Values of Water

Water resources can be characterized in many ways. Water has elements of being a private good (e.g., rivalness in use—one farmer's use reduces the amount available to another farmer; one homeowner's use of water for their lawn, reduces the amount available for another homeowner). But water also has characteristics of a public good as well, in that many people can derive benefits simultaneously from flows in rivers or water in lakes (e.g., water based recreation and non-use/passive use values). Thus water has both market and non market values. Some would add a third dimension that water has a social value that transcends economics. As such, in many areas of the U.S., water markets are not as developed as markets for other resources such as natural gas or electricity. But the scarcity and value of water has resulted in emerging formal and/or informal markets for water. Where possible we will rely upon evidence from these markets and associated transactions to estimate the economic values of water in their private good uses.

However, market values only reflect the value of the last units of water purchased by farmers. For our analysis of small changes in the amount of water likely to arise from any changes in the operation of Glen Canyon Dam, these market prices may be sufficient. However, ***if*** large changes in the supply or timing of water to irrigators were to arise, the market values will understate the value of these inframarginal units of irrigation water. Thus other methods such as residual imputation and optimization models would be necessary to calculate the WTP (i.e., producer surplus) of these inframarginal units of water. Unfortunately the literature provides very few empirical estimates for the crops grown in Arizona, and most of those estimates are quite old (see Shaw, 2005: 154-155 for a summer of these studies from the 1970's and 1980's). Only Schuck and Green (2004) provide recent estimates, and these are for the Central Valley of California. None of these studies look at the effects of timing of when a given amount of irrigation water is available. In the short run (within season) changes in timing of water may have higher values than in the long run (across multiple seasons)—see Young (2005) for more discussion. Therefore, one year lease values of water may be more appropriate for evaluating short run changes in the value of water, and sales of water rights more useful if there will be more permanent changes in water availability due to operations of Glen Canyon Dam. Further, the presence of the very large reservoir in the form of Lake Mead, may be able to moderate how direct changes in flow releases (e.g., timing) would have on downstream irrigators—a point brought up by one peer reviewer.

In this first section we focus on market values of water in irrigated agriculture and municipal/industrial uses as a private good for diversion and consumption. We emphasize the economic values of irrigation water because the vast majority (85% to 90%) of water use in the west occurs in irrigated agriculture (Young, 2005). The value of water is low enough in general crop production (e.g., corn) that as demand for water grows in cities, municipal water users can bid away a fraction of water from irrigated agriculture. Thus we study municipal water values second. In both irrigation markets and municipal water markets water prices or lease rates may not reflect the full WTP of a farmer or WTP of the consumer for incremental changes in water. I say incremental, as this analysis values a change in water quantity from a "with some action versus without some action/status quo", not with or without water as it is rare for the change to involve selling or leasing all one's water.

In addition, the non market values of river and reservoir recreation is discussed in detail below. However, this chapter does not discuss the non-market use and non-use values of maintaining minimum instream flows. The reader interested in this topic should see see Ward, (1987) and Loomis and McTernan, (2014) for recreation, and Berrens, et al. (1996) for such a discussion of non-use values of minimum instream flows for endangered fish.

1. Irrigation Water Valuation from Direct Observations of Water Markets

Direct analysis of water transactions between willing buyers and willing sellers in markets for both short-term leases and permanent sales can be a useful source of information on water users' valuations of irrigation water. However, these prices do not reflect the full WTP of the buyer. This would be measured by the buyer's producer surplus (Young, 2005: 55-56). Producer surplus is the total revenue the buyer will realize when they sell the incremental amount of the crop produced from this incremental amount of water minus their variable costs of production. Producer surplus is analogous to consumer surplus that has previously been discussed and will be evaluated on the municipal water demand side.

First we will review what water markets tells us regarding water values for irrigation water.

Lease markets for irrigation water. Data on short term (usually one year) water leases can be obtained from primary or secondary sources of data. Secondary sources of data in the U.S. include transactions in one of the many state run or state sanctioned water banks. These banks act as "clearing houses" to match buyers and sellers of water. Some such as the California State Water bank, lease water directly from farmers and then lease it to buyers such as other farmers and cities.

Secondary data from water districts can be another source of information on water market transactions. For example, the Northern Colorado Water Conservancy District (2013) reported that winning bids by farmers for one year agricultural water leases of additional/supplemental irrigation water from the Colorado Big-Thompson (CBT) project have been the in range of $10-$20 an acre foot from 2010 to 2012.

Annual lease rates for water tend to fluctuate widely with local climatic and water supply, reflecting a short-term demand for water that is quite price-inelastic. Hence using lease rates from only a few years to infer long-term valuation is tricky. However, using data from the *Water Strategist* (http://www.waterstrategist.com/) information on water leasing in the western U.S. from 1990 to 2003 (Brown, 2006) and 1990 to 2008 (Hansen, et al 2012) have been summarized and subject to econometric analysis. Agricultural user to agricultural user leases water volume weighted ***average*** lease prices were $89 per acre foot over the 1990-2008 time period in the 12 western states studied by Hansen, et al. (2012).

However, Brewer, et al. (2008) using similar data found that 1 year leases had ***median*** prices that were much lower at $10.68 per acre foot. This substantially higher average (or mean) value compared to the median suggest a skewed distribution in water lease prices with some agricultural water leases having very large values. Hansen, et al. identifies the 2006-2008 time period as a time when average agricultural lease values averaged $486 per acre feet, although it is not clear if that reflects a one year or multiple year lease as it exceeds municipal lease values during that time period.

Of greatest relevance to our study area is that average lease prices for water in agriculture in Arizona are $68 per acre foot and in California $119 per acre foot (Hansen, et al. 2012). But using earlier data, Brewer, et al. (2008) found that one year agriculture to agriculture leases averaged $33 an acre foot in Arizona and $39 in California. However, agriculture leases to urban uses averaged $55 per acre foot in Arizona and $83 per acre foot in California during the same time period. It should be noted the averages for California are statewide averages and do not reflect what are significantly higher values of water in Southern California where much of the Colorado River water goes to. However, there are very few transactions in Southern California. One of those transactions involves Colorado River water in the Imperial Irrigation District (IID). This irrigation district annually transfers (leases) 200,000 acre feet of water to San Diego for municipal purposes at a price of $258 per acre foot (www.wdcwa.org/water-transfer).

Market Prices for Perpetual Irrigation Water Rights. Time series data on prices for perpetual water rights are increasingly available for analysis. Water right prices are long-run and at-source values because buyers and sellers presumably account for all production, processing, and conveyance costs in their calculations of willingness to pay and to sell. Transactions for perpetual water rights are capitalized values, reflecting the anticipated present value of future net benefits.

Using data from the *Water Strategist* from 1990-2008, Hansen, et al. (2012) found that there were a substantial number of water right sales for all types of uses (about 2,000 transactions) and about 1.5 million acre foot sold during this time period in the 12 western U.S. states. Data on the purpose of the water right sales during the 1990-2003 time period indicated that 14% of all water right sales were water bought for agricultural irrigation (Brown, 2006). However, the volume of water transacted between agricultural users represented about 7% from 1990-2008, and was only 2% of the total from 2006-2008 (Hansen, et al.). During the 1990-2008 time period the price per acre foot paid by agricultural buyers was $1,744 per acre foot, although from 2006-2008, that price had risen to $1,976 per acre foot (Hansen, et al. 2012). Grafton, et al. (2011) report 13 agricultural to agricultural sales of water rights in the Reno/Truckee Basin of Nevada averaging about $1,700 an acre foot. This price was about one-tenth what agricultural to municipal uses were in that same basin (Grafton, et al 2011).

Of greatest relevance for our study is that the average sale price of irrigation water rights water rights is $705 per acre foot in Arizona and $917 per acre foot in California (Hansen, et al. 2012). Brewer, et al. (2008) found that agriculture to agriculture sales averaged $722 an acre foot in Arizona and $864 in California. However, agriculture sales to urban uses averaged only $182 per acre foot in Arizona (which seems low) and $641 per acre foot in California.

2. Water Markets for Estimating Residential Water Values

Data on water markets for municipal purposes have now accumulated to the point where relying on such data for at source water values are more feasible now than previously was the case. The trade publication *Water Strategist* <http://www.waterstrategist.com/> reports price, quantity and location data on water transactions for the western U.S. and was used in this analysis. As will be discussed briefly below, given the tendency of utilities to price on the basis of average costs, water prices may not completely reflect the WTP of end users such as households. While at the margin for small changes in water supply available to households the price is likely a good measure of their incremental WTP for that small change in quantity of water. In the short run larger changes in availability of water to municipal areas may result in loss in consumer surplus for water. This could happen in the short run if utilities raised prices for water to encourage conservation or constrained how much water a household could consume at existing prices (e.g., odd-even day watering). In the long run however, municipalities usually can obtain the water they need from irrigated agriculture, so price increases for conservation or watering restrictions tend to be temporary. Nonetheless, below we will provide a rough estimate from Phoenix and Las Vegas on the consumer surplus from water to municipal users just to provide some perspective.

Water Leasing: From 1990 to 2003, municipalities have been fairly active leasing water from other municipalities, from agriculture, and from what Brown (2006) describes as water management organizations (typically water conservation districts that hold water rights). About 18% of all water leasing transactions in the western U.S. have been by municipalities during the 1990-2003 time period. According to Hansen, et al. (2012), the water volume weighted ***average*** leasing price paid by municipalities has stayed fairly constant over the 1990 to 2008 time period at about $150 an acre foot in constant dollars. However, Brewer, et al. (2008) report ***median*** one year lease prices were about $41 per acre foot over a similar time period in the western U.S. (Again this indicates that there likely is a skewed distribution of municipal lease prices, with some being quite high. However, the Hansen, et al. average value may reflect multiple year leases creating a problem of comparability).

Water Right Sales: Broadly speaking, a water right entitles the owner to receive perpetually a specified quantity of water at a specified location. Water right transfers from irrigators to municipalities have been the dominant direction of water right sales in the western U.S. In the western U.S. as a whole, the price of purchasing water rights has risen from $560 per acre foot in 1990 to nearly $10,000 per acre foot in 2008 (Hansen, et al. 2012). The volume-weighted long term average from 1990 to 2008 was $1,543 per acre foot. However, for the Truckee River Basin in the Reno Nevada area, the price for more than a thousand agriculture-to-urban water rights sales has averaged $17,685 per acre foot (Grafton, et al. 2011: 13), suggesting a skewed distribution in this market as well. In the South Platte River Basin of Colorado agriculture to municipal trades averaged about $6500 per acre foot between 2002 and 2008 (Grafton, et al. 2011). As an example of an upper bound on Municipal water values, San Diego County Water Authority is using a desalination plant to provide water at about $2,000 an acre foot.

Table 6 presents state level median prices for both one year leases and permanent sales of water rights from agricultural users to municipal users from 1987-2005. This table is based on Brewer, et al. (2008) who also originally developed these data from the *Water Strategist*. These median values reflect long term values, but as seen in Hansen, et al., do not reflect relatively high increases in west wide average prices occurring during the 2006-2008 time period. The prices in Table 6 further reflect intuitions about relative water scarcity, with higher prices observed in rapidly growing but water-short areas such as Colorado, while lower prices or even lack of markets are observed in Montana, Idaho and Oregon.

Table 6 Agricultural to Municipal Water Median Lease and Sale Prices ($/Acre foot) 1987 to 2005.

	1 year lease	Water rights
Arizona	$ 55	$ 183
California	$ 83	$ 641
Colorado	$ 29	$ 3,687
New Mexico	none	$ 1,593
Nevada	$ 24	$ 1,953
Utah	$ 92	$ 331
Wyoming	$ 45	$ 1,440

Adapted from Brewer, et al. (2008)

As with many markets, the prices likely do not reflect any externalities of such leasing or trades in terms of changes (positive or negative) in instream flows or water quality between the new point of diversion and the prior point of diversion.

Consumer Net WTP or Consumer Surplus Values for Residential Water Use

Even when these prices are charged for water, they may not reflect the full net WTP or consumer surplus realized by the household if the household is quantity constrained such they cannot buy all the water they desire at the current price. In that case there would be a consumer surplus lost on the difference between the quantity they wish to purchase at the current price and the quantity they are constrained to. Much of the constrained water use would be for out of home use, as a substantial portion of arid west water use occurs out of doors (e.g., lawn watering, pools). If a change in timing of water releases from Glen Canyon Dam resulted in less water during summer months being released such that water rationing became necessary in the short run while the utility acquired additional water, there would be a temporary loss in consumer surplus for water. Ideally to estimate the consumer surplus, a demand curve for municipal water would be estimated, and the consumer surplus would be calculated from that demand curve. At present there are a limited amount of empirical demand curves for municipal water in our study area from which to calculate the consumer surplus or net WTP.

A demand curve for Las Vegas, a city which receives some of its water from the Colorado River will allow us to estimate the consumer surplus received by Las Vegas households. Lott, et al. (2013) estimate that the price elasticity of demand for municipal water to Las Vegas households is -.2817, a very price insensitive (inelastic) demand. Peak monthly usage during summer months is about 18,000 gallons a month. For purposes of illustrate, assume reductions in water flows during the peak summer time was minus 15% or -3,000 gallons. Using equation 7-2, in Young (2005), the loss in gross value of that water to the household is $12.53 per month. However, the loss in consumer surplus is only $3.53 since the household saves the cost of not purchasing that water ($3 per thousand gallons times $3,000 gallons—price from Lott, et al. (2013: 28). This loss in consumer surplus would translate into a WTP of $380 per acre foot for this water. Applying the same methodology to data in Yoo, et al. (2014) to a 16% reduction in monthly water use in Phoenix (what occurred from 2000-2008) the loss in gross value in Phoenix was $6.71 per household per month. Subtracting the mid point of the 2000-2008 prices times the reduction in quantity of water during that time, yields a loss of consumer surplus of $1.44. per month to Phoenix households. The loss is smaller in Phoenix than Las Vegas since the estimate of the price elasticity of demand is more price sensitive (elastic) in Phoenix than in Las Vegas. The WTP to avoid this reduction in water is about $200 per acre foot.

B. Non Market Values of Water

There are several non market values of water. As discussed in the theoretical section these include direct use values such as recreation and non-use values such as existence value. First we review the water related recreation use values, then turn our attention to other non market values associated with traditional water uses such as irrigation water, and then finally to non use values of water.

1. Water Related Recreation Use

Water supports a great deal of recreation activities including fishing, boating, swimming, and water skiing. These activities are quite popular will millions of visits annually.

Table 7 presents information on use of National Park Service (NPS) units associated with the Colorado River, and its tributaries such as the Green River and the Gunnison River. These areas include not only National Parks but also include National Recreation Areas (NRA’s), and National Monuments (NM).

Table 7. National Park Service Colorado River Units and Associated Visitation (Source Duffield, et al. 2007).

Park Unit	**Waters**	**Type of Water**	**Total 2005 Visitation**[a]	**Colorado R. Water-related 2005 visitation**[b]
Canyonlands NP	Colorado & Green Rivers	River	393,381	11,508
Curecanti NRA	Blue Mesa (Gunnison River), Morrow Point and Crystal reservoirs	Reservoir	882,768	882,768
Dinosaur NM	Green and Yampa Rivers	River	360,584	12,802
Glen Canyon NRA	Lake Powell Colorado River	Reservoir River	1,863,055 45,671	1,863,055 45,671
Grand Canyon NP	Colorado River	River	4,401,522	22,000[c]
Lake Mead NRA	Lake Mead Colorado below Hoover Dam Lake Mojave	Reservoir River Reservoir	7,692,438	7,692,438

[a] Total 2005 recreational visitation from the NPS Public Use Statistics Office http://www2.nature.nps.gov/mpur/index.cfm

[b] The NRA units (Curecanti, Glen Canyon, and Lake Mead) are assumed to be entirely water-based recreation.

[c] Total float use of Grand Canyon has been relatively stable at 20,000 to 24,000 visits in recent years (Grand Canyon NP Management Plan FEIS)

Table 8 reports river recreation use at non National Park Service rivers in Colorado, including those on National Forests and Bureau of Land Management lands (no data for Utah is available).

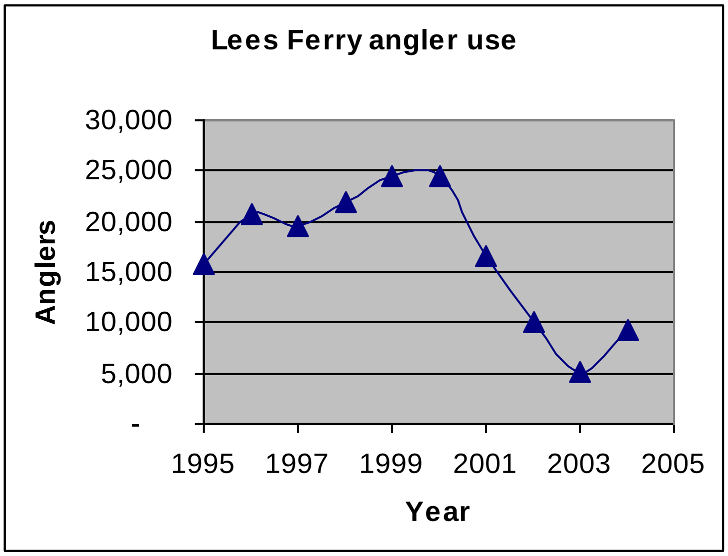
Table 8. Commercial Rafting Companies River Use on Significant Non NPS Rivers in Colorado

River	Use Days
Animas	41,921
Colorado (in CO)	94,994
San Miguel	3,782
Yampa	17,667

Source: Greiner and Werner, 2012

Figure 1 presents total recreational angler use in Glen Canyon NRA, the stretch below Glen Canyon Dam and above Lee's Ferry. The cold, clear water for the dam has made this reach a significant trout fishery. Figure 1 reflects both shore angler use and boat angler use (Loomis, et al 2005). Use has varied somewhat over the years, declining during the first half of the 2000's. In part this is believed due to decreasing size of fish being caught as well as fish catch per hour falling from 1.5 to .5 (Loomis, et al., 2005). Depending on the year, angler use is about evenly split between the two modes of fishing.

Figure 1. Lees Ferry-Glen Canyon Total Angler Use by Year



Economic Values of Water Based Recreation

The economic benefits of recreation is measured by the visitor's net WTP or consumer surplus. This is the measure of benefits used by federal agencies such as the U.S. Army Corps of Engineers and U.S. Bureau of Reclamation. This is also the benefit measure required by the U.S. Water Resources Council (1983) for benefit-cost analysis or in National Economic Development or NED account.

Valuation Methods

The two most commonly used methods to value recreation on public lands include the Travel Cost Method (TCM) and the Contingent Valuation Method (CVM). TCM uses variations in visitor travel costs and number of trips to trace out a demand curve. From the demand curve the analyst can calculate the amount the visitor would pay in addition to or in excess of their travel costs. This is the visitor consumer surplus or net WTP. CVM creates a simulated market in which visitors are asked if they would pay a higher cost per trip. The increase is varied across the sample, and a logistic regression is used to calculate the sample average consumer surplus or net WTP.

Table 9 reports the results of the most relevant studies for the economic values of water based recreation along the Colorado River, its tributaries and the associated reservoirs.

Table 9. Summary of Literature and Estimates of Colorado River NPS Units Direct Recreational Value Estimates. Source Duffield, et al. 2007.

Study	**Description**	**WTP Estimate**	**WTP Estimate (2005 $ per visit)**
Bishop et al. (1987)	Study of values of Grand Canyon - float boaters (CVM)	$236-$1,653 per trip depending on river flow level (1985$)	$430 - $3,000
Hammer (2001)	Study of Grand Canyon – Floaters (TCM)	$134 per trip (private) $314 per trip (commercial)	$157 (private) $368 (commercial)
Martin et al (1980)	Study of Lake Mead - Fishing Values (TCM)	$44.63 to $61.44 per angler day (1978-9$)	$643 - $887
Douglas and Johnson (2004)	Travel Cost study of Lake Powell – Recreationists (TCM)	$70.84 - $159.35 per visit consumer surplus (1997 $)	$86 - $194
Duffield & Neher (1999)	Visitor survey of Glen Canyon NRA and Grand Canyon NP Visitors. (CVM)	Glen Canyon NRA - $384 per party trip Grand Canyon NP - $319 per party trip (1988$)	Glen Canyon $109 Grand Canyon $142
Douglas and Harpman (2004)	Survey of Glen Canyon - improved trip quality scenarios (angler harvest, water quality)	$8.63 to $38.92 per visit[a] (1997 $)	$11 - $47
McKean et al. (1995)	Survey of Blue Mesa Reservoir visitors (TCM)	$37 to $101 per visit (1986$)	$69 - $187

[a] Not total value of current trip, but incremental values due to improvement.

Duffield, et al. (2013) using data from the National Park Service's visitor surveys to estimate a travel cost method (TCM) demand model for a sample of 58 National Park, National Monument and National Recreation Area. From the TCM demand function he calculated net willingness to pay per trip for each these 58 National Park, National Monument and National Recreation Area. He then regressed the resulting net WTP on the characteristics of these three types of areas including their geographic location, population within 10 miles, size, type of Park Unit, etc. The resulting meta analysis regression model explained 70% of the variation in value per day. From this he could calculate estimates of WTP per day at other National Park Units. For our purposes we use his estimates for the units listed in Table 10 down below. For National Parks in the intermountain west the value per day is $124. For National Monuments it is $153 per day. For National Recreation Areas it is $93 per day.

Table 10 combines Duffield, et al. (2013) valuation estimates for each type of National Park Unit (discussed above) with visitor use estimates in Table 7. The only exception is the estimate for rafting in Grand Canyon National Park which is an average of the lower bound of Bishop, et al. and Hammer shown in Table 9 above.

Table 10. Net Economic Value of National Park Service Colorado River Units and Associated Visitation

Park Unit	**Waters**	**Type of Water**	**Colorado R. Water-related**	Total Water Recreation Benefits
Canyonlands NP	Colorado & Green River	River	11,508	$1.4 million
Curecanti NRA	Blue Mesa (Gunnison River), Morrow Point & Crystal Res.	Reservoir	882,768	$82 million
Dinosaur NM	Green and Yampa River	River	12,802	$1.9 million
Glen Canyon NRA	Lake Powell & Colorado River-Day Rafting	Reservoir River	1,863,055 45,671	$173 million $4.2 million
Grand Canyon NP	Colorado River	River	22,000	$8.8 million[a]
Lake Mead NRA	Lake Mead Colorado below Hoover Dam Lake Mojave	Reservoir River Reservoir	7,692,438	$715 million

a. **Calculated as the average of the lower bound of Bishop, et al. and Hammer from Table 9 above as this is a more site specific value for this unique activity.**

As can be seen in this table the largest recreation values are associated with Lake Mead NRA and Glen Canyon NRA.

There have also been separate studies of the economic value of fishing below Glen Canyon dam. The first one in 1985 by Richards, et al. used the TCM to estimate a value per angler day. Updating his 1985 values yields a value of $580 per trip. Bishop, et al. (1987) used dichotomous choice CVM and estimated a value for fishing under two different flow regimes (constant and fluctuating). Their updated values range from $250 with constant flows to $200 with fluctuating flows. When combined with the 10,000 to 25,000 anglers each year (Figure 1), yields an annual value of at least $2 million per year (Bishop et al. low value and low average use of 10,000 anglers per year) to as much as $14.5 million (Richard's high value of $580 per trip times high annual use levels of 25,000 anglers per year). However, given that both of these values date from the 1980's an important future avenue for research is to perform a more recent study of angling in Glen Canyon.

There has been one study of day use rafting below Glen Canyon Dam by Bishop, et al. (1987). They found a value per day of nearly $50. When this value is multiplied by annual 40,000 rafting days, the annual value of current use is $2 million. This value is also reflective of conditions nearly 25 years ago, so this study is in need of updating as well.

Valuation of Water Based Recreation as a Function of Water Levels

The level of water in a reservoir or flows in a river can affect the quality of a recreation experience and hence the willingness to pay for that experience (i.e., the visitor's benefits). For example, a full reservoir allows users to access the lake from all the boat ramps, instead of queuing up just at one or two. Perhaps more important high reservoir levels provides a greater surface area that allows users to spread out and reduces crowding and congestion.

In part because of the increased benefits associated with higher water levels, recreation use, particularly at reservoirs, usually increases with water levels. This relationship has been statistically documented at Lake Mead and Blue Mesa Reservoir (see Duffield, et al. 2007 for more details). These increases in recreation use with additional water levels in conjunction with the value per day for such recreation results in an increase in total recreation benefits. Likewise, reductions in reservoir levels decrease visitor use and recreation benefits to users.

Table 11 provides estimates of the recreation benefits provided by reservoirs along the Colorado River and its tributaries. Because the storage volume of these reservoirs are known it was possible to calculate the incremental or marginal benefits of another acre foot of water in these reservoirs to recreation visitors.

Table 11. Estimated Marginal Recreational Net Economic Value per Acre Foot of Reservoir Storage.

Dam and Reservoir	Total Recreation Benefits (million $2005)	Marginal Recreation Benefits (annual 2005$ per acre foot
Flaming Gorge	$32	$12.0
Curecanti Unit	23	27.11
Navaho	16	13.90
Glen Canyon Dam/Lake Powell	99	5.14
Hoover Dam/Lake Mead	277	14.46
Davis Dam/Lake Mojave	100	55.04
Parker Dam/Lake Havasu	97	156.24

Updated from Duffield, et al. (2007). Original Source: Booker and Colby (1995), Table 4, p. 885 converted to 2005 dollars.

Likewise moderately high flows in rivers provides larger rapids, faster rate of travel and most importantly avoids boats getting stranded on the river bottoms or rocks. These characteristics of high flows also provide benefits to boaters. However, too high a flows may actually reduce benefits, thus the benefit-flow function may be quadratic in flow.

Table 12 provides the incremental or marginal net economic values for Grand Canyon float boaters at alternative river flows. However, the reader must recognize these values are more than 25 years old, and thus the values may have changed, and need to be updated.

Table 12. Marginal Net Economic Value Estimates for Alternative Grand Canyon Float Trips with Colorado River Flow Levels.

Flow	Value per Trip		Value per Day	
	Commercial passengers	Private boaters	Commercial passengers	Private boaters
(A) Study year dollars				
5,000 cfs	$127	$111	$21	$7
29,000-33,000 cfs	898	688	150	43
45,000 cfs	732	376	122	24
(B) 2005 dollars				
5,000 cfs	235	206	39	13
29,000-33,000 cfs	1664	1276	277	80
45,000 cfs	1357	697	226	44

Updated from Duffield, et al. 2007; Original Sources: Boyle et al. 1993; Bishop, et al. 1987.

Conclusion on Water Based Recreation

This section finds that water based recreation along the Colorado River and its tributaries is nearly 10 million visitor days per year. Some of this recreation use is commercial (e.g., some rafting, house boating) but the vast majority of it is non commercial use by individuals for activities such as boating, fishing, swimming, and water skiing. This has an economic value to the users of over $800 million annually. These values are sensitive to water levels in reservoirs and rivers.

2. Non market and Social Values of Water

It almost goes without saying that there are many different types of values of water. Burmil, et al. (1999) in Human Values and Perceptions of Water in Arid Landscapes suggests not only are there several values of water but they take on increasing importance in arid landscapes such as the desert southwest. Rogers, et al. (1999) provides a categorization of the “full” economic values of water that include social objectives where water can play a role. They note that surface irrigation water can provide positive water recharge as well as negative return flow externalities such as salinity or nutrients to receiving water bodies. Water economist Charles Howe (1999:362) recognizes that water has a “…wide range of cultural, spiritual and religious values…”

However, some of these social and cultural values are not subject to economic trade-offs needed to establish an economic value. That is, no one would seriously consider asking nor answering a willingness to pay question regarding their religious value toward anything, water included.

Nonetheless, for many uses of water, such as in irrigated agriculture that may provide open space, people are willing to make trade-offs. We review the literature on the direct non market values of agricultural lands to people, and the value of agricultural lands related open space in this section.

3. Non Market Values of Irrigated Agricultural Land

One of the only studies to focus specifically on the non market values of irrigated agricultural lands is by Pritchett, et al., 2009 and its associated journal article by Thorvaldsen, et al.(2010). The authors conducted a stated preference willingness to pay study of the values of using water in different purposes. The data came from an Internet survey of 17 western states conducted by Survey Sampling Inc. Only 3% of all email invitees responded but since no study subject was given in the email itself, the authors believe there was little self-selection bias with regard to the water topic. Of the 6883 who opened the email, 6250 or 91% responded. Non response check on demographics suggested some similarity between respondents and the western states population. However, it appears single family homeowners were over represented (from Pritchett, et al, 2009 CWI full report).

The specific valuation method was the dichotomous choice contingent valuation method (CVM). The way households would pay for water in each sector was through increased summer months water bill ranging from $5 to $25 in $5 increments. The respondent indicated if they would pay the increase that was randomly assigned to them in their survey version.

The results indicate that half the respondents were willing to pay something for one or more of the 8 listed water programs. These programs ranged from programs to reduce household water consumption to keeping irrigated farms in production. The median WTP was $15.65 per household per summer month, hence $47 annually.

In terms of our interest here was that respondents allocated about 16.2% of the average WTP of $15.65 to "Keep irrigated farms in production" or about $7.61 per household per year. Thus, there appears to be what is a non market WTP of the general public in the West of $7.61 per household for keeping water in irrigated agriculture. But how much of this value is due to a non-market value for open space that irrigated crop acreage provides is not readily apparent from the study, as irrigated agriculture as a source of open space is not discussed. Unfortunately these values are not broken out by state in the journal article or in their longer report. Thus we cannot identify the values for Arizona and California separately.

Another study that used stated preference methods is by Rolfe and Bennett (2004). These authors demonstrate that some people might be willing to pay to provide water to others so that that those receiving water may maintain their culture (rural farmers or rural towns) or aboriginal ways of life (in Australia). Since this is one of the only studies found to estimate a non market value of providing water to others (a form of altruism) we discuss this study at length for two reasons. One their research goes to great lengths to describe how they went about and how to properly go about conducting a stated preference (here CVM) study of household WTP to provide “free” water to other groups that might be deemed by some as deserving due to their culture or way of life. Second, their results of are of interest since they are the only study found that actually monetizes these values.

At the time of the study in Australia water market auctions were taking place that were starting to move a significant amount of water from rural areas to urban areas due to the far higher value of the water in the urban areas. However, there were concerns about the effects on the people in areas where water was being sold from. To paraphrase Rolfe and Bennett (2004) people may have preferences over social outcomes and these might be characterized as a non use non market value given that people gain satisfaction from knowing that certain social outcomes will have been achieved without them personally being involved. Since in their survey the way that these desirable social outcomes (water to rural farmers, rural towns, the environment and aboriginal people) would be attained was by setting aside some free water for these users that would not be subject to auction. Hence, this can be conceptualized as a type of paternalistic altruism, in which the donor wants the recipients to have a particular resource so as to maintain a particular rural or aboriginal way of life. Thus, as discussed in the theory section of this report, this value is admissible as a non market value (unlike non paternalistic altruism, where the donor’s concern is just for the overall well being of the other person, and is happy to give them money to maintain their material well being, without regard to how it does that).

Since Rolfe and Bennett felt that these were non use non market values, they suggest stated preference methods would be appropriate, either choice experiments or contingent valuation. In this analysis they used CVM. They asked households in the urban area of Brisbane what they would pay in a higher water bill to provide free water to: (a) small rural farmers for irrigation (b) small rural towns for municipal and industrial purposes; (c) environmental organizations; (d) aboriginal people. A dichotomous choice WTP question was used.

As is sometimes done, “not sure Yes” responses are coded as “No won’t pay responses” to ensure the WTP estimates are conservative (this is the same recoding made by Welsh, et al. in the Glen Canyon Non Use Value study discussed below). With this recoding about half the sample would pay and half would not pay the dollar amount they were asked to pay for providing free water to these groups.

Those agreeing to pay were asked to allocate the percentages of the amount they would pay to the four different groups. The paying respondents allocated on average about 60% of their WTP to small farmers irrigation water, about 22% to small rural towns, about 18% to environmental groups, and about 1% to aboriginal groups.

When data on average age and household income levels of the sample were used to calculate WTP, the sample median was negative $11, but the mean was a positive $66. However, when the sample sociodemographic characteristics were replaced with the population census values for the sample area, Brisbane, the median was $6, and the mean $74. The authors are cautious though about applying the sample positive bidders percentages for each of the four groups to the overall Brisbane population WTP estimates, however.

Rolfe and Bennett conclude that their results suggest that while there may be some community values associated with accounting for social equity impacts of water, the values may not always be significant or positive. Nonetheless, their study demonstrates how one can attempt to monetize these values using standard non market valuation techniques. If these values are to be included in a non market valuation, care must be taken so as to ensure the values reflect paternalistic altruism and not simply a distributional issue (e.g., pure altruism) or how a given amount of benefits are distributed among the population.

4. Open Space Values provided by Agricultural Land

McConnell and Walls (2005) provide a comprehensive survey of non market use values of various types of open space including forests, wetlands, and agricultural land. One common way to value the economic value of open space is to see if there is a property price premium associated with houses that are adjacent to or nearby open space relative to other houses. This is clearly a non market use value to residents as they enjoy seeing the land itself. But trying to isolate the irrigated agricultural component from general agriculture is difficult. Most of the property value studies aggregate all types of agricultural land into one category so it is difficult to determine if homeowners have differential values for irrigated lands versus other types of agricultural land. Since most studies have been in the east, many pasture lands do not require irrigation, so would not be considered irrigated lands there but pasture lands might often be considered irrigated lands in the west. One study did separate out crop land from other open space land types and found cropland not to have a statistically significant effect on property values in their hedonic property study in Maryland. Shultz and King (2001) studied the effect of several different types of open space on house prices in Arizona. Unfortunately, none of their land types related to agricultural land, let alone irrigated agriculture (although golf courses were one of the open space land types studied—and these are of course heavily irrigated in Arizona).

Stated preference studies such as contingent valuation method (CVM) and choice experiments (CE) have often focused on agricultural land preservation versus development, rather than on WTP for agricultural land as distinct type of open space to be valued. So these studies do not shed much light on the value of irrigated agricultural land as open space. Thus, this is an important area for future research. In some cases, transferring water from irrigated lands at significant distance from population centers is not likely to result in a net change in open space. The unirrigated will remain as open space as there is no development pressure in the area.

Although some studies show there are multiple benefits of agricultural land preservation Kline and Wilchens (1996) found that maintaining environmental quality was the main preference for agricultural land preservation. Maintaining agriculture in order to maintain an agricultural way of life in the surrounding communities was in the middle ranking. Hellerstein, et al. (2002) found no conclusive pattern of preferences for type of agricultural land.

In a thorough review of more than two decades of open space studies Bergstrom and Ready (2008:34) found some evidence from several studies of open space amenity value and that WTP for cropland were than to forests and pastureland. But one study did not find any difference. Bergstrom and Ready conclude that it is “Difficult to draw firm generalizations on this”. But while having active and viable farms is a strong public preference, too intensive of agricultural can reduce or outweigh amenity values of the contribution of agricultural land preservation to open space values.

With the exception of Pritchett, et al. (2009) and Thorvaldsen, et al. (2010) not many studies have explored the economic value of irrigated agricultural lands, particularly in the Western US. Most are eastern US studies. Therefore the non market values and differential open space values of irrigated agricultural lands are an important gap to be filled in the literature.

A more revealed preference approach to assessing agricultural preservation/open space values would be an analysis of open space land purchases. Loomis, et al. (2004) analyzed open space land transactions along the urban Front Range of Colorado. Colorado has an active open space acquisition program, funded in part by its lottery and in part by sales tax increment in cities and counties. An analysis of over 100 open space transactions found the mean price per acre was $13,635 for purchase of open space land. The value per acre decreased as the size of the parcel increased (in part due to lower transactions cost on acquiring a single large tract versus several tracts). The higher agricultural land value and development land value, the higher the open space prices, an indication of the supply costs of open space. The larger the population in the area where the open space was located, the higher its value as well.

5. Non Use or Passive Use Values of Water Resources in the Western U.S.

There are several studies of the passive use benefits (e.g., existence and bequest values) that water resources provide to people. By necessity, all these studies use the contingent valuation method to estimate households' WTP. There are almost a dozen such studies, primarily in the western U.S. (Duffield, et al. 2007). While these studies include two natural lakes, the vast majority of studies involve maintaining instream flows for rivers, sometimes with specific reference to recreational fisheries (see Duffield, et al. 2007 for a listing of these studies) or endangered fish in California (Hanemann, et al.1991) and the Rio Grande River in NM (Berrens, et al 1996). One study valued removal of two dams on the Elwha River in WA that blocked salmon migration (Loomis, 1996).

Of course the most relevant and well known non use value study for the Colorado River was performed by Welsh, et al. (1995). This contingent valuation study valued different fluctuations in the Colorado River below Glen Canyon Dam. The study described the consequences of these different flow scenarios in terms of beaches, endangered fish, riparian vegetation and archeological/cultural sites. Households in the western U.S. were asked to pay in the form of higher electric bills. Households in the rest of the U.S.

were asked to pay in higher taxes. A mail survey was conducted. The study received a very high response rate of 74% for the national sample and 83% for the western sample. To provide conservative estimates of WTP, only those responding "definitely yes" to the CVM WTP question were counted as "Yes" would pay responses. The values per household are then generalized to all the households in the two regions. The public good nature (non rivalness in benefits) is evident in the total annual benefits reported in Table 13 for the two samples, especially the national sample.

Table 13. Welsh et al. (1995) Estimates of Nonuse Values for Three Glen Canyon Flow Scenarios. (2005 dollars)

	Rest of Nation Sample		Western (Power Marketing) Sample	
Flow Scenario	**Per Household**	**Annual Value (millions)**	**Per Household**	**Annual Value (millions)**
Moderate Fluctuations	$17.74	2,791	$29.05	79
Low Fluctuations	$26.19	4,386	$28.25	80
Steady Flow	$26.91	4,474	$38.02	107

C. Conclusions

In the arid west, irrigated agriculture is the dominant market use of water, with between 85% and 90% being used for that purpose. Municipal and industrial market uses are relatively small, but highly valued, being able to "bid" water away from irrigated agriculture.

Water provides both market and non market use values depending on its particular use. In some cases a flowing river provides instream flow recreation as it runs downstream to where portions of it are diverted for irrigated agriculture. In other cases there may be more of a competitive nature, whereby water for diversion directly reduces instream flows for recreational use. Our literature review found numerous studies of the economic values of recreation for water resources (rivers and reservoirs) along the Colorado River system (including its tributaries). Our literature review found one study recent study that indicated residents' have a small non market value of keeping a significant portion of water in agriculture.

Water can provide non-use values, although the vast majority of the non-use studies (10 out of 12) involve rivers rather than natural lakes. Our literature review did not turn up any non-use value studies for reservoirs per se (rather one study was found indicating a non-use value for removing two dams and associated reservoirs that blocked salmon migration in the state of Washington). Determining if and by how much reservoirs have a non-use value could be an area of future research.

SECTION V
ADAPTING LITERATURE VALUES TO GLEN CANYON DAM OPERATIONS

A. Health Damages Avoided by Hydropower

As emphasized above one of the non market values of hydropower is the avoided health damages from air pollution from substituting hydropower for coal fired power plants. These health damages per ton are summarized below in Table 14 and 15.

Table 14 External Damages per Ton for Different Pollutants, by State

		Air Pollutant			
State	SO2	NOX	TSP	VOC	CO
California	$ 7,341	$ 14,925	$ 7,541	$ 6,932	N/A
CA/Million Pop	$ 229	$ 466	$ 236	$ 217	
Nevada	$ 2,808	$ 12,241	$ 7,525	$ 1,656	$ 1,656
NV/Million	$ 1,835	$ 8,001	$ 4,918	$ 1,082	$ 1,082
Avg/Million Pop	$ 1,032	$ 4,234	$ 2,577	$ 650	$ 541

State totals updated from 1992 dollars in Table 18 DOE 1995 report to 2012 dollars. Calculations of damages per million done by the author.

Unfortunately, values for other states of more interest to this analysis (e.g., Utah, Colorado, Arizona) are not available in the literature. However, values for California and Nevada have been adjusted for population to facilitate application to our other states of interest.

A 500 MW coal fired powerplant puts out 10,000 tons of SOX and NOX per year (Union of Concerned Scientists, 2013). So as one can see the damages per can be quite substantial even using the low end damages per million population from California.

Table 15. Air Quality Damages Per MWh per Million Population from Burning Coal

	SO2	NOX	PM
Tons per MWh	0.000047	0.0002	0.00002
Average Damage per ton Per Million Population	$ 1,032	$ 4,234	$ 2,577
Damages per MWh per Million Population	$ 0.05	$ 0.85	$ 0.05

Tons per MWh from Keske, et al. 2012, Damages per ton per million population from Table 14.

This table should allow one to calculate the health damages that might arise if a MWh of electricity from hydropower had to be replaced with a MWh of electricity from coal fired powerplant. To finalize the calculation the number of people downwind from the particular coal fire powerplant would need to be known. This may require some atmospheric modeling of where the emissions from the particular coal fired powerplant would travel to.

An example of such a calculation could be performed for the Navajo Generating Station at Page, Arizona. This powerplant is a very large source of NOX that has both health and visibility concerns.

B. Improved Visibility at National Parks Arising from Glen Canyon Dam Hydroelectricity

If there were to be reduced hydroelectric output from Glen Canyon Dam, whether there would be air quality impacts over National Parks would depend on what the replacement power source would be and where it is located relative to the National Parks. If the replacement power came from coal fired powerplant then the location of that plant relative to National Parks matters in terms of impacts on air quality. And it is not just the plant's proximity to a National Park, but proximity in terms of typical wind direction that would matter. Such a determination would require a combination of an integrated power modeling and atmospheric modeling. Obviously these analyses are well beyond the scope of this economic analysis other than to point out that this is what would be required. However, once the decrement in visibility was simulated relative to: (a) current visibility at nearby downwind National Parks; and (b) to distribution of visibility over the year, then the analyses of Rae for visitors could be applied. The estimates of Balson, et al. (1991) and Industrial Economics Inc (2013) could be applied to estimate recreation damages and damages to households, respectively.

An example of such an analysis could be conducted of the Navajo Generating Station since its NOx emissions reduces visibility air quality at 11 National Parks and Wilderness areas that are designated as Class I air quality (USPA, 2013). The estimates of benefits to National Parks and Wilderness areas not quantified by the three existing economic values of air quality studies would have projected based on a benefit transfer of values from the three existing studies.

C. Benefits of Reduced Climate Change

CO2 damages per MWh can be calculated using the same approach noted for effects on air quality. However, there appears no reason to adjust to damages per million population since climate change is truly a global problem. The damages to the globe are presumably embedded into the many damage estimates. Keske, et al. calculate about .7295 tons of CO2 per MWh. USEPA (2000) calculates 1.1245 tons per MWh. As noted above the damages per ton of CO2 vary depending on whether the analyst is using prices from carbon markets (and which carbon market) or damage estimated for integrated assessment models (Tol, 2005). As reviewed in the previous sections, a permit to emit one ton of CO2 in most markets where emissions are regulated (i.e., non voluntary) ranges from about $5 a ton world wide average to $10 a ton in California. Alternatively, damages as estimated by the Interagency Working Group on the Social Cost of Carbon (2010) for US Federal agencies ranges from $5-6 a ton to $21-$24 a ton. Tol (2005) review of the literature found $14 to $16 a ton. Thus we provide a range of damage estimates from a MWh of coal fired powerplant CO2 emissions. The High estimate of $22.50 per ton is from the upper end of the US damage estimate, the low end of $5 a ton is quite consistent across the damage estimate from the U.S. federal agencies and low end of Carbon Markets. The middle estimate takes Tol’s estimate from his review of the literature $15 a ton. The range of estimates is presented in Table 16.

Table 16 Damages per MWh from CO2 Emissions at Different Damage Estimates

	$/Ton CO2	Per MWh	Per MWh
Tons of CO2 per MWh		0.7295[a]	1.1245[b]
Low	$5	$ 3.65	$ 5.62
Medium	$15	$ 10.94	$ 16.87
High	$22.50	$ 16.41	$ 25.30
Source		a. Keske, et al	b: USEPA, 2000

This table should allow one to calculate the damages that might arise if a MWh of electricity from hydropower had to be replaced with a MWh of electricity from coal fired powerplant.

D. Hydropower as a Renewable Energy Source

While hydropower is undoubtedly renewable energy, it has not been viewed as such explicitly in by researchers doing surveys of the public for renewable energy. In part this may be due to the fact that unlike solar (and possibly wind) traditional large hydropower projects have been perceived is having their own undesirable environmental impacts (e.g., blocking fish migration, loss of riverine habitat, etc.).

Further there is mixed signals as to what extent hydropower is eligible under state and federal guidelines as a power source for meeting renewable energy standards or whether hydropower is eligible to supply Renewable Energy Credits/Certificates (RECs). There are two renewable energy credit markets that are segmented into voluntary markets were firms can purchase renewable energy credits for any number of reasons (e.g., green marketing like some ski areas and other companies do) or compliance markets for utilities located in states with legislative or regulatory renewable energy standards. Interestingly enough in national voluntary markets RECs have been selling for about $1 MWh (DOE, 2013) about the same price as in the compliance markets in the seven states currently with standards and that allow utilities to use RECs (DOE, 2013).

There are also five Arizona utility companies that offer the green electricity pricing program. At the low end, the extra cost per kWh ranges from .4 cents a kWh from Arizona Public Service to .8 cents per kWh for Tri-State Generation and Transmission through Columbus Electric Cooperatives (where the ***eligible*** renewables come from wind and small hydropower (30 megawatts or less) even though Tri-State's website indicates it gets a substantial amount of hydropower from Glen Canyon Dam and Flaming Gorge—see http://www.tristategt.org/greenpower/Small-Hydro.cfm). At the high end is 3 cents a kWh from the Salt River Project (where renewables come from PV, wind, landfill gas, small hydro and geothermal).
See http://apps3.eere.energy.gov/greenpower/markets/pricing.shtml?page=1 for more details.

The one CVM survey for renewable power most geographically applicable to the Glen Canyon Dam region is willingness to pay survey for renewable energy (wind energy is emphasized but solar is mentioned as well) in New Mexico by Mozumder, et al. (2011). Their study yielded monthly WTP, among that those households that would pay extra for renewable power, of $6 a month for 10% renewable power and $15 a month on their bills for a 20% of their power coming from renewable sources (Mozumder, et al.

(2011: 1125).[3] However, they note that currently only 5% of NM's customers served by the largest utility (serving half the households in the state) voluntarily pay extra toward renewable energy (Mozumder, et al. 2011:1120). It is not clear if this value for wind power would be applicable to hydropower, and thus this is noted below as an important avenue for future research.

To illustrate how survey information on WTP for renewable power might be applied to hydropower, consider the following example based on the NM results. According to DOE, NM uses 22.4 Gigawatts of electricity (2/3 produced from coal) and roughly 10% coming from renewable (mostly wind power as only about 1% of total energy use comes from hydropower). To increase renewable power from 10% to 20% would require another 2.2 Gigawatts of electricity. Mozumber et al. (2011) estimated WTP for the additional 10% renewable power to be $9 ($15-$6) per household. Given the number of households in NM (about 660,000), the total WTP for another 2.2 Gigawatts of renewable power would be roughly $6 million annually.

Dividing $6 million by 2.2 Gigawatts (2,200 million megawatts) yields about 27 cents per MWh. So if Glen Canyon Dam reduced its output, households in NM would be willing to pay about 27 cents more per MWh for another renewable power source instead of relying on a non renewable such as coal.

Conclusion

To arrive at a benefit per MWh of relying on hydropower rather than coal suggests that the air pollution and CO2 emissions are the dominant benefits. Drawing on the results presented above we estimate the non market costs of using coal for electricity in terms of air pollution (SO2, NOX and PM) and Carbon Dioxide amount to $.95 and $4.64, respectively per MWh.

E. Potential Native American Values Affected by Glen Canyon Dam Operations

There are two sources of values for any impacts to Native Americans that might arise from changes in management of Glen Canyon Dam: (a) Native American valuation of these impacts to themselves; (b) non-Native American population values for avoiding these impacts to Native Americans.

As noted above, Hammer indicates (a) is a challenging task. However, with regard to (a) the literature review above also noted there have been a couple of successful attempts of having U.S. tribes answer

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[3] The reported estimates reflect a downward adjustment for potential hypothetical using the ratio of hypothetical to actual WTP calculated from Champ and Bishop (2001).

stated preference surveys for valuation of restoration of their lands in Maine (Duffield, et al. (2002) and forest management in Montana (Gonazlez-Caban, et al.).

Thus it is conceivable that such a study could be done with tribes in the Glen Canyon area, but such study has not been done to date. Given the significant cultural differences between tribes and the resources valued in the past two studies, no benefit transfer would be conceivable to arrive at tribal values in the Glen Canyon area if there were a change in operation of Glen Canyon dam.

There has been even less valuation literature on non-Native American values for protecting Native American resources. The only study our literature review uncovered was in Australia by Rolfe and Windle (2003). This was a study of valuation of reserving water for aboriginal people to Australians. Once again, no feasible benefit transfer can be performed given the cultural differences between the two types of native peoples and cultural differences between U.S. residents and Australians.

The infeasibility of performing a benefit transfer for Native American values suggest it is a high priority area for future research. This is noted below.

F. Water Values of Glen Canyon Dam

1. Market Values

Under the Colorado River Compact, water from the Colorado River goes to both Arizona and California. As such market values of water from both states are relevant here. We rely upon data from market transactions to provide an indication of market values of water. We emphasize agricultural irrigation values as the vast majority of the water is used in irrigated agriculture in both Arizona (roughly 80%) and California. Further the high values of water in municipal uses usually results in municipal water providers being able to buy or lease water from agriculture.

Agricultural Lease Values in Arizona: The average per acre foot one year lease values range from $33 an acre foot (Brewer, et al. (2008)) to $68 per acre foot (Hansen, et al. 2012).

Agricultural Lease Values in California: The average per acre foot one year lease values range from $83 an acre foot (Brewer, et al. (2008)) to $119 per acre foot (Hansen, et al. 2012).

It should be noted the averages for California are statewide averages and do not reflect what are significantly higher values of water in Southern California where most of the Colorado River water goes to. The Imperial Irrigation District (IID) annually transfers leases 200,000 acre feet of water to San Diego for municipal purposes at a price of $258 per acre foot (www.wdcwa.org/water-transfer).

Agricultural Water Right Values in Arizona: The average per acre foot purchase price for permanent water rights range from $705 an acre foot (Hansen, et al. 2012) to $722 per acre foot (Brewer, et al. 2008)).

Agricultural Water Right Values in California: The average per acre foot purchase price range from $722 an acre foot (Brewer, et al. (2008)) to $917 per acre foot (Hansen, et al. 2012).

Desalinization of Water in San Diego: As an example of an upper bound on Municipal water values, San Diego County Water Authority is using a desalination plant to provide water at about $2,000 an acre foot.

2. *Non Market Values of Water*

Recreation

Perhaps one of the largest economic values of water associated with Glen Canyon Dam is recreation on Lake Powell. As shown in the prior sections (Table 5) this is estimated at $173 million annually for 1.863 million trips annually. The extended rafting season in Glen and Grand Canyons depends in part on storage in Glen Canyon Dam. The annual value of day use rafting is about $4.2 million based on use averaging 45,000 day users and a value per day of $93 (Duffield, et al. 2013). The annual value of the Grand Canyon National Park rafting is estimated at $8.8 million base on the average of the lower bound of Bishop, et al. (1987) and Hammer (2001). The Bishop, et al. (1987) is by far the most thorough study, but it is decades old. As such this study is candidate for updating.

Also the recreational trout fishery below Glen Canyon Dam would not be possible if not for the cold clear water provided by Glen Canyon Dam. It has a minimum annual value of $2 million to as much as $14.5 million depending on angler use (angler use fluctuations significantly from year to year) and which valuation study is used (Richards, et al. (1985) vs Bishop, et al. (1987)). Given that these studies are nearly 30 years old, they area are in serious need of updating and this an important area of future research.

Non Market Values of Irrigated Agriculture

Only one study was found indicating any non market value of providing water to farmers. A survey was done in the western U.S. by Pritchett, et al., asking people how much they would pay for different water programs. In terms of our interest here was that respondents allocated about 16.2% of the average WTP of $15.65 to "Keep irrigated farms in production" or about $7.61 per household per year. Thus, there appears to be what is a non market WTP of the general public in the West of $7.61 per household for keeping water in irrigated agriculture. But how much of this value is due to a non-market value for open space that irrigated crop acreage provides is not readily apparent from the study, as irrigated agriculture as a source of open space is not discussed. Likewise, how much of the value is for paternalistic altruism is not evident. A worrisome feature of the Pritchett, et al. study is that it did not inquire about whether some of the motivation for paying was related to concerns about food supply (a market use value), and not a non market value. Further, unfortunately these values are not broken out by state in the journal article or in their longer report. Thus we cannot identify the values for Arizona and California separately. Another difficulty that one would face in trying to apply their study to quantify non market values of irrigation water is that respondents were not being asked to value any specific quantity of water (e.g., no acre feet of water was presented in the survey).

SECTION VI. IMPORTANT FUTURE RESEARCH AREAS

A. Non Market Values of Hydropower

While there are numerous studies on the economic value of renewable energy in general and wind power in particular, there have been no studies specifically on hydropower as a renewable energy source to produce electricity. Also I could not find any hydropower specific studies relating hydropower to its contribution to reducing CO2 emissions. While markets now exist for Renewable Energy Credits (RECs) and for Carbon Markets, and more than 800 utilities allow consumers to pay extra for renewable power (http://apps3.eere.energy.gov/greenpower/markets/pricing.shtml?page=0), there has not been any studies on pure non-use value for hydropower.

It is possible that there may now be some reason to explore this concept, first with focus groups to see if the concept of non-use value for a market good like electricity is plausible to the general public. The second phase of the focus group would focus, as other renewable power studies have, on household's willingness to pay higher electricity bills for additional hydropower the respondent's household would not use. The additional hydropower could be in the form of paying for increased efficiencies in hydropower generation at existing large dams, retrofitting old dams with hydropower facilities or new small hydropower projects that would provide renewable energy to electric service areas other than where the respondent lives.

If the focus groups indicated this study was feasible the next phase would be to move into pretesting via "verbal protocols or speak out loud" to evaluate the internal validity any survey instrument. The purpose is to make sure the respondent is valuing the particular attributes of hydropower that we are intending to value, and not valuing other aspects of hydropower (e.g., saving coal in the ground, when there is already a 100-200 year supply) or valuing all electricity or implicitly including the same value twice (e.g., valuing the air pollution reduction, CO2 and renewable energy itself, if the primary reason the person values renewable energy is due to the pollution and greenhouse gases avoided due to relying on renewable energy). This concern for double counting of the benefits of improved air quality and reduction in greenhouse gases when estimating WTP for renewable energy was brought up by two of the peer reviewers as an important issue to avoid. Building on one of their comments, it seems a choice experiment may be a more fine grained approach. In particular, hydropower as a renewable energy source, reduced air pollution and reduced CO2 emissions are essentially three attributes in a choice experiment. Employing a choice experiment would allow isolating the incremental values of hydropower as a renewable energy source from the benefits realized from air pollution and CO2 emissions.

B. Potential Native American Values

Probably the biggest gap in the literature is that little is known about: (1) how Native Americans relate to water resources in a market and non-market (cultural values and aesthetic values) sense; (b) how non-Native Americans value Native Americans having incremental quantities of water for irrigation (paternalistic altruism). It is important in conducting this empirical research that the emphasis be maintained on valuing just what people would pay to provide the specific resource to the tribe, and not the tribes overall material well being. Many people may very well feel care about improving the over all material wellbeing of a tribe, but this is a form of non-paternalistic altruism toward any means of improving the well being of the tribe, not the specific resource. As discussed in the theory section, non-paternalistic altruism does not give rise to a non market economic efficiency value. If there is a positive cost to the members of the Native Americans of providing this irrigation water, this may offset some of the paternalistic altruism non market benefits. Also, as noted above in the literature review in Section III, care must be taken, particularly when asking Native Americans their values toward natural resources to value only incremental changes in the quantity of water for irrigation and other purposes (e.g., livestock) as well as cultural/aesthetic purposes. The literature suggests it is not advisable to attempt to estimate a total value for the continued existence of all of a particular tribal resource.

The choice experiment format that would present Native Americans as well as the general public with a variety of Native American related attributes would seem to be a more promising avenue than the traditional contingent valuation method (CVM). CVM tends to focus more specifically on the price/cost of the project/policy/resource, whereas a choice experiment, presents price/cost of the project/policy/resource as just one attribute along with other quantity or quality dimensions. This would seem to defuse somewhat the economic orientation that many Native Americans might find repugnant in being asked questions about changes in their resource.

C. Market Values of Water

The primary studies needed here is to simply keep existing transactions data on market values of water from the Water Strategist magazine up to date for Arizona. Second would be to put additional effort into trying to locate more water transaction values for Southern California, as distinct from the San Joaquin and Central Valley's of California, where a great deal of the trading has taken place.

E. Non Market Values of Water

Most of the available water based recreation studies that exists are decades old. For example, recreational fishing downstream of Glen Canyon Dam was last valued in the 1980's. Both fishing valuation studies date back to the mid 1980's, and a seriously out of date. Thus a new study should be performed reflecting angling in Glen Canyon under current fishing conditions and angler use.

The annual value of the Grand Canyon National Park rafting was estimated by Bishop, et al. (1987) and Hammer (2001) are one to two decades old. The Bishop, et al. (1987) is by far the most thorough study so it would serve as the best template for designing an updated study.

Non market use values of irrigated agriculture in Arizona has not been estimated. In the same survey it would be important to estimate how this value is divided between: (1) the value of preserving of irrigated agriculture for the benefit of farmers (paternalistic altruism); (2) the value of open space that irrigated agriculture may provide in some lands near urban areas; (3) value of local foods. There has been no work done on non-use value of irrigation water, and it might be quite tricky to do this. Specifically, a choice experiment would be needed to estimate values 1-3, and then have a fourth non-use attribute to make sure the non-use value of the irrigation water is just that, and not comingled with concerns about food supply (a private market use value) or values 1-3.

As the reader can see there is a paucity of up to date non market valuation studies of water and hydropower related to Glen Canyon Dam. These gaps in the literature could be filled by a series of non market valuation studies over the next several years. The theoretical literature suggests non market valuation of some of the external benefits of Glen Canyon dam is at least plausible. However, other than air quality, it is difficult to apply the existing empirical valuation literature from other areas to the effects of Glen Canyon Dam.

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