Understanding Customer Preferences for Future Energy Supplies:
When is an Integrated Resource Plan Similar to a New PC?

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As part of its Integrated Resource Plan (IRP) development for the 2005 / 2006 cycle, Portland General Electric (PGE) wanted to take into account customer preferences for alternative energy resources. The company faced several problems in developing insight on the relevant customer preferences, however. On the one hand, there was some question about whether or not resource "preference," was really the question. On the other hand, it was not at all clear how best to measure the relevant customer preferences (however these were defined) given the well recognized concerns that many researchers have about customer tendencies to overstate their preferences for certain kinds of energy resources (particularly "green" resources). Beyond these issues, the company was aware that most customers are not familiar with either energy supply planning processes, and at least some (if not most) of the supply options that might be available for use in current plans. The core problem the company faced, then, was how to design a research effort that would provide meaningful market insight

The Problem

In order to achieve its business objectives PGE needed to be able to place individual resource options (whether new generation, demand reduction, or new wholesale power purchases) on a ratio scale of customer support for inclusion in an IRP. Even beyond this, however, the company needed to be able to establish (again on a ratio scale) customer preferences for resource mix options. By a "ratio scale," of course, we mean a scale that is not merely ordinal (meaning that we can tell that people like one option more than another), but is one in which the distance between scale ratings is meaningful.

Before a ratio measurement could be defined, however, the team worked to clarify what it meant by the customer "preference" in question. The conclusion they reached was that the key issue was not "preference" where this means how much customers say they "like" a given resource, or how much they would be willing to pay (incrementally) for it. Rather, the focus of this measure had to be on the likelihood that customers would support the inclusion of that resource / mix option in a PGE IRP inventory. The distinction between these two notions of "preference" may be subtle, but the team decided they were important because a thoughtful review of the logic of the two versions of preference suggested that they might not always overlap ("liking" would not always result in "wanting it included in an IRP"). Based on a review of research on issues related to customer preferences, willingness-to-pay, and specific customer preferences for utility resources, the research team believed that they could assume the following:

- Some respondents say (and mean) that they would be willing to pay more for certain types of resources (renewables, for example), but they also say very clearly that these costs should not be imposed on all ratepayers regardless of their ability to pay. They are saying essentially, "yes, I would choose to pay more for this, and I can afford to do so, but I'm not saying that everyone should be "forced" to pay more for this type of resource – only if they voluntarily choose to do so."

- Other respondents say quite clearly that they would be unwilling to pay any amount more for certain types of resources (typically renewables), not because they do not want these resources included in utility portfolios, but because they believe that it is the responsibility of utilities to include such resources regardless of any incremental costs associated with those resources and without passing along any of those costs to customers
- Still other respondents recognize that they derive what might be called "passive use value" from certain kinds of resource options (again, typically renewables) which do not map exactly to the "use value" they have for those resources. That is, they want a resource to exist for reasons that do not have to do with the amount of electricity it produces, and what they are willing to pay for the electricity generated by that resource will always underestimate the value they place on it (because the existence of the resource creates value for them which is not reflected in the "product" it produces).
- Respondents also typically understand that electricity supply portfolios are portfolios composed of different amounts of different types of resources. The issue of support for a given resource option, then, is made by customers within the context of a resource mix, rather than independently. As a result, capturing willingness-to-pay (WTP) information on a resource-by-resource issue would not tell us anything really about support for the inclusion of a given resource option within the context of a resource mix. If we know, for example, that customers say they would pay more for solar than for coal by some number of cents per kilowatt hour, does this mean they would not support the inclusion of a coal plant within a resource mix that was predominantly "green?" The short answer is that while this question was critically important, the team also recognized that it was impossible to answer if all you had was WTP information (or the equivalent) on a resource-by-resource basis.

Approach to the Research

The team concluded, for the reasons outlined above, that WTP – even if it could be measured accurately (or at least consistently) – was the wrong measure for their purposes. The research approach the team did implement focused on asking respondents directly the question that we want them to answer. That is, the team developed a set of exercises in which respondents were asked to directly express their preferences for how PGE should make choices about constructing a resource portfolio for the future. This task was not a simple one, of course, certainly not as simple as just "asking them" their preferences on a resource-by-resource basis. Rather, in order to deal with the complexities of having preferences articulated in a specific context, the team chose a research tool that has been labeled "user design[1]." This method of presenting stimuli and capturing information enables respondents to design their own virtual "products," and in doing so, allows the analyst to understand the interactions between "product features" and the tradeoffs that respondents make as they select one set of "product features" over another. While, to the team's knowledge, this tool had not been applied in a directly analogous situation, they believed that it offered real benefits in this context. Before turning to a discussion of how the tool was actually used in this research, we provide a more general discussion of the way the tool works.

[1] E. Dahan and J. Hauser, "The Virtual Customer," 2001; *Journal of Product Innovation Management,* 19, 5, (September), 332-354. The paper can be downloaded at mitsloan.mit.edu/vc

The user design interface begins much the same way that traditional conjoint discrete choice exercises begin; by defining the attributes (product features) and levels (the amount and type of variability possible within each feature) that can be used to define a given product. Rather than having the survey specify the combinations of features / levels for given products and asking respondents to evaluate those combinations, however, user design essentially allows respondents to select their preferred feature / level set, while recognizing the tradeoffs (including price) that are inherent in each feature / level selected. Imagine, for example, one of the online PC design interfaces provided by Gateway, Dell, or many other suppliers. In this example, the respondent (the PC buyer) selects the level they want from each feature (processor speed, for example, or RAM, or weight) and, as they do so, the price of the unit changes to reflect the features they have selected. What a buyer does in this situation is to select the set of product features that best meets their needs at a price they are willing to pay.

A "user design" task operates in almost exactly the same way. If we were using a "user design" interface to design a new PC, we would have respondents do just what buyers do, but we would manipulate the prices associated with the different features, and perhaps include certain interaction terms (if you want the lower weight, you can't have the larger screen size). By having respondents complete the exercise several times with different underlying prices and interactions, we can capture information that gives us similar, but much more detailed, information about how respondents trade off different product features / levels than does traditional discrete choice analysis.

The team didn't need to design PCs, of course, nor did they need to design any other traditional product, but even so, they concluded that this tool was uniquely suited to the context. Rather than designing the PC they want to buy, the team asked respondents to construct the resource portfolio that they would like to see PGE pursue. The final set of exercises had the following characteristics:

- Respondents were told that they had a X amount to invest in new resources and a target of a certain amount of generating resources needed
- They had the ability to meet the MW need by selecting "units" of different types of resources that would have different costs attached to them (but note that these are "investment" / development costs and not WTP prices)
- The exercises were constructed to force difficult tradeoffs (it was not always possible to meet the MW needed by choosing only low impact renewable resources)
- We added links to pop-up windows so that respondents could access reminders of the environmental impact, and the other key characteristics, of each option as they selected it to add it to their resource mix
- Respondents were allowed to go over a pre-specified baseline budget, but were reminded that this increase would affect all ratepayers by a specifiable amount
- Respondents completed multiple versions of the exercise which differed in terms of their implicit prices and the options that were available.

The data yielded by these exercises is, essentially, the number of units of each resource that respondents chose to put into their mix, and the "prices" at which they selected them. Analytically, the data allowed the team to develop quantitative (and ratio-scaled) estimates of the relative "preference" that respondents exhibit for each option in the aggregate (by indicating how

much budget they choose to allocate to each option), but in addition, allowed us to understand portfolio mix questions directly (are they willing to include some "dirty" options as long as they have a preponderance of renewables, and if so, which ones? Are customers sensitive to different resource costs?).

What is most important, of course, is that this approach allowed the team to answer the key business questions directly. Rather than assuming that an individual's stated WTP for a given resource maps to their preference for the inclusion of that resource in a given portfolio of resource options, we were able to develop quantified, and ratio-scaled, data that allowed us to array resource options on the dimension PGE cared about directly (that is, along the "what options should be included in PGE's IRP" dimension).

Examples of the Questionnaire Design

After several introductory questions, respondents were provided with background information on each type of resource that was explored in the research and asked an initial question about their assessment of that resource. An example of the type of information provided for each resource follows below:

> *NATURAL GAS-FIRED POWER PLANTS:*
> *Over the last decade, natural gas-fired power plants have been the preferred fossil fuel resource for new power plants at many utilities around the country. The plants tend to be dependable and are easy to operate in ways that respond quickly to changes in customer demand for electricity.*
>
> - *Resource Cost: Low cost to build; operating costs depend on the price of natural gas*
> - *Price Stability of Electricity Produced: Low, since natural gas prices vary significantly and prices change rapidly*
> - *Environmental impacts: Moderate; substantially lower than conventional coal plants*
> - *Reliability of the Resource: High; a proven, efficient technology that, however, depends on a fuel (natural gas) that the U.S. is increasingly dependent on importing from other countries.*
>
> *Given these factors please rate "Natural Gas-Fired Power Plants" in terms of the extent to which you would prefer that this resource be made a part of PGE's long-term energy supply plans. [0-10 scale; 0=Do not want this resource included, 5=Do not care one way or the other, 10=Prefer that this resource be included]*

Respondents were provided with similar information for:

- Conventional coal power plants
- Next generation coal plant with reduced emissions
- Next generation nuclear plant using Advanced Safety Technology
- Renewables (not including Hydro-electric Power Plants)
- Energy conservation

Once they reviewed information about each type of resource, respondents were engaged in the key resource planning "user design" exercises. A total of 17 different combinations of resource options and relative costs were specified by the team, and each respondent evaluated five different options. The specific questions were structured as follows:

> *Now we would like to give you the opportunity to develop your own energy supply plan for Oregon for the next 10 years.*
> *The table below provides several electricity resource options that are available to you to build an energy plan. It also tells you the cost "points" associated with each unit of electricity resource you select.*
> *To complete this exercise you must:*
> - *Select 10 units of electricity resource in total*
> - *You can select only one type of resource or select a mix of resources. You do not have to include every resource, only the ones you want in your plan*
>
> *You do NOT have to spend exactly 1000 cost points:*
> - *For every 250 points your plan EXCEEDS 1000 cost points, the bills for ALL PGE customers will go up by 5%*
> - *For every 250 points your plan costs LESS than 1000 cost points, the bills for ALL PGE customers will go down by 5%*
>
> *Please enter the number of units of each resource to be included in your plan in the table below. When you have selected the 10 units of electricity resource you want – recognizing the total cost impact of those resource selections – you are done.*
> *Please note: The cost points associated with each type of resource may or may not reflect the actual costs that would be associated with acquiring each resource in the marketplace. For the purposes of this exercise, however, please make your energy planning decisions assuming the relative costs reflected in the resource cost points indicated.*

Resource	*Units of Each Resource Available*	*Cost Points for Each Unit (including cost to build, operate & cost of fuel)*	*Enter Number of Units of Each Resource to be Included in Your Resource Plan*	*Cost for Units of Electricity Selected for Each Resource*
Energy conservation	*10*	*120*	*[RECORD UNITS 0-10]*	*[DISPLAY TOTAL FOR E.C.]*
Conventional coal plant	*10*	*100*	*[RECORD UNITS 0-10]*	*[DISPLAY TOTAL FOR COAL]*
Gas-fired power plant	*10*	*110*	*[RECORD UNITS 0-10]*	*[DISPLAY TOTAL FOR GAS]*
Next generation coal plant with reduced emissions	*10*	*100*	*[RECORD UNITS 0-10]*	*[DISPLAY TOTAL FOR NG COAL]*
Next generation nuclear plant using Advanced Safety Technology	*10*	*80*	*[RECORD UNITS 0-10]*	*[DISPLAY TOTAL FOR NUKE]*
Renewables (not including Hydro-electric Power Plants)	*10*	*100*	*[RECORD UNITS 0-10]*	*[DISPLAY TOTAL FOR RENEW 1]*
		Total Number of Blocks of Electricity Selected Must Equal 10 ➔	*Click Here for Total [DISPLAY TOTAL NUMBER OF UNITS SELECTED]*	*Click Here for Total Cost of Energy Plan [DISPLAY TOTAL COST]*

If cost points were less than 1000 respondents saw the following: “Energy bills for ALL PGE customers will go DOWN by [a calculated value that equaled 5% for every 250 cost points under 1000 multiplied by $68 (the average residential monthly bill for customers without air conditioning (a different value was provided for those with AC))]”. If cost points equaled 1000, then they saw this message: “Energy bills for ALL PGE customers will remain the same.” If cost points were greater than 1000 they saw this message: “Energy bills for ALL PGE customers will go UP by an average of (a calculated value that equaled 5% for every 250 cost points over 1000, multiplied by $68].”

After they "signed off" on their plan, respondents were asked the following:

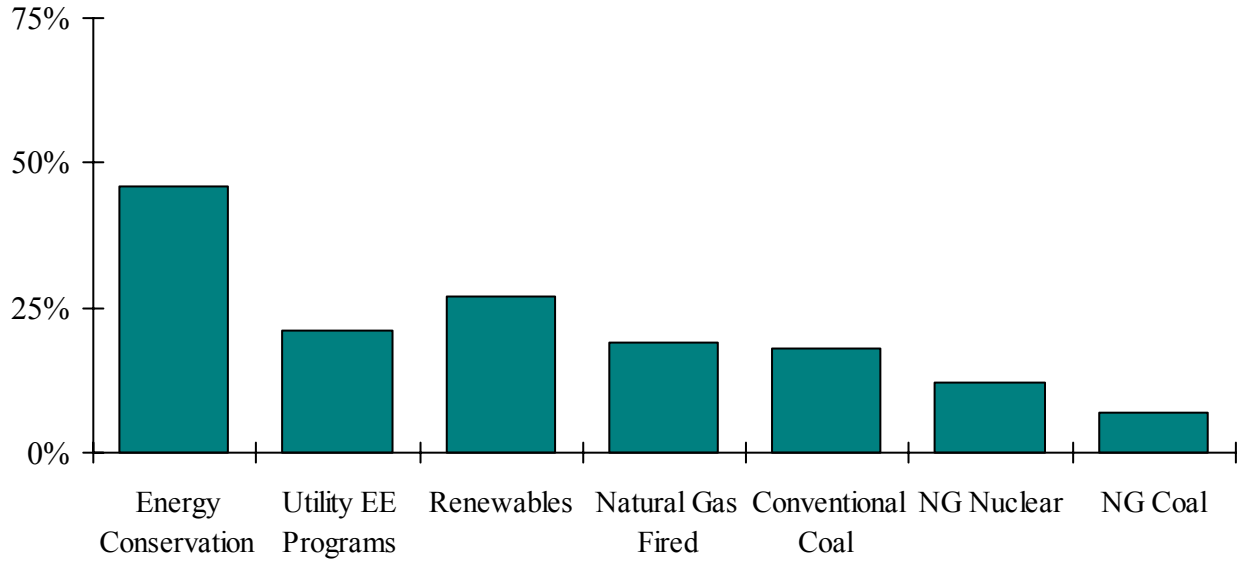
. *Thinking of this resource plan you just created, how much would you prefer that PGE use this as its long-term energy supply plan? [0-10 scale; 0=Strongly prefer PGE Not use this as its long term energy supply plan; 10=strongly prefer that PGE use this as its long-term energy supply plan]*

Results

A total of 507 residential PGE customers completed the survey (while business customers were also surveyed, this paper focuses on responses from residential customers). An initial telephone screening interview was used to ascertain respondent qualification and willingness to participate, and the final survey was then completed on the web.

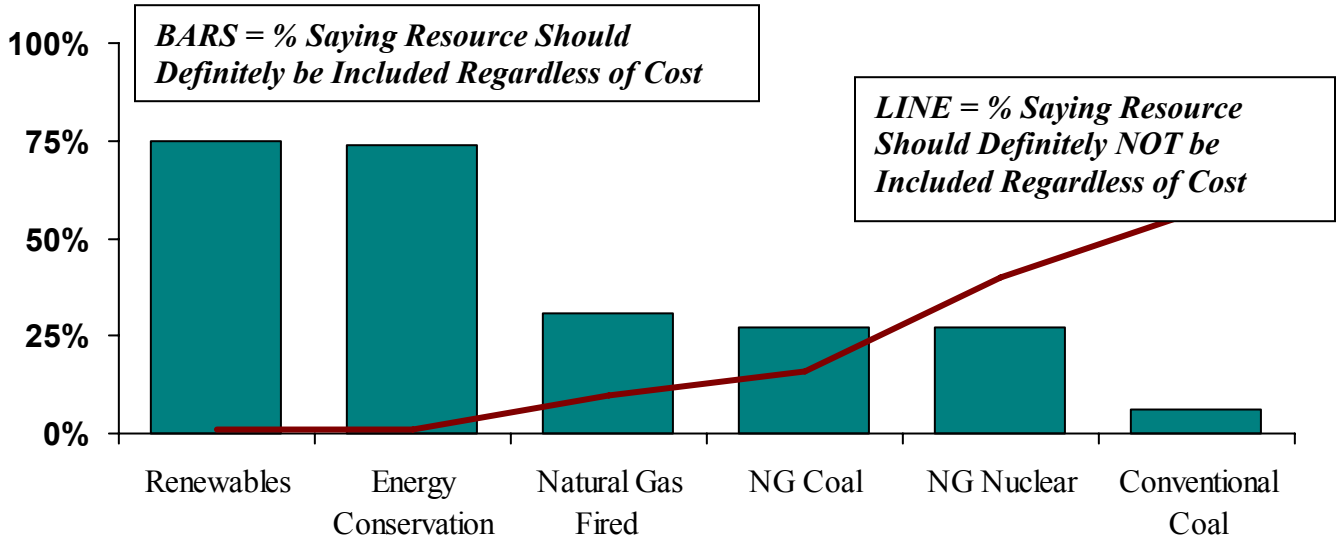
Initial questions in the survey focused on understanding ingoing levels of familiarity with, and preference for, each type of resource. As the team anticipated, stated familiarity with most types of resources was low.

Chart 1: Percent of consumers saying they are familiar with each resource



As respondents moved to evaluating each of these resources independently, the team was somewhat surprised to learn that conventional coal plants were even more actively disliked than were nuclear plants (see Chart 2 below). It was much less surprising, of course, that renewables and energy conservation were viewed most positively.

Chart 2: Ingoing Preference for Each Resource



Of course, these results are simply context-setting for the central issues addressed. The responses that customers made to the user-design exercises were used to develop a model of relative preferences (and relative resource mix preferences) for including each resource in a supply plan. Poisson regression was used to model relative preference for each of the six energy resources given their relative cost or price advantage as compared to all other available options. By analyzing the way that respondents evaluating each scenario make their resource choices, it was possible to specify – on average – how much they value each resource in the mix - the more it is chosen, given its cost relative to others, the more it is preferred. By taking into account the way that respondents also react to the other scenarios in the set, the team was able to model aggregate and relative resource preferences within each customer class.

The first step in estimating customers' optimal energy resource portfolio was to understand how the cost of each option, given the cost of every other option in a given scenario, affected preference for a given resource. The summary measure for this relationship between the prices of each resource present in a given scenario is referred to as the resource's "price advantage" in this analysis. This measure provides a way to standardize the effect of price in the analysis. The average price advantage for each resource, given a particular set of resource options is calculated in the following way:

$$A_i = \frac{1}{n-1}\sum_{j=1}^{n}(P_j - P_i)$$

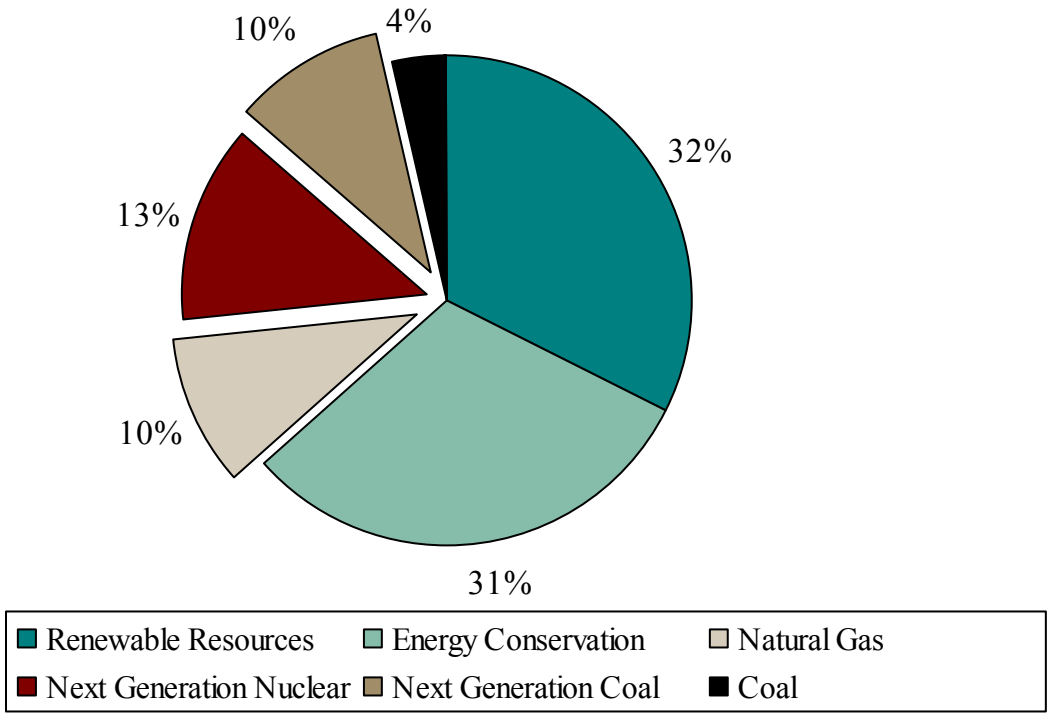
where A is the price advantage, n is the number of resource options, and P is a given price. The price advantage of a given resource option is dependent not on the absolute value of the prices of competing resource options, but rather the differences in these prices. That is, looking at just two energy resources priced at $100 and $150 dollars respectively, we could say that the first resource has a $50 price advantage. Similarly, if the two energy resource options were priced at

$50 and $100, the first option still has just a $50 price advantage. Regression analysis was then used to determine the values of parameters for a function that caused the function to best fit the set of observed data. In linear regression, the function is a linear or straight line equation. Linear regression assumes that the data are normally distributed around the mean. Because the data used in this analysis are integer valued and the variation in response was roughly proportional to its magnitude, the data is non-normally distributed. A Poisson regression model was used in this analysis because such models do not require normally distributed data. Using Poisson regression, the average demand of a given energy option E(Y) given the average price advantage of a given resource (A) can be calculated using the following equation, where the parameters β_0 and β_1 are estimated by the maximum likelihood method.

$$E(Y) = \exp(\beta_0 + \beta_1 A)$$

Based on this analysis, it was possible for the team to estimate relative preferences for resource inclusion in an IRP under a wide variety of assumptions about resource availability and relative price. Considering the simplest example to start – all resource available and equal cost – Chart 3 below provides modeled results for this scenario. It suggests that while "green resources" are most preferred, they account for "only" 64% of the average aggregate resource plan, while Next Generation Nuclear resources account for 13%.

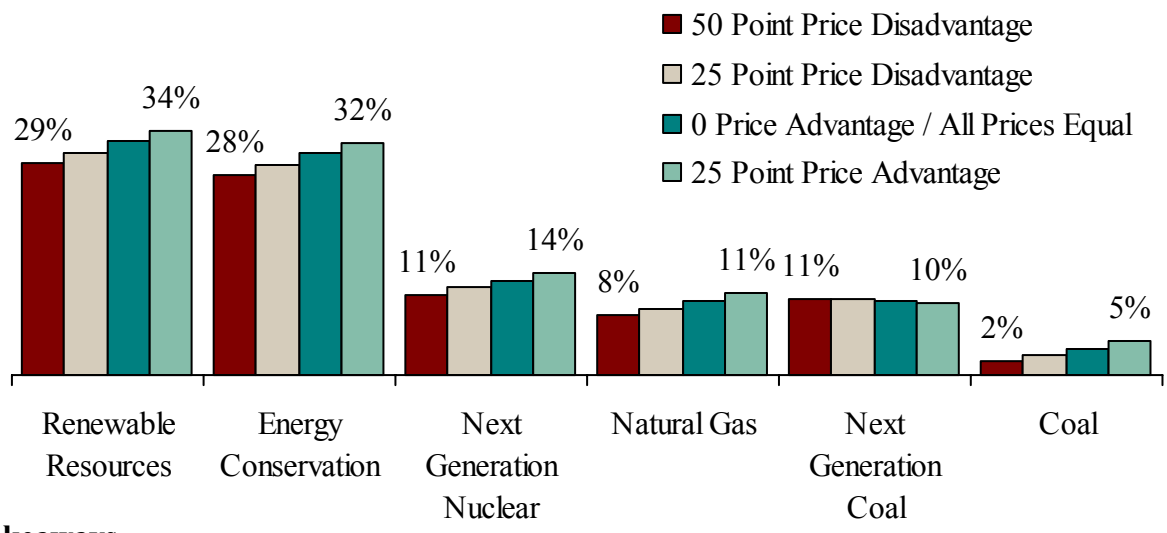
Chart 3: Residential customer resource preference given availability and equal cost



Evaluating a variety of resource scenarios also enabled the team to understand how resource preference (again, where this means preference for the inclusion of the option in an IRP) varied with resource availability (i.e., What happens when nuclear is not an option? What happens when renewables are not an option?) and relative price advantage. Results on relative price advantage are reported in Chart 4 below. These results indicate the preference for any given

resource is relatively inelastic (not dramatically affected by relative price advantage) for any of the resources, though this is particularly true for Next Generation Coal.

Chart 4: Price Sensitivity of Preference for Different Resources



Key Takeaways

The key conclusions and takeaways the team drew from the research were as follows:

- Most customers are not aware of the current generation mix
  - Given their concern about conventional coal, educating them on this subject may well be a double-edged sword (on the one hand, we tend to assume that more education / awareness is a good thing, although the fact that customers now underestimate the proportion of the resource mix that is conventional coal, means that improving the accuracy of their awareness on this issue may simply make them more negative toward the current mix)
- Support for renewables is strong – and remains strong even if ALL customers are required to pay more for them:
  - And Wind is the key option here – it is frequently considered as a category of its own
- Nuclear has a strong negative preference – but the preference for conventional coal is even more consistently negative
  - Nuclear does have some support – conventional coal does not
- In general, customers believe that renewables & conservation should account for 50-65% of new energy needs:
  - Natural gas, gassified coal, and next generation nuclear are essentially tied as the next preferred option.
  - However, most customers also believe that a diverse resource supply is desirable
  - Preferences are relatively resistant to cost differences

Table 1: PGE IRP Option Research – User Design Scenarios

Resource Option	Energy Conservation	Coal	Gas-fired	Next Gen Coal	Next Gen Nuclear	Renewables
Scenario 1	100	100	100	100	100	100
Block 1: Cost Units – All Possible Resource Options Available						
Scenario 2	125	75	100	100	75	125
Scenario 3	150	75	100	125	75	150
Scenario 4	150	125	125	125	100	150
Scenario 5	125	100	125	150	150	125
Scenario 6	125	75	75	100	150	100
Block 2: Cost Units – Only Fossil Fuel Options Available						
Scenario 7	--	100	125	100	75	--
Scenario 8	--	100	125	125	100	--
Scenario 9	--	75	100	125	75	--
Scenario 10	--	75	75	100	125	--
Scenario 11	--	125	100	75	125	--
Block 3: Cost Units – Green and 1 Fossil Fuel Option Available						
Scenario 12	125	100	--	--	--	125
Scenario 13	125	--	100	--	--	125
Scenario 14	125	--	--	100	--	125
Scenario 15	150	--	--	125	--	150
Scenario 16	125	150	--	--	--	100
Scenario 17	100	150	--	--	--	125