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In search of an inclusive approach: Measuring non-market values for the effects of complex dam, hydroelectric and river system operations

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ABSTRACT

Hydroelectric dams have social, cultural, and environmental impacts on society through both alterations of riverine effects (both downstream and in reservoirs) and the production and distribution of hydropower in a broader geographical area. Management of complex dam, hydroelectric, and river systems frequently requires tradeoffs between alternative operational profiles, each with its own set of heterogeneous external effects. Substantial evidence suggests that segments of the public hold non-market values, including non-use values, for both riverine environmental effects and a wide array of external effects of hydropower production and distribution. However, non-market non-use valuation exercises related to re-purposing dam operations continue to focus exclusively on downstream external effects, calling into question their usefulness in decision-making processes. Focusing on the Glen Canyon Dam (GCD), a critical source of hydropower and peaking capacity on the Colorado River, US, we measure non-market values, expected to be significantly composed of non-use values, using the contingent valuation (CV) method for two proposed management options inclusive of multiple social, cultural, and environmental effects of both downstream riverine effects and hydropower production and distribution in the broader basin. To provide a defensible basis for inclusion of relevant external effects in the valuation exercise, we undertook a multi-year study of the GCD policy domain. Using a nationally-representative, address-based CV internet survey, results from an advisory referendum voting format suggest that the average US household has a median *net* willingness to pay (WTP) to continue existing GCD operations of $21.51 per year [95% CI: $2.98, $40.04] after accounting for WTP to change operations under the US Department of Interior's preferred alternative. Net non-market value for continuing operations is $2.9 billion per year, aggregating across US households.

1. Introduction

Understanding public values for or against operational changes to highly-engineered river systems, such as hydropower production from large dams, requires sorting through complex patterns of often-competing dimensions. Non-market values are attached to changes in goods and services not reflected in market prices, including both use values and non-use values. Non-use (or passive use) values are those that are not directly related to an individual's in situ use of the valued resource. A recent meta-analysis by Mattmann et al. (2016) identified multiple externalities attached to hydropower, both use and non-use values, including downstream of dams and within the riverine reach, as well as beyond, such as greenhouse gas emissions, historical and cultural effects, and aesthetics.

Non-market hydropower benefits might include reduced health effects from air pollution and improved visibility, low carbon emissions, and enhanced reliance on renewable energy (Loomis, 2014). Klinglmair et al. (2015) found a significant willingness to pay (WTP) for employment and reduced air emissions benefits related to hydroelectricity in Austria, and argued for recognizing such external effects in energy policy. While not monetized, simulation modeling of the Western Electricity Coordinating Council (WECC) region in the US supports hydropower as a flexible, renewable resource facilitating integration of intermittent renewables (wind and solar) into the electrical grid (DOE, 2016; EPRI, 2013). This ancillary benefit of hydropower is recognized as a public good, with national interest implications, where quantification might alter benefit-cost evaluations, but is also recognized as potentially trading off with downstream ecosystem service effects (EPRI, 2013).

As part of broader economic analyses of proposed operational changes in the GCD, prior investigations have sought to estimate how non-market values with an expected non-use component are affected by these changes. Using stated preference survey approaches, the

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focus of these investigations has been restricted to primarily non-use values attached to downstream environmental impacts of GCD flow patterns (e.g., Duffield et al., 2016; Welsh et al., 1995). Because of this restriction, these studies overlooked non-downstream dimensions of non-market value affected by proposed operational changes to the GCD (Jones et al., 2016; Jenkins-Smith et al., 2015). While not a full valuation study, Jones et al. (2016) replicated the essential elements of a prior GCD contingent valuation (CV) non-use study (Welsh et al., 1995) and found that voting preferences were highly sensitive to the presentation of additional value dimensions; these included non-pecuniary externalities such as the loss of hydroelectricity as a renewable energy source, and social disruption to the viability of dependent communities.

As awareness has grown about the complexity of the external effects connected to hydropower (Jones et al., 2016; Mattmann et al., 2016; Jenkins-Smith et al., 2015; Klinglmair et al., 2015; EPRI, 2013), the use of non-market values in policy decisions cannot similarly be restricted to a simplified environmental framing (of, say, the downstream reach effects in complex river system with hydropower production). If they are to be used, non-market value studies of re-purposing dam operations must meet this challenge by being inclusive of a wider array of external value dimensions than previously considered and inclusive of both "winners" and "losers" of any proposed policy.

To demonstrate implementation of such an *inclusive approach*, the objective of this analysis is to investigate for the first time, non-market values for managing the GCD that include both identified non-pecuniary external effects of hydropower production as well as downstream impacts in the river reach. Using the US Department of Interior's (DOI) 2015 Glen Canyon Dam Draft Environmental Impact Study (GCD DEIS) as our policy reference, we explore the public's WTP for the DEIS preferred alternative—a change in operations reducing hydropower optimization and improving downstream environmental benefits—and compare that to WTP for continuing existing operations.[1]

2. Background

2.1. Operations of complex dam, hydroelectric, and river systems

Large, complex, highly-engineered river systems represent examples of coupled human and natural systems (CHANS) – complex systems comprised of human and environmental interactions (Chen et al., 2015; Ostrom, 2009; Liu et al., 2007). The science of CHANS focuses on processes that link human and ecological systems, including reciprocal interactions and feedbacks (Liu et al., 2007). The GCD system is a good example of a CHANS. Public preferences concerning large dams, whether focused on construction, removal or operational changes (e.g., as with the GCD), cannot be restricted to a singular framing (Jones et al., 2016; Jorgensen and Renoflat, 2013), and defy simple narratives.

GCD operations are responsible for roughly 70% of the hydropower generated from a series of upper basin dams on the Colorado River (CR) system through the Colorado River Storage Project (CRSP) (USDOI Bureau of Reclamation, 2015). As part of the Western Electricity Coordinating Council regional grid, GCD hydroelectricity is distributed to 5.8 million people by the Western Area Power Administration (WAPA) under contracts to a mix of utilities, 57 Native American tribes and pueblos, rural electrical cooperatives, etc., which in turn distribute to communities and agricultural irrigators in Arizona, Colorado, Nevada, Utah, Nebraska, New Mexico and Wyoming (Jones et al., 2016).

The GCD provides a renewable supply of hydroelectricity while regulating flows between the upper and lower basins of the CR; this federally-subsidized hydropower remains considerably cheaper than electricity from fossil fuels and other available renewables. The interruption of total and peak hydropower production would likely involve significant replacement by fossil fuel-based power production, at a much higher cost (e.g., O'Fallon, 2015) and with increases in air pollution including nitrous oxides, sulfur oxides and carbon dioxide (GCDAMP, 2015). As noted in Jones et al. (2016), disruptions to GCD operations may have an impact on farmers, ranchers, and Native American entities who have long used low-cost GCD hydroelectricity distributed under contract with WAPA. After covering operational costs, CRSP revenues are distributed to the Upper Colorado River Basin Fund to pay for irrigation projects, environmental programs (e.g., upper basin endangered fish recovery, salinity control), and the Glen Canyon Dam Adaptive Management Plan (USDOI Bureau of Reclamation, 2015). Thus, the GCD, with the Lake Powell Reservoir behind it and its downstream reaches below, leading into the Grand Canyon, represents a key operational element in the broad multi-state CR region.

Operational patterns generate trade-offs, which are seen in the mutually exclusive value expressions in broad compilations of "desired future conditions" for GCD operations and the downstream river system (e.g., see Colorado River Study Group, 2016 and GCDAMP, 2015). Periodically, re-consideration of the current operational patterns of key engineered-elements of complex river systems is either desired or legally required. In the US, this can range from federal dam re-licensing, to re-examining the legally-allowed purposes for a system of reservoir operations, to required or needed updating of Environmental Impact Statements, as is the case with the GCD. In December 2015, the US Department of the Interior (DOI), through the Bureau of Reclamation and National Park Service, issued a Public Draft of the *Glen Canyon Dam Long-Term Experimental and Management Plan Environmental Impact Statement* (GCD DEIS, 2015). The DEIS identifies and analyzes potential implications of alternative ways to manage monthly and hourly releases of water from GCD, focusing chiefly on changes in resources directly along the CR in the downstream reach. Alternatives considered include "no-action" (continuation of current policy), and a range of alternative actions that would achieve different objectives. Under the "no-action" alternative (Alternative A), release volumes are determined by historic monthly patterns that are (partially) responsive to peaks in demand for electricity. The DOI's "preferred alternative" (Alternative D) would establish condition-dependent flow and non-flow actions that would be triggered by resource conditions.

2.2. Non-market values for operational alternatives

For economic analyses, natural resource operational trade-offs generate a variety of effects – both direct and indirect, market (e.g., the change in value of the electricity produced at the GCD), and non-market in nature; the latter includes consideration of use values such as for outdoor recreation, but also includes consideration of non-use values. Non-market valuation refers to attempts to assign monetary values to goods or services not priced or traded in a functioning market (Boyle, 2003). Efforts at fully assessing non-market values include survey-based assessments of stated preferences, which might be significantly motivated by efforts to estimate non-use values. Non-use values are not attached to any direct in situ use of the good (Loomis et al., 2005; Harpman et al., 1995), and may be composed of bequest, option and existence values. Within the total economic value connected to any proposed bundle of changes, non-market values that include non-use motivations represent the most difficult to measure component (Haab et al., 2013).

The original introduction of non-market and non-use values into required governance assessments and economic analyses of proposed changes to river systems played an important role in more fully considering environmental effects in the US and elsewhere (Loomis et al.,

[1] Additional background information on the overall study, as well as expanded details on survey design, is available in a 2016 University of Oklahoma, Center for Energy, Security, and Society report written by the authors (Jenkins-Smith et al., 2016); http://cess.ou.edu/resources/2016093-GCD_3B_FinalReport.pdf. Here, we expand the motivation and discussion, along with providing a more extensive econometric investigation.