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Engaging attribute tradeoffs in clean energy portfolio development

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ABSTRACT

Governments and privately-held utilities will have to drastically reduce their carbon emissions to mitigate climate change. Such reductions will require transitioning electrical infrastructure to rely on cleaner fuels and power-generation technologies. Despite the myriad factors influencing both the process and eventual outcome of these transitions, it is typically transitions' cost and individuals' willingness to pay (WTP) for them that dominate both strategic planning and political discourse. Studies used to calculate the public's WTP however often rely on vague policy options, ignore important social and environmental attributes, and fail to provide individuals means for engaging tradeoffs. Here we report on three studies that provided individuals multiple choice tasks for evaluating real-world portfolio options across key social and environmental attributes. Our results show that individuals placed high importance on minimizing costs, yet also consistently ranked strategies highest that reduced both greenhouse gas (GHG) and air particulate emissions, even when those portfolios require considerable cost increases. When provided an opportunity to construct their own portfolios, participants again constructed costly portfolios that significantly reduced both GHG emissions and air pollution. Using multiple choice tasks, we demonstrated individuals' WTP for low-emission energy strategies to be higher than previous studies relying on contingent valuation suggest.

1. Introduction

In order to prevent global mean temperatures from increasing beyond 2 °C, governments and privately-held utilities would have to quickly and drastically reduce their greenhouse gas (GHG) emissions (Hoffert et al., 1998; Tollefson and Weiss, 2015). Such reductions would require a wholesale, disruptive transformation of electrical infrastructure with significant clean energy and carbon capture and storage (CCS) investment, development and deployment (Verbruggen et al., 2010). Despite the myriad factors influencing both the process and eventual outcome of these transitions, it is typically their cost and individuals' willingness to pay (WTP) for them that dominate both public discussion and political discourse.

This focus on the cost of transitioning and determining what individuals are capable and willing to pay for it is not without merit. Indeed, cost is considered to be the public's greatest concern in discussions about energy—along with energy's risk to human health (Ansolabehere and Konisky, 2014). However, recent research suggests that focusing on the cost of clean energy may reduce support, particularly for renewable portfolio standards (RPS) in the US (Stokes and Warshaw, 2017); RPS are state-specific standards that require electric suppliers to supply a minimum portion of their retail load using renewable energy. Such concerns raise the question of which attributes, instead of or in addition to cost, analysts should focus on when eliciting the public's energy preferences.

To try and answer this question, we present three studies in which individuals' WTP for clean energy and transition strategies in the US and Canada were investigated. These studies used an expanded range of attributes, specifically social and environmental attributes identified by community members, and multiple choice tasks, including portfolio construction, to help respondents engage tradeoffs between options and attributes. The results are WTP responses for clean-energy strategies, or strategies that dramatically reduce GHG and air particulate emissions, that are higher than many previous studies, particularly those relying on contingent valuation (CV), demonstrate.

1.1. Literature review

A wide spectrum of studies examines the US and Canadian public's WTP for clean energy production, provision and research—as well as

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RPS in the US. Most of these studies use either conjoint analysis (CJ) or CV. CJ provides respondents a brief opportunity to evaluate a few goods or options along a number of attributes, while CV typically asks respondents to assess the change in a single attribute. Considerable controversy exists regarding the latter; for instance, it has been argued that i) CV responses are not consistent with economic theory, i.e., they are scope insensitive (individuals' preferences for cleaning up one lake is roughly equal to cleaning up five) (Diamond and Hausman, 1994); ii) CV surveys capture one's WTP for the moral satisfaction of contributing to a public good rather than determining the good's *economic* value (Kahneman et al., 1986); and iii) due to individuals rarely thinking about environmental and public goods monetarily, CV surveys actually result in the construction rather than revelation of preferences (Gregory et al., 1993).

In both the CJ and CV studies examined below, the elicitation procedure, options and attributes vary considerably, as do the resulting WTP figures. For instance, in a CJ study, Roe et al. (2001) asked individuals to compare two electricity information sheets differing across the attributes monthly price, contract terms, fuel source mix (per cent renewables), and air emissions profile (NO_x, NO_2, CO_2). Their results show US individuals were willing to pay between $0.11 and $14.22/year for each 1% increase in renewables and 1% decrease in CO_2 emissions—a hedonic regression suggested a figure roughly in the middle, i.e., $6.21/year. In another CJ study, Borchers et al. (2007) presented individuals choice sets containing one of two cost increases (between $5 and $30/month) for different quantities of electricity (percentages between 10% and 25%) provided by different sources (i.e., wind, solar, biomass, farm methane or a generic green energy source). Their results show US residents willing to pay $37.29/month for a portfolio made up of 25% solar, but just $31.54/month for a portfolio made up of the same percentage of "green energy."

Studies relying on CV often delineate between government policy or pricing options. For example, Kotchen et al. (2013) showed participants one of three policy options to reduce emissions 17% by 2020: a cap-and-trade policy, a carbon-tax policy, and a "policy to regulate carbon dioxide as a pollutant," and 8 WTP responses ranging from $0 to $475 or more/year. They found US households' WTP to be between $79 and $89/year. Those same authors sought US households' WTP for a carbon tax, or a "tax on fossil fuels to help reduce global warming" in 2017, again using CV, and found a mean WTP of $177/year (Kotchen et al., 2017). Similarly, Wiser (2007) showed each participant one of four different interventions ranging from mandatory increases in all customers' utility bills to increases for only those who choose to pay (voluntary), and the funds collected then spent on renewable energy projects by either the government or by electricity suppliers. Using three different price points ($0.50, $3 and $8/month), the authors found 50% of US residents would pay $8/month in the form of mandatory payments for government-provided renewable energy; less than 40% would voluntarily pay $8/month for projects led by electricity suppliers.

Some CV studies rely on a specific RPS percentage to gauge respondents' WTP, while others use less precise targets. In a study using CV, Mozumder et al. (2011) asked participants to provide a single, open-ended, WTP for a scenario in which New Mexico's energy would come from 10% renewables (result: $14/month). Stokes and Warshaw (2017) presented individuals a more aggressive RPS of 35% by 2025, a set of statements that varied the RPS's impact on employment, clean air and GHG emissions, and a hypothetical price increase of either $0, $2, or $10/month. They found that proposed utility bill increases of only $2 and $10/month led to a 6% and 13% decline in support, respectively. Mills et al. (2015) asked participants if they would support an undisclosed "set portion" of electricity coming from renewables at a cost increase of either $25 or $50/year, while Borick et al. (2011) asked individuals to select from a range of $0 to $500 or more per year for simply "more renewable energy to be produced." The former showed that a majority of individuals in the US would no longer support an RPS if it cost $50 per family per year, while Borick et al. (2011) showed that 41% of those in the US were unwilling to pay anything for increased renewable energy production—up from 22% just two years prior, and only 13% were willing to pay upwards of $100/year. In that same report, only 21% of Canadians were unwilling to pay anything for increased renewable energy production, and 26% were willing to pay $100/year and 7% $500/year or more.

Finally, Krishnamurthy and Kriström (2016) used a single CV question, which asked respondents for the maximum annual percentage increase (on their utility bill) they would pay to use *only* renewable energy, while Rowlands et al. (2002) used CV around five price options ($0 to $50/month) for Waterloo, Ontario residents to select from to ensure that *all* of the electricity they use would come from "green" sources. The former found Canadians were willing to adopt a 12.4% utility premium increase for 100% renewables, while the latter showed over 90% willing to pay an additional $5 to $25/month for 100% "green" energy.

Each of the studies above varied the RPS, fuels, policy options, price points, or emission reductions in question, or else altered how such information was framed. The CJ studies resulted in higher WTP for clean energy than did the CV studies, with the former showing individuals willing to pay upwards of three to six hundred dollars per year for increased renewables, while CV often led to WTP responses of less than $100/year. Such differences in WTP figures, both within and between CV and CJ studies, complicates the development of publicly acceptable clean-energy policies. Additionally, the studies described above touched only briefly—or not at all—on the real-world social and environmental costs and benefits of supporting different clean energy and RPS options. We contend that studies which fail to make clear these costs and benefits may elicit less accurate WTP for energy transition plans and portfolios.

1.2. Expanding the range of and engaging tradeoffs between attributes

Indeed, research shows individuals consider a number of costs and benefits, or attributes, in their energy decisions. For instance, people consider energy's risk to human health (Ansolabehere and Konisky, 2014), its impact on air quality (Roe et al., 2001) and alterations required to local landscapes or changes in land use (Abbasi and Abbasi, 2000; Pasqualetti, 2011; Apostol et al., 2016)—especially regarding wind energy (Johansson and Laike, 2007; Pasqualetti, 2011). They consider energy's impact on employment (Stokes and Warshaw, 2017), wildlife habitat and biodiversity (Bergmann et al., 2006), and national security, as well as the extent to which energy relies on risky technologies (Huijts et al., 2007) or technical, social and market innovations (Wüstenhagen et al., 2007). Individuals also consider energy's role in mitigating GHG emissions (Howe et al., 2015), and it has been suggested that in order to better motivate mitigation policymakers should characterize GHGs as a *local* risk and focus people's attention on mitigation's *localized* benefits (van der Linden et al., 2015).

Making clear how different energy plans perform across such attributes is certainly important; however, simply expanding the range of attributes people consider may not go far enough. This is due to the technical and cognitive complexity associated with recognizing and confronting tradeoffs between attributes, a complexity which increases with the number of attributes included (Arvai, 2014). In such situations, particularly contexts that incorporate conflicting values and objectives, uncertainty, and nonlinear or complex adaptive systems (Payne et al., 1992; Dietz, 2013), people tend to rely more heavily on mental shortcuts and the systematic biases that plague them (Arvai et al., 2012). In such cases, structuring decision processes, working to de-bias choices, and decomposing complex problems into more cognitively manageable steps can improve decision outcomes, increase stakeholders and decision-makers' satisfaction (Gregory et al., 2012) and increase the degree to which people's choices align with their values (Bessette et al., 2016).

A recent advance in both tradeoff analysis and de-biasing choices