Session FB1-1

The Texas Interactive Power Simulator - an Analytical Tool for Direct Instruction & Informing the Public

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Abstract

Establishing a reliable and sustainable electricity supply is one of the daunting challenges facing communities today. Unfortunately, discussions on this topic include wide varieties of misinformation, subjective analysis, and biased resources. The Texas Interactive Power Simulator (TIPS) tries to address these shortcomings by providing a quantitative and transparent tool that teaches the basic tradeoffs of electricity generation choices via an interactive website. The tool can be used for direct educational instruction as well as informing the public.

The Texas Interactive Power Simulator gives users the ability to quantitatively compare the economic costs and environmental impacts of electricity production methods according to fuel source. The Texas Interactive Power Simulator's interactive interface allows the user to set a desired electricity mix according to the percentage of electricity produced from each fuel. The economic costs and environmental impacts of a unit of electricity are determined by the user's inputs. These costs and impacts are calculated using the characteristics of each fuel type based on data from government sources and peer reviewed technical literature.

The Texas Interactive Power Simulator provides a level of basic education on electricity generation. It generates graphs, charts, and pictograms to effectively communicate the differences between electricity production methods as well as unique characteristics of each. Portions of the model's website are specifically designed for classroom use in courses teaching the topic of electricity production in Texas. However, the model's flexible framework lends

itself to easy expansion for characterizing other electricity markets and larger geographic regions. Thus, the model structure provides the ability to reach a wider audience.

Introduction

The Texas Interactive Power Simulator was designed at the University of Texas at Austin in partnership with Power Across Texas, a 501(c) (3) non-profit organization. The purpose of the partnership was to devise a model that effectively communicates key lessons concerning the tradeoffs of electricity generation methods to a predominately Texas audience. Target audiences include students, state legislators and their staff, as well as the general public. The Texas Interactive Power Simulator accomplishes the project goals by allowing the user to manipulate the electricity generation mix in the state of Texas and immediately view the economic and environmental impacts of these changes. This manuscript covers the functionality and user interface details of The Texas Interactive Power Simulator.

Background

Texas generates and consumes more electricity than any other state in the United States. In 2006, power plants in Texas generated more than 400 terawatt-hours of electricity, with 49% from natural gas as a fuel source. Also, emissions from Texas' electric power generation were higher than any other state at 257,552,000 metric tons of carbon dioxide and 260,000 metric tons of nitrogen oxide during 2006.[1] In fact, Texas had more carbon dioxide emissions due only to coal-powered generation (150,590,000 metric tons of carbon dioxide) than the total emissions from all electricity generation in any other state.[1] At the same time, Texas emissions rates per quantity of electricity generated (e.g. metric tons CO_2/MWh) are below the average in the United States.[1]

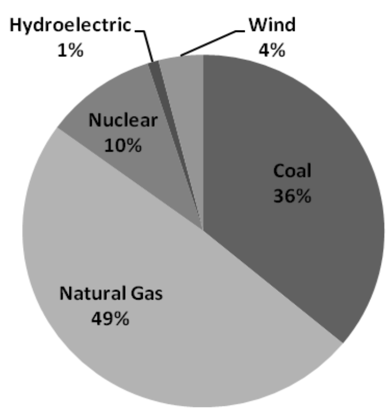

Figure 1: The fuel mix for power generation in Texas, 2006 [1-3]

Texas is and has been incorporating more renewable electricity generation including wind and solar power. In 1999, a renewable portfolio standard was established for the state requiring 2,000 MW of new installed renewable capacity by 2009. Since 1999, due largely to the rapidly growing wind power industry in Texas, the renewable portfolio standard has been amended. In August of 2005, Senate Bill 20 was passed to require 5,000 MW of newly installed renewable capacity by 2015. That bill also includes a target of installing 500 MW of non-wind renewable capacity within the 5,000 MW. Further, Senate Bill 20 established a long term goal of 10,000 MW of new installed renewable energy capacity by 2025. [2, 4]

To reach these goals, and to guide further decision-making, Texans must understand the tradeoffs of different generation technologies in order to make educated choices. All existing technologies have economic or environmental tradeoffs. Understanding and balancing them is impotant to Texas' energy future.

Target Audiences

The Texas Interactive Power Simulator is designed for use inside and out of the classroom. Its target audiences include students, state legislators and their staff, as well as the general public. The model is designed to allow for easy communication of the tradeoffs of different electricity generation technologies. The version of TIPS described here specifically targets students from middle school to the sophomore undergraduate college level. An advanced version currently under development targets upper division undergraduates and graduate students as well as legislative staffers.

User Inputs

The Texas Interactive Power Simulator basic version allows the user to change the amount of electricity that is generated using each of six types of fuels (coal, natural gas, nuclear, wind, hydro, solar). The economic and environmental impacts of the fuel mix, as selected by the user, are then calculated by the tool and displayed both graphically and numerically. Values for the percentage of total electricity generated by a single source to integers between 0 and 100, with the exception of hydroelectric electricity generation, which is fixed at 1% of total.

Economic Impacts

Economic impacts are measured in terms of three categories; cost of new capacity, cost of fuel, and cost of operation and maintenance (O&M) of the plant facility. Costs used in the model are non-lifecycle costs, including only costs incurred at the power plant facility. Costs are also selected as a representative value from within a range of published costs for all technologies that utilize the indicated fuel.

Cost of new capacity includes the capital investment required to build any new power plants required by the user's specified generation mix ("Your Mix"). If the user's scenario requires that power plants be taken offline, they are not given a cost credit (negative cost) for this plant. Cost of fuel and cost of operation and maintenance are calculated on a cost per megawatt-hour generated basis. Calculated costs represent the weighted average cost of a single megawatt-hour generated using the user's scenario. All of these calculations are completed using the data found below in Table 1.

Table 1: TIPS uses the following cost factors to determine the economic impacts for different fuel mixes [5-7, 8-16]

	Cost of New Capacity ($/kW)	Cost of Fuel ($/MWh)	Cost of O & M ($/MWh)
Coal	1,500	15.00	5.00
Natural Gas	900	5.00	80.00
Nuclear	5,000	5.00	15.00
Wind	1,750	0	10.00
Hydroelectric	1,700	0	10.00
Solar	5,000	0	9.50

Environmental Impacts

Three environmental impacts that result from power plant operations are characterized: air emissions, water consumption, and land required for the power plant footprint. Similarly to the costs of fuel and operation and maintenance described in the previous section, air emissions and water consumption are calculated on a per megawatt-hour basis. Values are calculated for a weighted average megawatt-hour of generated electricity and are also displayed graphically. As with economic costs, these impact values are non-lifecycle.

Air emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur dioxide (SO_2) are calculated using the model and are displayed graphically. Also calculated and displayed is the amount of water consumed during the generation of a megawatt-hour of electricity. Water consumption does not refer to the total amount of water used for power plant cooling (pass-through water use), but specifically refers to the amount of water that is consumed during this process. All calculated values use the data found below in Table 2.

Table 2: TIPS uses the following emissions and use factors to determine the environmental impacts for different fuel mixes[17-20]

	Air Emissions (lbs/MWh)			Water Consumption (gal/MWh)	Land Required (acres/MW)
	CO_2	NO_x	SO_2		
Coal	2,293	6.8	5	426	1.2
Natural Gas	1,146	0.03	1	223	0.05
Nuclear	0	0	0	600	0.05
Wind	0	0	0	0	25
Hydroelectric	0	0	0	0	131
Solar	0	0	0	0	4.6

User Interface

The user interface for the Texas Interactive Power Simulator was designed with care to enable the effective communication of key lessons to the user. The initial portal into the website is displayed below in Figure 2 and is used to provide background information and collect statistical data about the user as described in later sections.

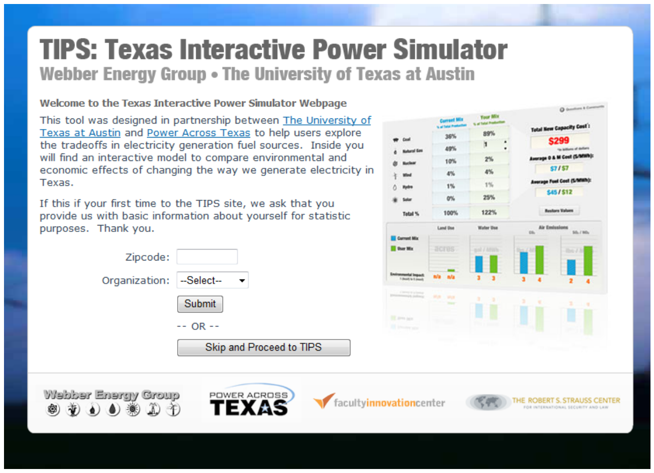

Figure 2: Welcome Page

The Texas Interactive Power Simulator tutorial page allows users to self-teach components of the model's back-end calculations and user interface displays. There are links to three documents: a detailed tutorial, functionality overview, and key technical bullet points. The tutorial page, shown below in Figure 3 is also linked to the main model interface page shown in Figure 4.

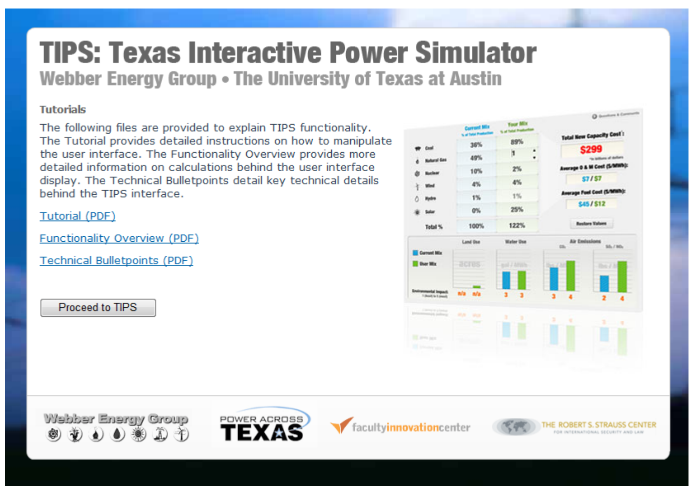

Figure 3: Tutorial Page

The model itself is accessed by selecting the "Proceed to TIPS" button showed in Figure 3 which brings the user to the model interface page. On this page, the user may manipulate the values listed under the "Your Mix" column with the exception of the percent of generation from hydroelectric power sources, which as previously mentioned is fixed at 1% of the total 2007 generation. As the user changes the generation mix, the resulting environmental and economic effects are automatically updated in real time.

Economic impacts are displayed on the right hand side of the user interface in numerical form. Environmental impacts are displayed on the bottom portion of the screen in graphical form. The first graphs displays land use for the "Current Mix" and "Your Mix." Similarly, water use and air emissions are displayed to the right of the land use graph. All graphs are scaled to accommodate the maximum and minimum values producible by "Your Mix." Below the environmental impacts graphs is an environmental impact ranking system.

All model output values resulting from the user's changes are displayed in green throughout the webpage with the exception of total new capacity cost displayed in red. Values for the "Current Mix" are fixed and displayed in blue to provide users with an easy way to compare the differences between their customized "Your Mix" and the "Current Mix". The model's interface design is displayed below in Figure 4.

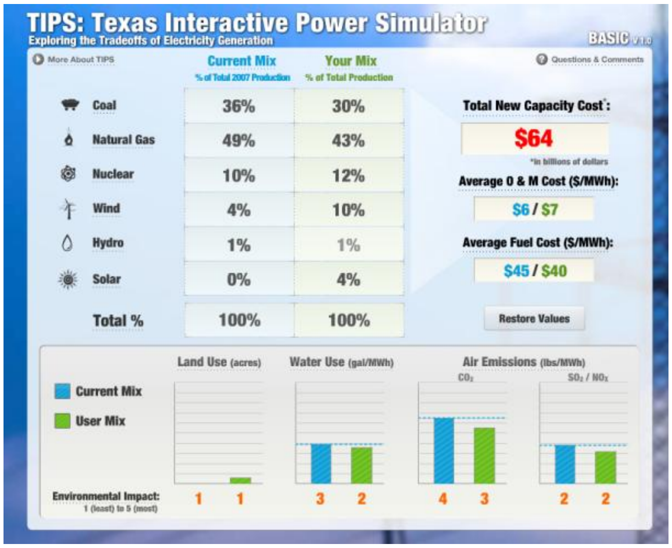

Figure 4: Model Interface Page

As the user changes values for percent of total electricity generation the Texas Interactive Power Simulator displays the altered impacts in real time. Example outputs of the model are displayed in Figures 5 and 6 by using the following inputs from the user's "Your Mix" scenario: 30% of total generation from coal, 43% from natural gas, 12% from nuclear, 10% from wind, 1% from hydro, and 4% from solar. Figure 6 shows the economic impacts display for this scenario. For the example scenario, a $64 billion cost for new capacity is required to meet the 6% increase in wind and 4% increase solar electricity generation. Negative costs are not included for the decrease in natural gas and coal generation. A drop in average fuel cost from $45 to $40 per megawatt-hour is also seen. This drop is the result of the decrease in generation from natural gas ($80/MWh fuel cost) coupled with an increase in generation from wind and solar ($0/MWh fuel cost). For this scenario, average operation and maintenance cost also rose from $6 to $7 per megawatt-hour, primarily due to the decrease in coal generation and increase in wind generation. These results are displayed below in Figure 5.

Figure 5: This image gives us a snapshot of how the economic costs are displayed.

Environmental impacts are displayed using graphs and an environmental impacts ranking system. The land use graph displays the impact ranking for the total amount of land required for the indicated generation mix, including all currently used land. The water use and air emissions graphs show the impact ranking based upon the weighted average values of the fuel-specific environmental impact values in Table 2.

The environmental impacts ranking system is used to provide users with a feel of how the generation mix in Texas currently compares to the least and most environmentally impactful scenarios. The ranking system uses a value of 1 for the least impactful scenarios and a value of 5 for the most impactful scenarios. To explain the ranking system, the water use category is used as an example. Because nuclear power has the highest water consumption factor, maximum consumptive water use occurs with a generation mix 100% nuclear power and 0% from all other fuel sources. This scenario would provide a maximum value for water use of 600 gallons per megawatt-hour generated. A ranking of "5" is defined as 80-100% of this 600 gallons per megawatt-hour value. A ranking of "4" is defined as 60-79% of this value and so forth.

The environmental impact graphs and rankings are displayed below in Figure 6 for the aforementioned example scenario. The decrease in water use and air emissions per megawatt-hour generated in the example scenario versus the "Current Mix" results in a drop in ranking from a 3 to 2 in water use and a 4 to a 3 in air emissions for carbon dioxide. While an appreciable decrease in air emissions of sulfur dioxide and nitrogen oxides also occurs, the change is not significant enough to result in a decrease in environmental ranking. Blue bars are used to represent the "Current Mix" and green bars are used to represent example scenario "Your Mix". Taller bars indicate increasing environmental impact for that category.

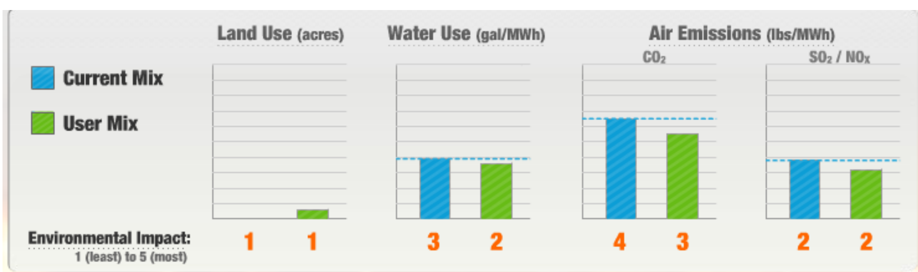

Figure 6: This image gives a representative snapshot of how the environmental impacts are ranked and displayed.

If the user-selected mix may lead to problems with meeting base or peak load requirements during the year, a warning flag appears to alert the user that problems may arise with their chosen generation mix. Additionally, the user input that is the root of the potential problem is shaded yellow to remind the user that this value may provide difficulties in a real generation mix scenario. An example of a warning issued by the program may be seen below in Figure 7. This particular warning is issued in the case where the user requests more wind than is acceptable without backup peaking power.

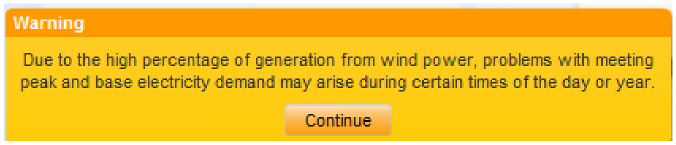

Figure 7: Warning flags are used to alert the users to fuel mixes that might not meet demand requirements.

User Data Collection

To date, the Texas Interactive Power Simulator collects user data regarding their geographical location in the United States according to their zip code as well as their organization type (academia, industry, government, military, or other). These data are gathered on the Texas Interactive Power Simulator's welcome page as previously shown in Figure 2.

Classroom Use

At the University of Texas at Austin the Texas Interactive Power Simulator is used in an undergraduate lecture course that is targeted toward first year students with an interest energy, technology, and policy. It is currently slated for use in additional courses at the University of Texas at Austin including a small-format freshman seminar (primarily for engineers), one general undergraduate studies course and one graduate elective course (for students from engineering, geosciences, policy and business).

The goal for using the Texas Interactive Power Simulator in the classroom is twofold. First, it allows students to become exposed to the key topics displayed in the model regarding the tradeoffs of electricity generation technologies. Second, it allows the developers to gather important pedagogical information that will enhance future versions of the model in terms of its teaching abilities.

Summary & Conclusions

In summary, we have described the user interface design for the Texas Interactive Power Simulator and have summarized its applications and potential in classroom and other settings. Preliminary data indicate that this tool will be effective at conveying a few basic lessons about the tradeoffs in power generation, but comprehensive data about the tool's efficacy are not yet available. The statistical data collection abilities of this and the more advanced versions of this model will help determine whether this tool helps people learn about the tradeoffs in conflicting scenarios such as those encountered in electricity generation.

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