Electricity Economics

Power System, Reliability, Costing, Economic, Financial, and Scheduling Analysis

Qualifications and Experience

Veritas Economics (Veritas) applies sophisticated data collection techniques in concert with econometric, simulation, and optimization modeling to develop state-of-the-art economic models and software tools that are used to evaluate electricity supply and demand. Veritas' supply side experience includes evaluating power system, reliability, cost, schedule, economic, financial, supply chain, and workforce impacts associated with electricity generator additions, modifications, and removal. Veritas' demand side analysis includes evaluating consumer preferences and developing adoption models of new electricity service plans that include time of use rates, peak demand charges, and green rates; estimating adoption of electric vehicles and residential solar; and evaluating the effect of variable peak pricing on electricity demand.

Veritas' experience ranges from modeling the economic, financial, and power system impacts of constructing and commissioning new power plants and the premature shutdown and decommissioning of old power plants to the system-level impacts of potential policies that will affect the entire US power system. The following bullets highlight Veritas' electricity supply and demand experience:

Electricity Supply Analysis

- Evaluated the economic, price, and reliability effects of delisting a confidential nuclear plant.
- Evaluated the power system, supply chain, workforce, and economic impacts associated with developing new nuclear energy generation (Veritas Economics 2024).
- Evaluated the effects of offshore wind development and hydrogen generation on electricity production, prices, and excess capacity in ISONE (Normandeau Associates, Veritas Economics, Tetra Tech 2023).
- Conducted power system modeling and reliability analysis using Veritas' Electricity Policy Simulation Model (EPSM) to evaluate power system reliability and price impacts from plant modifications and premature retirements in the PJM, ERCOT, ISONE, MISO, NYISO, and SERC.
- Conducted over a hundred peer reviewed power system, reliability, costing, scheduling, economic, and financial evaluations at electricity generators throughout the United States.

Electricity Demand Analysis

- Developed Veritas' Residential Rate Model (RRM) to evaluate residential customers' likelihood to adopt new electricity rate plans and estimate the corresponding change in bills, revenue, and peak load expected to occur under new rate plans.
- Measured customer preferences for alternative electricity service plans and developed an electricity service plan adoption model (EPRI 2015, 2019; Veritas 2018a).
- Analyzed Oklahoma Gas & Electric variable peak pricing impacts using electricity demand models (Neenan et al. 2015).
- Measured customer preferences for residential solar and developed a residential solar adoption model (EPRI 2017).
- Measured customer expectations and purchase plans for electric vehicles and developed an electric vehicle adoption model (EPRI 2011g, 2011h; Neenan and Kinnell 2012).

The following descriptions provide examples of Veritas' electricity supply and demand project experience.

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- **Evaluated Power-System and Reliability Impacts of Modifications, Premature Retirements, and Delisting at Hundreds of Electricity Generating Stations Throughout the United States –** Veritas has conducted power system and reliability analysis of modifications, premature retirements and delisting at hundreds of sites throughout the United States through either regulatory impact analysis of new national regulations or as part of compliance evaluations with existing regulations. At the heart of Veritas' power system modeling is its Electricity Policy Simulation Model (EPSM – Veritas Economics 2024). EPSM is an analytical tool designed to assist policy makers and corporate strategists in their evaluations of alternative electricity-system and resource-allocation choices. Results from EPSM include the physical, economic, and financial performance of the electricity system and of its elements and institutions.

  There are two components to evaluating reliability impacts: adequacy and security. Veritas uses EPSM to evaluate adequacy impacts, and power flow modeling to simulate grid stability under NERC contingency conditions to identify security impacts. Figure 1 depicts an illustration of EPSM's reliability optimization module that can evaluate the reliability impacts from unplanned outages of individual electricity generating units. See EPRI 2011d; Bingham, Matthews, and Kinnell 2009; and Veritas 2018b for examples of Veritas' power system and reliability evaluations.

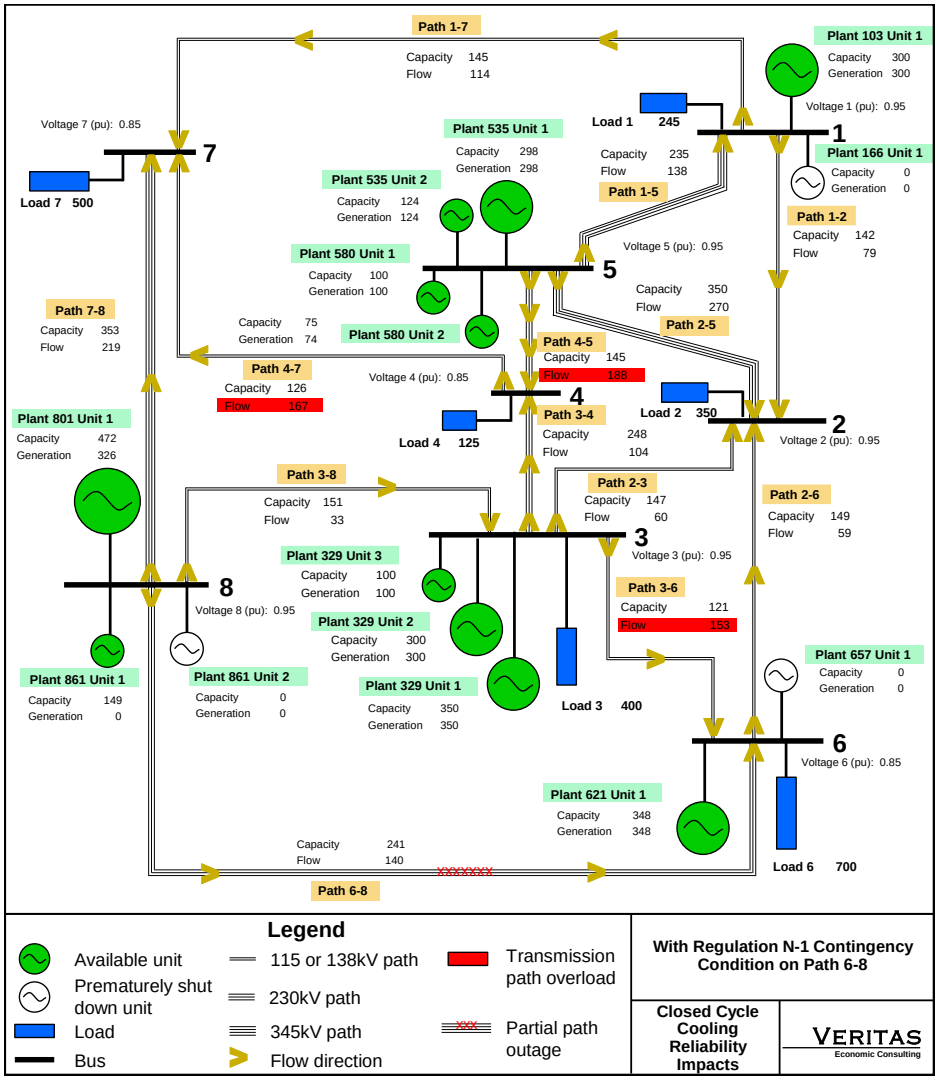


Figure 1 – Visual Depiction of the Outputs from Veritas' Reliability Impacts Optimization Module

- **Developed Peer-Reviewed Regulatory Evaluations of Power-System, Costing, Financial, and Economic Impacts of Modifications and Premature Retirements of Electricity Generating Stations Throughout the United States** - Veritas has conducted peer-reviewed power system, reliability, costing, economic, and financial evaluations at over 100 electricity generating stations throughout the United States, including 15 nuclear power plants, as part of regulatory compliance submissions. These projects include estimating costs and schedule for plant modifications; conducting power system modeling to evaluating impacts to electricity prices and grid reliability; conducting economic impact analysis to evaluate effects on jobs and income; estimating the environmental benefits of plant modifications; and conducting cost-benefit analysis of the plant modifications or premature retirements. See Veritas Economics 2018b, 2018c, 2020a, 2020b, and 2024 for examples of these efforts

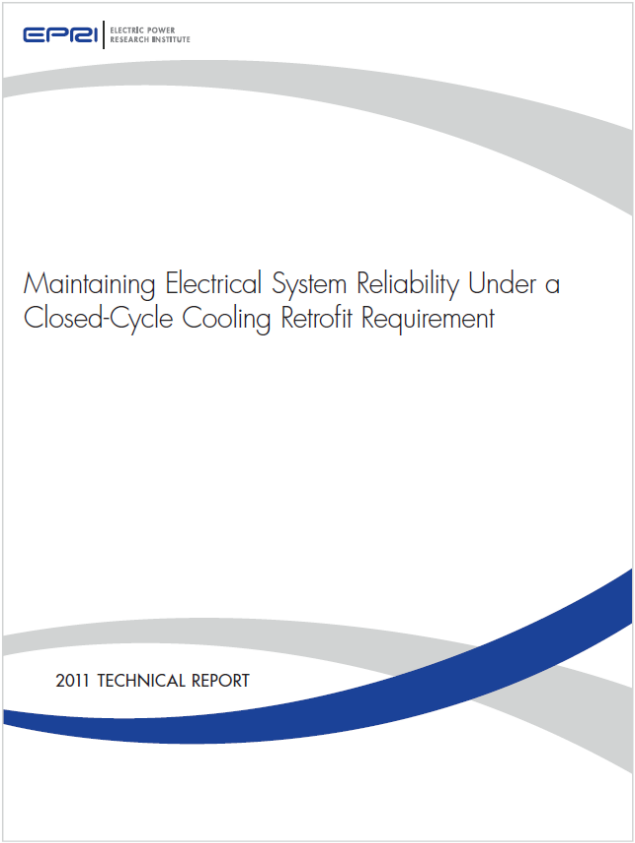
- **Conducted Economic, Financial, Reliability, and Cost Analyses for EPRI's Closed-Cycle Cooling Retrofit Research Program –** Veritas participated as a Principal Investigator in four of the five studies that comprise the Electric Power Research Institute's (EPRI) National Closed-Cycle Cooling Retrofit Research Program, a research project designed to evaluate the socioeconomic, financial, and reliability impacts and the social costs and benefits of proposed regulatory alternatives for the U.S. Environmental Protection Agency's (USEPA) 2014 316(b) Rule (79 Fed. Reg. 158, 48300–48439). As part of its research efforts, Veritas

  - Veritas utilized its Environmental Policy Simulation Model (EPSM) to analyze five NERC regions to estimate the number of megawatts at risk from premature retirement for economic reasons. This information was compared to forecasted new generation in the regions in order to assess power generation adequacy and reliability (EPRI 2011d).

  - Analyzed the financial and economic impacts of a national closed-cycle-cooling retrofit requirement (EPRI 2011c). Veritas used its EPSM to analyze owners' retrofit decisions and estimate the economic and financial impacts (e.g., changes in owner revenues, costs, and profits; changes in electricity prices; and changes in employment).

  - Supported the analysis of the national costs associated with a closed-cycle-cooling retrofit requirement (EPRI 2011a). Veritas modeled the hourly efficiency implications of cooling water temperature changes from a closed-cycle conversion to support the national cooling tower cost evaluation.

  - Developed a national estimate of the economic benefits of a closed-cycle-cooling retrofit requirement (EPRI 2011b). Veritas evaluated the national benefits associated with the impingement and entrainment reductions that would result from a national retrofit requirement following USEPA's Guidelines For Conducting Economic Analysis (USEPA 2016).



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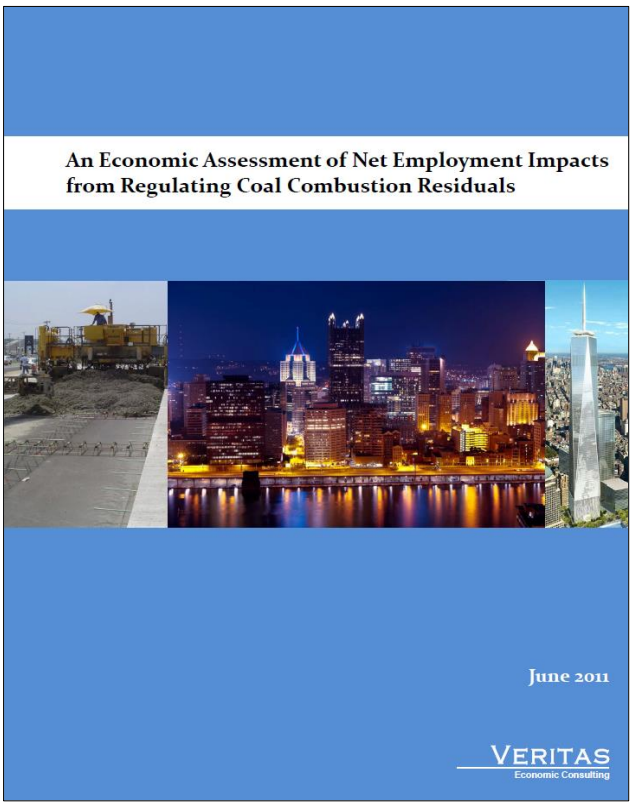
- **Estimated the Costs and Evaluated the Financial and Reliability Implications of Regulating Coal Combustion Residuals as Hazardous Substances –** A breach in an ash surface impoundment caused a large coal ash spill at a Tennessee Valley Authority facility in Kingston, Tennessee. In response to resulting public scrutiny of coal combustion products (CCP) disposal practices, EPA developed regulations addressing the management of coal-combustion residuals. Veritas estimated the costs and evaluated the financial and reliability impacts based on expected changes to coal combustion residual management and disposal that would be mandated by USEPA through a national regulation (EPRI 2010). Veritas estimated unit-level compliance costs of the regulatory alternatives and assessed the unit-level financial impacts to owners of each regulatory alternative. Veritas used its Electricity Policy Simulation Model to assess changes to the baseline (without regulation) financial conditions of each unit under with-regulation conditions and estimated the effect of the regulation on electricity prices and reliability in the PJM, ERCOT, ISONE, MISO, NYISO, and SERC regions.

  An important part of the study was the use of non-public information gained from interviews with individual utilities on CCP handling, management and disposal practices at the unit- and plant-level. These interviews covered 274 generating units at 95 plants. This information was utilized to develop cost functions that were site-specific for the utilities interviewed, and to refine the assumptions of the cost specification for non-interviewed utilities. An important result was that costs would be highly variable depending on (for example) the possibility of constructing Subtitle C compliant landfill, proximity to other (commercial or utility owned) landfills, and the amount of CCPs generated. Using this cost information, plant financial and system reliability implications were evaluated for six major electricity reliability regions. The results of the Veritas analysis were presented to the One Hundred Twelfth Congress of the U.S. House of Representatives, Subcommittee on Energy and Environment.



- **Conducted Power System Modeling to Evaluate the Effect of Offshore Wind Development and Hydrogen Generation in the Gulf of Maine on Electricity Production, Prices, and Excess Capacity in the Northeast United States –** Veritas evaluated offshore wind development and energy storage possibilities in the Gulf of Maine (Normandeau Associates, Veritas Economic Consulting, Tetra Tech 2023). As part of the analysis, information about wind speed, wind farm configuration, development costs, energy prices, distance from interconnection, and tax credits are input into Veritas integrated results from its Wind and Storage Analysis Tool (WASAT). Results from Veritas' WASAT tool are integrated into its Electricity Policy Simulation Model (EPSM) to evaluate the effect that offshore wind generation, hydrogen generation, and other energy storage would have on electricity production, prices, and excess capacity in ISO New England. It also utilizes EPSM to evaluate the regional reliability impacts and increased demand for dispatchable generation associated with the closure of Millstone Nuclear Station.

- **Michigan Nuclear Feasibility Study –** Veritas, in conjunction with Enercon, evaluated the costs; schedule; and power system, supply chain, workforce, and economic impacts associated with developing new nuclear energy generation in Michigan (Veritas Economics 2024). Veritas and Enercon evaluated numerous potential generation facility designs and reactor sizes ranging from the Westinghouse AP1000® Pressurized Water Reactor to small modular reactors (SMRs). Veritas and Enercon chose SMRs for the economic evaluation and developed cost estimates and a construction and operation schedule for a 720 megawatt unit to be installed at potential siting alternatives throughout Michigan. Veritas used Input/Output Modeling to estimate changes in jobs, employment income, and Gross State Product associated with a new nuclear plant. The input-output analysis identified the contribution that expenditures resulting from nuclear plant development would have on Michigan's economic activity.

  Veritas also used its Electricity Policy Simulation Model (EPSM) to estimate the change in electricity generation and air emissions resulting from constructing and operating a new nuclear generating facility in Michigan. Veritas used EPSM to simulate the operation of Michigan's power systems under Baseline Conditions in 2036 and then simulated changes in the power system resulting from incorporating the operation of a new nuclear generating station. EPSM's results include estimates of each unit's generation, fuel consumption, cost, and emissions.

  In order to estimate the economic impacts and air emission changes resulting from installing a new nuclear plant, siting decisions had to be made. Although the analysis did not advocate for any specific location, modeling the local economic and power system effects of a new nuclear plant required specifying a location. Figure 2 illustrates the range of potential sites that Veritas considered. As the figure shows, the siting evaluation considered a range of potential service territories and existing sites. Important location decisions include system operators, grid connections, utilities, and physical areas. Ultimately, the chosen sites for consideration were retiring coal plants because of their existing permits, plant infrastructure, and grid connections.

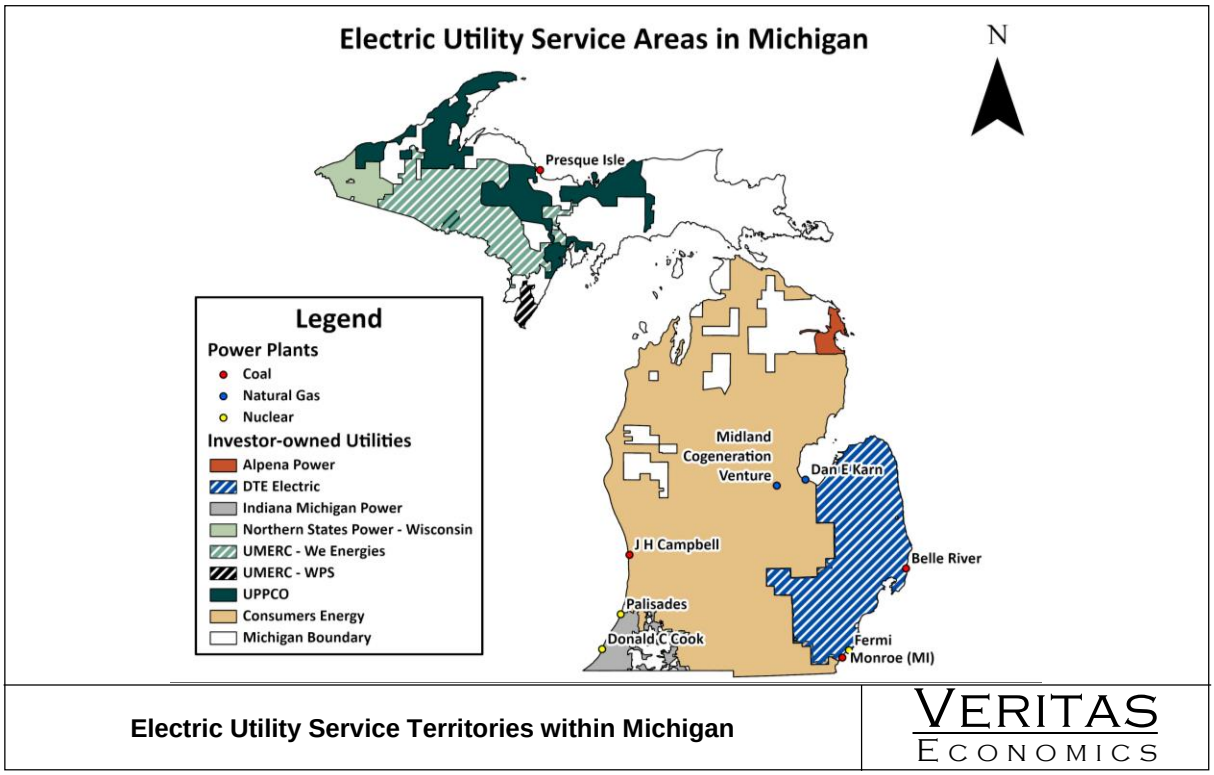


Figure 2 – Evaluation of Potential Locations for New SMR Facilities in Michigan

Veritas has also conducted a significant amount of electricity demand analysis as described in the following examples:

- **Veritas' Residential Rate Model (RRM) –** Veritas has developed and administered sophisticated economic techniques to evaluate and support residential electricity rate transitions using its Residential Rate Model (RRM). Veritas developed RRM using experience gained from working on EPRI's Customer Insights program over a period of several years and with funding from a dozen utilities around the country with a variety of rate concerns and diverse customer bases and load profiles. Veritas' RRM simulates customer rate selection and subsequent changes in electricity use behaviors. RRM aggregates predicted rate selection and electricity use over the customer base to produce system level changes in loads, bills, and revenues that are associated with rate offering packages.

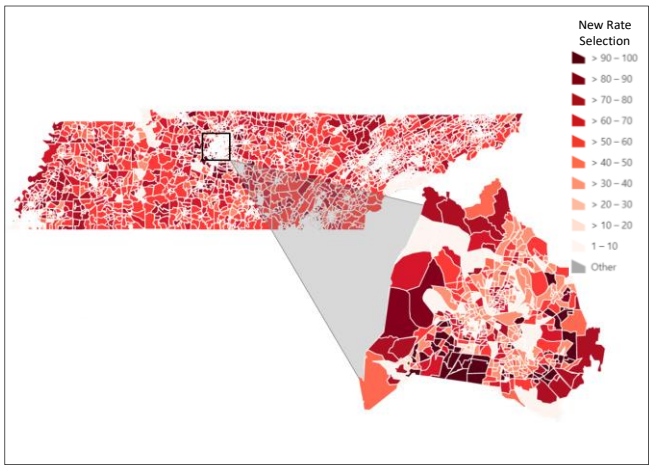


Figure 1: Predicted Adoption of TOU Rates in Tennessee

To implement RRM in an individual service territory, Veritas tailors existing survey and modeling tools to represent the specific service territory and customer base. Administering the tailored survey is a cost-effective way to collect the data necessary to develop predictive quantitative models of customers' preferences for alternative electricity service plans. The approach also has important qualitative outputs such as a deeper understanding of how customers think about and use electricity. This understanding can be critical for improving communications and supporting outreach as electricity providers transition to business models that involve customer engagement that is important for system modernization.

Veritas incorporates the estimated preference function into RRM's Rate Plan Selection Module to simulate the likelihood of rate plan selection in the service territory based on the electricity provider's plan characteristics. The Rate Plan Selection Module fuses the preference function with market segment data for the service territory at the Census block group level to produce neighborhood level adoption predictions. Figure 1 provides predicted plan adoption in Tennessee where plan uptake varies from 0-10% to 90-100% in contiguous neighborhoods.

The Rate Plan Selection Module's predictions provide the inputs to support the behavioral functions that relate electricity use to rate features. Veritas incorporates the Selection Module's predictions into RRM's Appliance Behavioral Module that contains appliance-specific functions that account for how customers respond to hourly prices such as Time of Use (TOU) rates. Veritas uses RRM's Appliance Behavioral Module to evaluate changes in electricity use. Changes in hourly load can be combined with plan characteristics to evaluate implications for bills and system revenue. Market segments applied in the Rate Plan Selection Module operate all the way through electricity use allowing the prediction of peak load reductions geospatially. Figure 2 illustrates the Appliance Behavioral Module's predicted change in 24-hour load based on an individual electricity provider offering Time of Use rates in its service territory.

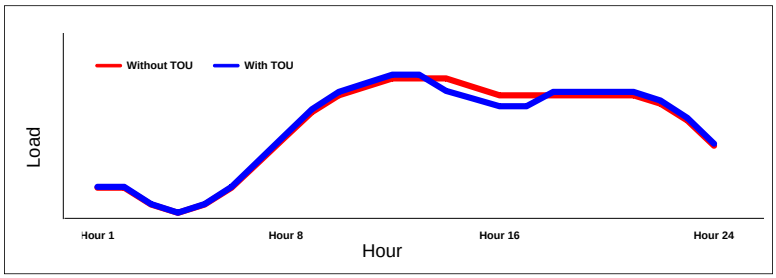


Figure 2: Predicted Load Changes with an Offering of New TOU Rates

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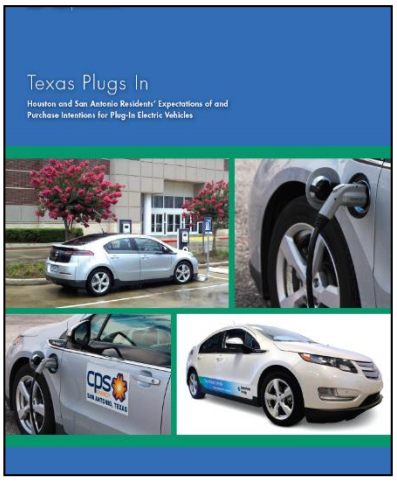
- **Veritas' Electricity Service Plan Adoption Model –** Veritas conducted economic analysis and built custom software to evaluate customers' preferences for and adoption of varying Electricity Service Plans for six service territories throughout the United States (EPRI 2019; Veritas Economics 2011). The adoption model evaluates customers preference for and likely adoption of rates that include varying combinations of time varying prices, fixed bills, variable peek pricing, demand charges, and green rates. The adoption model incorporates the results of a discrete choice experiment administered to more than a thousand electricity customers eliciting their preferences for alternative electricity service plans.
- **Estimated the Demand Impact of Alternative Rate Structures –** Veritas modeled the impact that Oklahoma Gas and Electric's (OG&E) Smart Hours Residential Electric Service program has on electricity demand. Veritas econometrically modeled hourly kilowatt customer usage for weekdays in June through September as a function of the customers' type of Variable Peak Pricing (VPP) service, whether they have a programmable communicating thermostat (PCT), hourly weather conditions, and hourly prices.
- **Veritas Residential Solar Adoption Model** Veritas integrated baseline penetration information with econometrically modeled survey data to predict solar adoption rates under various conditions and in different locations throughout the United States. Veritas developed and administered its Residential Solar Survey to collect the data that underlies the econometric model. The model data arose from a discrete choice experiment of 7,000 electricity customers in 17 service territories throughout the United States. Veritas incorporated the results into a software-based, dynamic residential solar adoption model that each utility could use to evaluate the residential solar adoption decisions of the customers in their service territories.
- **Veritas' Electric Vehicle Adoption Model –** EPRI's US Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model contains a Transportation Module which includes projections of US car purchasing and driving behaviors. EPRI was interested in embedding a structural dynamic model of electric vehicle adoption and use (e.g., one that is responsive to fuel prices and battery improvements) into the Transportation Module. Veritas created a module which combines results from Veritas and EPRI's electric vehicle preference survey with a revealed preference model of vehicle choice to develop customer preferences for new vehicle purchases and operation including electric vehicles. Choice model results are incorporated into a stock turnover model following Struben and Sterman's (2008) innovators and imitators structure. The choice modeling component of Veritas' adoption model identifies new car purchases using a mathematical simulation of vehicle choices given consumer characteristics, preferences for vehicle attributes, and vehicle choice sets. Preferences for non-electric vehicle characteristics are based on a statistically estimated model using vehicle sales and customer attribute data. Vehicle preferences are tied to the unique characteristics of electric vehicles through parameters that can be calibrated based on electric vehicle adoption estimates and relationships identified in Veritas and EPRI's electric vehicle survey research. The adoption model software allows utilities to conduct adoption simulations under various conditions of electricity costs, solar costs and performance, and



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