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A Look at the U.S. Energy System – A Strategic Impact Model (2050 SIM)

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Abstract. Although the United States (U.S.) energy infrastructure is reliable and accessible, it is also excessively reliant on foreign energy sources, experiences high volatility in energy prices, does not always practice good stewardship of finite indigenous energy resources, and emits significant quantities of greenhouse gases. The U.S. Department of Energy is conducting research and development on advanced nuclear reactor concepts and technologies, including High Temperature Gas Reactor (HTGR) technologies, directed at helping the United States meet its current and future energy challenges.

This paper discusses the systematic approach used to develop the 2050 Strategic Impact Model (2050 SIM), which allows the user to analyze and depict the benefits of various energy sources in meeting the energy demand. It also provides an overall systems understanding of the tradeoffs between building and using HTGRs versus other existing technologies for providing energy (heat and electricity) to various energy-use sectors in the United States. This paper also provides the assumptions used in the model, the rational for the methodology, and the references for the source documentation and source data used in developing 2050 SIM.

Introduction

Although the United States (U.S.) energy infrastructure is reliable and accessible, it demonstrates the following vulnerabilities:[1]

- Relies heavily on foreign sources of energy
- Experiences high volatility in energy prices
- Does not always practice efficient stewardship of finite indigenous energy resources

- Emits significant quantities of greenhouse gases (GHG).

To overcome U.S. energy infrastructure vulnerabilities, the nation must employ not only energy conservation and efficiency methods on the demand side but also employ new technologies on the energy supply side. Demand side conservation methods may include car pooling, work from home options, and turning off the lights and other practices. Demand side efficiency methods may include technological improvements such as increasing miles per gallon for vehicles, as well as more deploying efficient refrigerators, heating, and cooling systems. Increased use of low carbon-footprint power plants on the supply side may include deployment of contemporary nuclear power plants for electricity production and additional renewable energy sources, such as wind, solar, and geothermal power. In addition, it may include the development of new technologies, including nuclear high temperature gas-cooled reactors (HTGR) for the co-production of electricity and industrial process heat, and the deployment of coal and natural gas-powered plants with carbon capture and sequestration technologies.

Nuclear reactors can play a significant role in transforming the U.S. energy infrastructure. There are currently 104 light water reactors (LWR) in the United States, which collectively supply 21% of the nation's electricity demand.[2] HTGRs operate at much higher reactor outlet temperatures than conventional LWR technologies. Accordingly, HTGRs can be used in place of fossil fuels for generating heat and steam in industrial applications and for generating electric power while reducing or eliminating the GHG emissions from the power production cycle. The use of HTGR technology also provides a long-term secure energy source at a more stable price, thus insulating end users from the economic uncertainties associated with the relatively higher price volatility and uncertain availability of crude oil. HTGRs supply electricity, steam, and high-temperature gas to a wide range of industrial processes, including high temperature steam electrolysis (HTSE), which produces hydrogen and oxygen for use in petro-chemical plants, refineries, conversion of coal to transportation fuels, chemical plants, fertilizer plants, and other uses.

Model Approach and Assumptions

The 2050 SIM allows users to simulate the deployment of various combinations of energy processes to achieve specific energy goals. The model is a relatively simple but robust tool for analyzing U.S. energy supplies and demands to estimate the potential contributions that can be made by developing and deploying HTGR technologies. The general approach utilized in this project, as outlined in Figure 1, overlays renewable and HTGR energy solutions on existing energy supply sources to better meet demand sector needs and address the challenges presented.

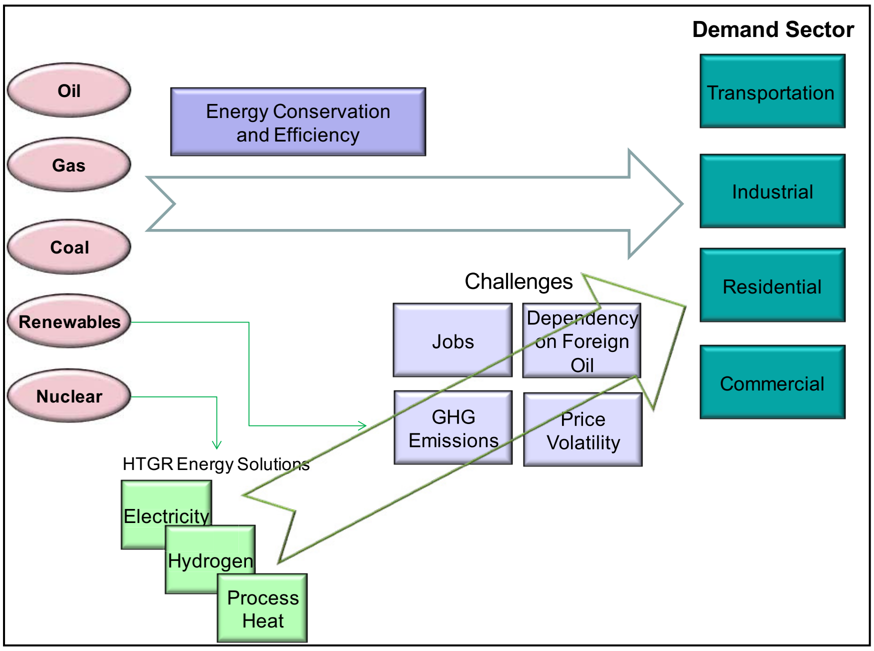

Figure 1. HTGRs address energy challenges while meeting energy demand

Approach. A simplified systems engineering approach was used for the development of this energy model. Requirements were obtained from the customer and documented. Alternatives for development were considered. The team decided to initially develop the model in Excel to enable rapid development and allow ease of use and accessibility by the broadest range of users. After development, a verification plan was developed and followed to eliminate calculational errors. Validation was done by demonstration to the customer as well as demonstration to various subject matter experts.

Energy supply, demand, conservation, and efficiency data were collected from U.S. Government documents and other published sources. For HTGR process applications, the data used comes from the report *Integration of High Temperature Gas-Cooled Reactors into Industrial Process Applications*[3], which discuss the following process applications:

- Ammonia Production
- Methanol-To-Gasoline Production
- Substitute Natural Gas Production
- Coal and Gas To Liquids Production
- Power Cycles for the Generation of Electricity
- Hydrogen Production
- Oil Sands Recovery via Steam-Assisted Gravity Drainage.

Detailed flowsheets were developed, and the associated technical evaluations summarize process variations, emissions, relative product costs, etc.

For the 2050 SIM, energy production and consumption data and projections were primarily collected from Energy Information Agency (EIA)[2] publications and databases and supplemented as necessary with other published data. In addition, appropriate legislative and policy information (e.g., GHG reduction targets) was collected from appropriate government documents, such as draft and final legislation from the Library of Congress' THOMAS website[4] and reports from the Congressional Research Service and the Government Accounting Office. By using primarily U.S. Government documents and other published sources, the quality of the data and information are known and each document is readily available to those who wish to review the source information.

For the 2050 SIM, applicable data and information were collected and assessed, aggregated, or separated as appropriate, and uploaded into the model spreadsheets. The data were normalized to common energy units to facilitate straight forward comparison and use, and then the appropriate links were made between the various supply and demand data sets. Energy supply data included HTGR program energy-production estimates[3] (i.e., electricity, hydrogen, and process heat), EIA data[2], and other published data for energy resources[5,6,7,8] (e.g., fossil fuels, hydropower, LWRs, and alternative energy sources).

U.S. Census Bureau data were used to estimate population and population growth, and EIA data[2] were used to develop the Gross Domestic Product (GDP) forecast. Both were extrapolated as necessary to allow for projections to 2050. The model initially breaks down the U.S. energy infrastructure into supply sources and demand sectors, as shown in Figure 2 (from EIA[2]). HTGR products and energy efficiency/conservation benefits were assessed against current and projected future energy demands by sector to estimate the potential for HTGR products to displace fossil fuels currently being used in each sector. For example, process heat and hydrogen from an HTGR could be used (1) to produce synthetic gasoline and diesel as a replacement for petroleum in the transportation sector or (2) in place of natural gas in ammonia production. For example, increased mileage standards (e.g., increased corporate average fuel economy [CAFE] standards) would reduce the amount of petroleum used in the transportation sector.

The deployment of HTGRs in the United States has the potential to help meet the four critical U.S. energy challenges, namely, depending on foreign oil, GHG emissions, price volatility, and jobs (see Figure 1). The design, construction, operation, and decontamination and decommissioning (D&D) of HTGRs, along with the economic stimulus provided by obtaining new energy sources, will potentially create new jobs in the future. The production of electricity and hydrogen can potentially reduce our dependency on foreign oil by displacing the use of petroleum-based fuels in various vehicles (e.g., using electric vehicles); and electricity, hydrogen and process heat could displace the use of natural gas and oil for producing industrial process heat and industrial, residential, and commercial space heat (e.g., heating oil in the northeast). Hydrogen can be used in the industrial sector as feedstock (e.g., to supplement the use of natural gas in producing fertilizers and petrochemicals). Process heat can be used directly in the industrial sector, thereby displacing the current use of coal or natural gas.

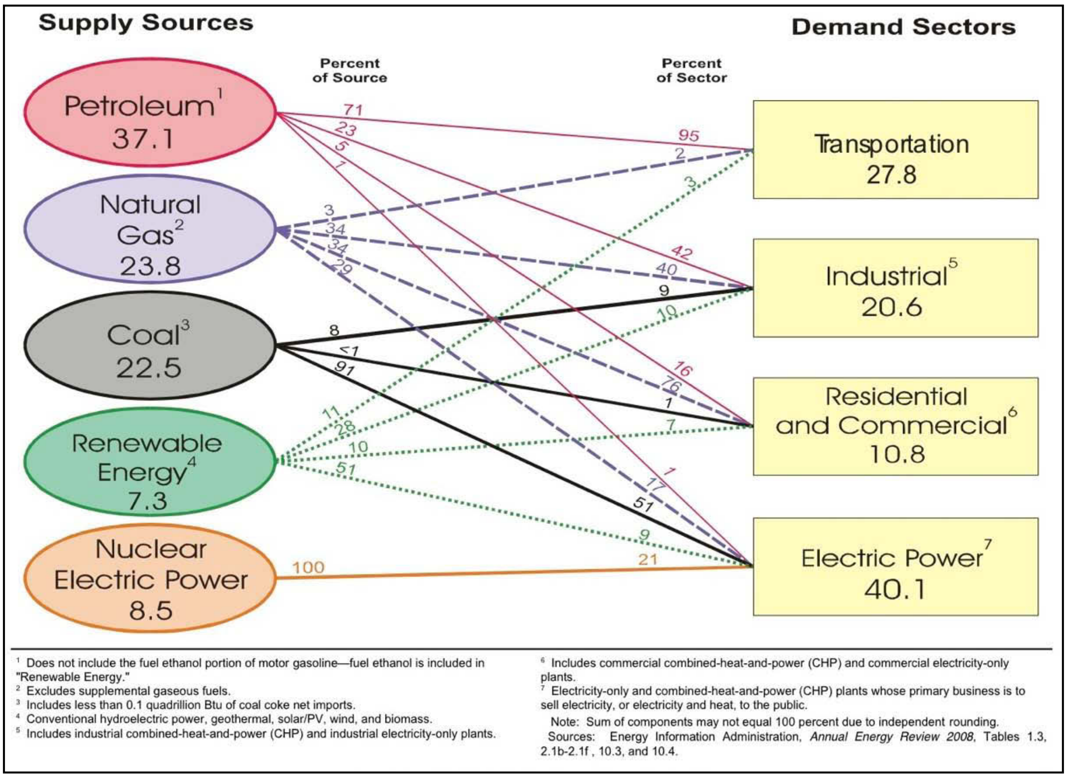

Figure 2. Quantified energy consumption by source and sector

Assumptions and Limitations. This modeling effort required data/information simplification and the use of assumptions to appropriately quantify aspects of data input and output. The general assumptions and limitations for the 2050 SIM include:

- New plants/processes are built according to user specified ratios, starting in the earliest year possible, considering lead time to build (see Table 1), and then building in the next year until the user specified goals are met. If 2050 is encountered, then the model loops back to the beginning year and builds more plants stepping toward 2050 again.

- New electricity producing plants (e.g., HTGRs, LWRs, renewable plants) can replace coal or natural gas fired plants according to the energy goals set by the user. The model currently has the limitation of only tracking new jobs created by building new plants. No jobs lost or costs are tracked for a replaced coal or natural gas plant. If future energy demand is above 2010 levels for a particular electricity energy sector, new plants will be built to meet new demand and will not replace other energy sources, such as coal or natural gas.

- All capital costs are in 2009 dollars, and the user is allowed to input a discount rate for the present value calculation.

- For Oil Imports, the model uses past import data from EIA[2] up to 2009. For future data, a 0.4% reduction per year is assumed (based on EIA[2] future projections). This value could be changed to create different scenarios.

- For Natural Gas Imports, the model uses past import data from EIA[2] up to 2009. For future data, a 0.6% reduction per year is assumed (based on EIA[2] future projections). This value could be changed to create different scenarios.

- Linear treatment of industrial process applications approximates actual process operations.

The user initiates the 2050 SIM by selecting whether projected demand for energy will be driven by GDP or U.S. population from 2010 to 2050. If GDP is selected, then a percent change per year for GDP is used to calculate what the projected U.S. GDP will be out to 2050. The default value is 2.4% growth per year.[2] Along with GDP, the other factor needed to calculate future energy use is the energy consumption per GDP. This factor represents nation-wide energy conservation (e.g., using lights in your house less often) and efficiency (e.g., increasing vehicle mileage). The default value for this factor is a 1.9% decrease per year, based on EIA's reference case.[2]

If the user selects population to drive demand, a population growth rate of 0.9% per year is used (along with an energy consumption per capita factor of -0.3%) to estimate future energy demand out to 2050. The default values for population are found in EIA's *Annual Energy Outlook 2010*.[2] Each of these parameters affecting future U.S. energy demand can be varied by the user to generate a range of different future energy demand scenarios.

Three user-adjustable efficiency factors are used to model the effect of energy efficiency gains in the United States. The first factor estimates efficiency in all sectors except transportation. For the transportation sector, the user predicts miles per gallon efficiency for cars and light trucks in 2020 and 2050. For the other areas of transportation (e.g., rail, heavy trucks, and air), a separate user-defined transportation efficiency factor is applied.

Next, the total energy demand for the United States is divided into four main energy demand sectors: Transportation, Industrial, Residential & Commercial, and Electric Power. Each demand sector is supplied by the energy source depicted in Figure 2 according to the 2008 percentage split data. As other plants/processes are built in the future, the supply source percentages change.

As new plants/processes are built to meet simulated demand, the model calculates an energy balance, as illustrated in Figure 3. This energy balance flow shows how the model simulates impacts to the four demand sectors—transportation, industrial, residential/commercial, and electricity. New energy products shown below the four energy demand sectors displace energy products shown above the demand sectors. For example, when an HTGR Hydrogen Production plant is built, it adds to the nuclear industrial supply source sector and subtracts from the natural gas industrial sector to meet the desired percentage of energy provided by each supply source. A comprehensive list of the possible plants/processes that can be built in the model are shown in Figure 3 along with their effect on the energy balance.

The assumptions used for the demand side of the model include:

- The model assumes the energy demand for the United States is met.
- U.S. energy demand can be adjusted by the user and can be based on GDP or population.
- The cost of efficiency improvements is not included in the model.
- Efficiency is accounted for in the model with the efficiency factor and future MPG. Conservation is accounted for with energy use per GDP or energy use per capita.

The assumptions used for the transportation demand side of the model include:

- Cost for electric cars is assumed to be absorbed by consumers and is not included in the total cost.
- Transportation data used for cars and light trucks includes number of registrations (to get number of vehicles currently in use), vehicle miles traveled per year, fuel use, and fuel economy (MPG).
- Future MPG (a national average) is specified by the user for 2020 and 2050 (calculated as linear growth from 21.0 MPG in 2010 to each of the input values).[9]
- Future electric vehicle use is a user input (% of total cars) that is calculated as a linear growth from 0% in 2010. As electric cars replace internal combustion engine cars, and energy supply is shifted from petroleum-transportation to electricity.
- Ethanol use, as a percent per year, can be specified by the user for years 2022 and 2050.

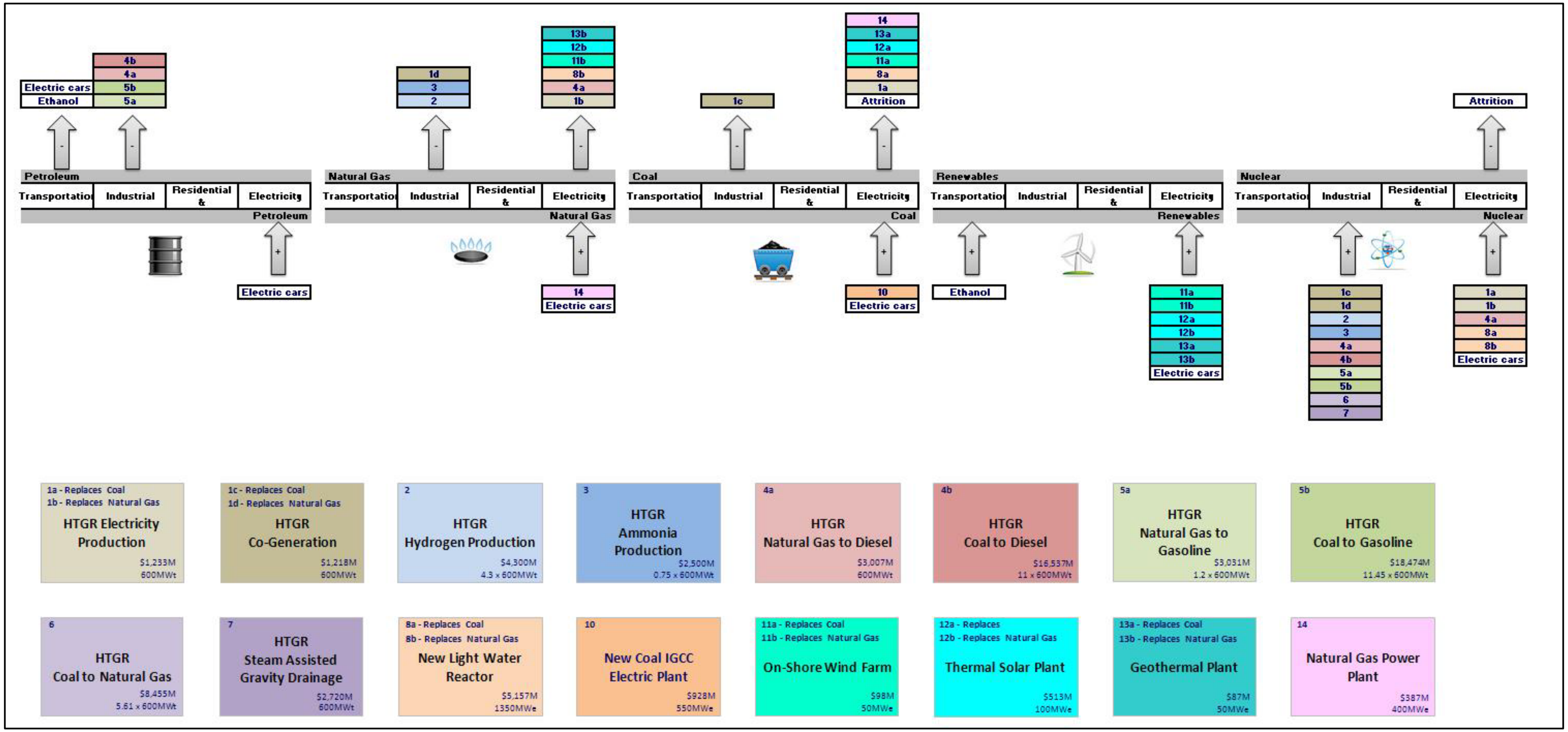

Figure 3. Model energy balance flow

The 2050 SIM is built to supply energy to meet projected U.S. energy demand (as estimated in Section 3) according to user specified inputs. As shown in Figure 3, the 2050 SIM user can use 16 different plants/processes to affect the overall U.S. energy mix. A summary of characteristics of each plant/process is shown in Table 1.

Table 1. Process summary (references for each line of data are shown in the "name" column)

ID	Name	Size	Capacity Factor	Lead Time (yrs)	Plant Life (yrs)	Unit cap cost (millions$)
1a,1b	HTGR Electricity Production[3 +]	600MWt	90%	6	60	1,233
1c,1d	HTGR cogeneration plant[3 +]	600MWt	90%	6	60	1,218
2	HTGR Hydrogen production[3 +]	4.3 × 600MWt	90%	6	40	5,624
3	HTGR Ammonia Production[3 +]	0.75 × 600MWt	90%	6	40	2,533
4a	HTGR NG to Liquids[3 +]	600MWt	90%	6	40	3,007
4b	HTGR Coal to Liquids[3 +]	11 × 600MWt	90%	6	40	16,537
5a	HTGR NG to Gasoline[3 +]	1.2 × 600MWt	90%	6	40	3,031
5b	HTGR Coal to Gasoline[3 +]	11.45 × 600MWt	90%	6	40	18,474
6	HTGR Coal to NG[3 +]	5.61 × 600MWt	90%	6	40	8,455
7	HTGR SAGD[3 +]	600MWt	90%	6	40	2,720
8	New LWRs[12]	1350MWe	90%	6	60	5,157
10	New Coal IGCC plant with CCS[6,7]	550MWe	80.0%	4	50	1,328*
11	New Onshore Wind farm[12]	50MWe	37.3%	3	20	98
12	New Thermal Solar Plant[12]	100MWe	37.3%	3	30	513
13	New Geothermal Plant[12]	50MWe	84%	4	30	87
14	New Natural Gas Electric Plant[12]	400MWe	87%	3	50	387

* $1,328 for Coal IGCC plant with 90% CCS; $1,293 for plant with 70% CCS; $1,209 for plant with 50% CCS; $1,140 for plant with 30% CCS; and $928 for plant with no CCS.

+ HTGR capacity factors are an initial assumption and will be updated as better information becomes available.

The current U.S. nuclear power reactor fleet includes 104 reactors providing about 21% of the total U.S. electricity needs. EIA[2] provides information about each of these reactors and when their licenses expire.[5] The model calculates when these reactors would go offline (with and without license extensions) and allows the user to specify whether or not to maintain the existing capacity by building new LWRs to replace the lost capacity out to 2050. The model also performs the same calculation for coal fired electric plants and builds replacement capacity as needed (also using EIA data[12]). A general overview of each process is presented below, with most of the data extracted from *Integration of High Temperature Gas-Cooled Reactors into Industrial Process Applications* (May 2010).[3]

The assumptions used for the supply side of the model include:

- If building HTGRs, the default start date is 2021 but can be changed by the user. If building LWRs. 2016 is the earliest date a new LWR could be practically deployed.
- The model will build new natural gas fired electric power plants if the percentage of natural gas for the electricity sector is increased.
- The model will build new coal fired electric power plants (with user specified carbon capture and sequestration) to maintain the specified percentage of coal electricity

production and as the current fleet of coal plants retire (assuming a 50 year life). The choices for the number of plants that will use CCS are 0%, 30%, 50%, and 90%.

- All new cogeneration using nuclear energy (process heat and electricity) will be used in the industrial sector.

Benefits of the Selected Energy Mix

Each of the challenges shown in Figure 1 is affected to some degree by the energy mix employed. Greater investment in renewable and nuclear energy can significantly overcome these challenges and shown in the 2050 SIM. Each of the four challenges or energy vulnerabilies are shown below with the approach used to quantify the benefit.

Greenhouse Gas Emissions. The burning of fossil fuels—including petroleum products, coal, and natural gas—contributes to the levels of CO_2 in the atmosphere. Renewable energy sources—such as wind, solar, and geothermal, nuclear power and hydroelectric power—do not burn fossil fuels and therefore have a minimal carbon footprint. To compare each energy source on a common basis, none of the energy sources consider the mining operation (e.g., coal mining, uranium mining) in the GHG production equations.

The United States accounts for about one-third of all GHG emissions world-wide, and the U.S. energy sector accounts for about 84% of the U.S. GHG emissions.[2] As a non-CO_2 emitting substitute for the burning of fossil fuels in industrial applications, the HTGR offsets significant quantities of CO_2 emissions attendant to the burning of these fuels. This includes both the direct combustion of these fuels in the industrial processes (e.g., providing steam, electricity for internal use, and high temperature gas) as well as the emissions associated with electrical power taken from the grid. This is one of the several benefits of the HTGR technology that have been explored in the 2050 SIM. Several studies have been performed that demonstrate this benefit as well as the technical and economic viability of integrating the HTGR technology with specific applications[3] (e.g., cogeneration of steam, electricity and high temperature gas, coal to liquid transportation fuel conversion, bitumen extraction from oil sands using steam assisted gravity drainage, chemical production, and ammonia and ammonia derivative production).

CO_2 emissions are calculated based on data from EIA.[2] EIA provided both total emissions for each energy sector and total energy supplied for each sector for 2007.[2] From this, average emissions per energy factor can be calculated based on the following equation:

$$\textit{Emissions per energy factor} = \textit{Total emissions}/\textit{Total energy}$$

Table 2 summarizes the factors used in the model. The model calculates the amount of energy in each sector for each year. This energy amount is then multiplied by the emissions per energy factor to get the current year emissions.

Table 2. Emissions factor summary[2]

	Petroleum				Natural Gas				Coal			
	Transp.	**Industr.**	**Res & Comm.**	**Electric**	**Transp.**	**Indust.**	**Res & Comm.**	**Electric**	**Transp.**	**Industr.**	**Res & Comm.**	**Electric**
Total emissions[a]	1,974	406	134	66	35	405	420	376	0	172	7.4	1,980
Total Energy[b]	$27x10^6$	$8.7x10^6$	$1.8x10^6$	$4.1x10^5$	$5.7\ x10^5$	$8.4\ x10^6$	$8.4\ x10^6$	$7.0\ x10^6$	0	$1.9\ x10^6$	$1.1\ x10^5$	$21x10^6$
Emissions per Energy[c]	$7.3x10^{-5}$	$4.6x10^{-5}$	$7.6x10^{-5}$	$1.6x10^{-4}$	$6.2x10^{-5}$	$4.8x10^{-5}$	$5.0x10^{-5}$	$5.4x10^{-5}$	N/A	$9.1x10^{-5}$	$6.7x10^{-5}$	$9.4x10^{-5}$

a – Million Metric Tons CO_2 b – Billion BTUs c – Million Metric Tons CO_2 per Billion BTU

Current legislation being considered by Congress (e.g., The American Clean Energy and Security Act of 2009 and the Clean Energy Jobs and American Power Act of 2009) would require varying levels of reduction in GHG emissions by the year 2030 and extrapolated to the year 2050, some as high as an 83% reduction over 2005 emission levels. Reductions of this magnitude would penetrate all sectors and require significant transformation of the energy infrastructure. The 2050 SIM estimates future CO_2 emissions for each future energy scenario selected by the user. Figure 4 shows a sample output graph of potential GHG emissions for electricity production only for the baseline scenario. The baseline scenario includes leaving the future electricity generation mix at current levels (nuclear=21.2%, renewable=9.1%, coal=51.5%, natural gas=17.2%, and petroleum=1%). Figure 5 shows a sample output graph of potential GHG emissions for an alternative scenario where the future (2050) electricity generation mix was set to: nuclear=35%, renewable=14%, coal=34%, natural gas=16%, and petroleum=1%.

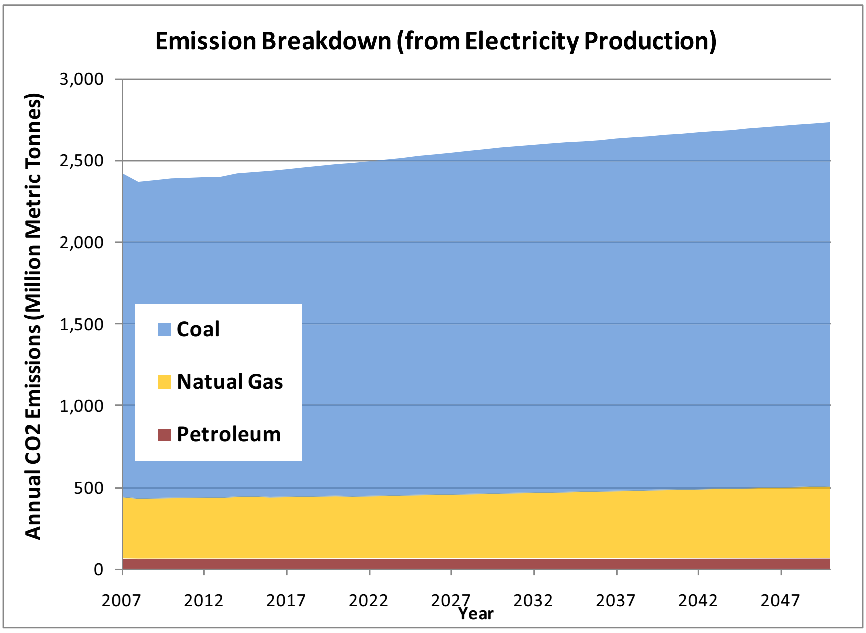

Figure 4. GHG Emissions for Baseline Scenario

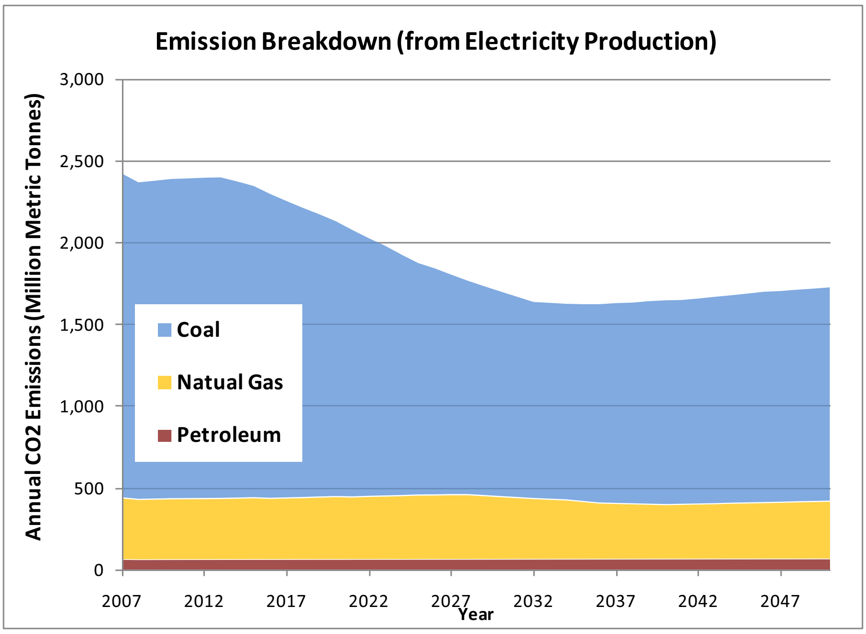

Figure 5. GHG Emissions for Alternative Scenario

Foreign Energy Independence. The United States currently imports 60% of its crude oil supply from foreign sources and consumes the oil primarily in the U.S. transportation sector (95% of car and light truck transportation use petroleum). Several of the foreign sources represent governments that are antagonist to the United States. This daily foreign acquisition represents not only an export of U.S. wealth but also a vulnerability to the U.S. economy, security[13], and way of life.

The 2050 SIM depicts the extent to which foreign energy independence is attained through the use of domestic resources and domestic gasoline and diesel production technologies, and alternative energy efficiency technologies (e.g., electric and hybrid vehicles). The model depicts the reduction of crude oil importation by allowing the user to:

- Adjust the use of hybrid plug-in vehicles
- Adjust the use of ethanol in place of petroleum
- Build HTGRs to assist in converting natural gas to diesel and gasoline
- Build HTGRs to assist in converting coal to diesel and gasoline.

A sample output from the model is shown in Figure 6. Setting the 2050 electric cars to 25% (meaning 25% of all cars and light trucks are plug in electric in 2050 in the U.S.) and building 76 HTGR assisted coal to diesel plants, and 76 HTGR assisted coal to gasoline plants results in a 50% reduction in crude oil imports.

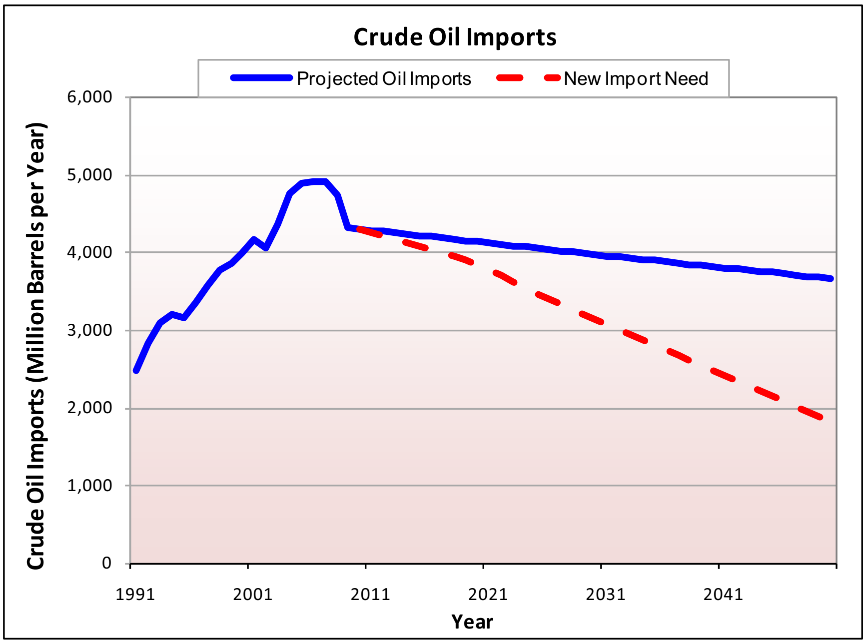

Figure 6. Projected Crude Oil Imports

Energy Price Stability. Crude oil and natural gas are traded on a global market, and the prices fluctuate with demand, supply, conflicts, wars, and speculation. Increased conservation efforts and shifts to alternative technologies (e.g., plug-in hybrid vehicles) can reduce the U.S. demand on this volatile global market and shifts to an energy supply (electricity) that can be domestically controlled. Domestic gasoline and diesel production further reduces the U.S. demand for foreign imports and supplies the demand with a fully amortized product at a more predictable price.

Energy price stability can be quantified and valued using the same methods and equations employed to calculate call option prices in financial markets. The Black-Scholes option pricing model used extensively in today's financial markets was used in the 2050 SIM to calculate the value of "call options." Through a relationship known as put/call parity, the value of "put options" can also be calculated. The Black-Scholes model is developed using partial differential equations. Empirically, the model has been fairly justified, although some empirical failures have been noted.[14]

The call option prices developed in the 2050 SIM depict the value of purchasing crude oil or natural gas at a known price and at a certain time in the future. Just like investors are willing to pay a premium to buy a commodity for a known price at some time in the future, there is value (premium) in stable crude oil and natural gas pricing at some time in the future. The 2050 SIM uses the Black-Scholes model to calculate this value for crude oil and natural gas.
A demonstration of the effect of building HTGRs on crude oil price volatility is shown in Figure 7. Here the effect of building 76 HTGR assisted coal to diesel plants, and 76 HTGR assisted coal to gasoline plants results in a decrease in price volatility in 2050.

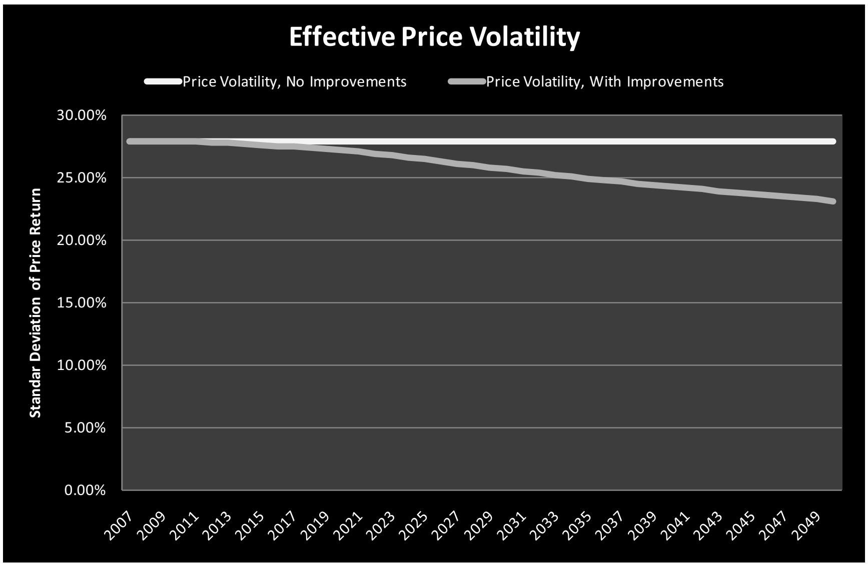

Figure 7. Projected Effective Price Volatility of Crude Oil

Jobs Creation. The creation of permanent U.S.-based engineering, manufacturing, and construction jobs while reducing the flow of capital offshore should remain a strategic U.S. priority. The number of jobs is estimated by year for the given energy strategy by calculating the job breakdown into the following seven areas: Engineering, Manufacturing, Construction, Operations, Decommissioning, Induced Operations, and Induced Construction. Each of these job areas is assigned a duration and a yearly number of associated jobs. The operation duration is equal to the plant life and starts at the year specified by the user as the start year of operation. The construction duration is the lead time minus 1 year and occurs in the years leading up to operations. Engineering and manufacturing start at the beginning of the lead time and last 1 to 3 years depending on plant data. Decommissioning starts at the end of operations and lasts 2 years. Induced construction and operations jobs occur during construction and operations, respectively. The jobs data come from four different sources.[8,15,16,17] Projected job calculations resulting from the addition of HTGRs and other nuclear and renewable energy technologies is shown in Figure 8. Projections beyond 2050 s how job requirements for operation and maintenance only as no new construction is undertaken.

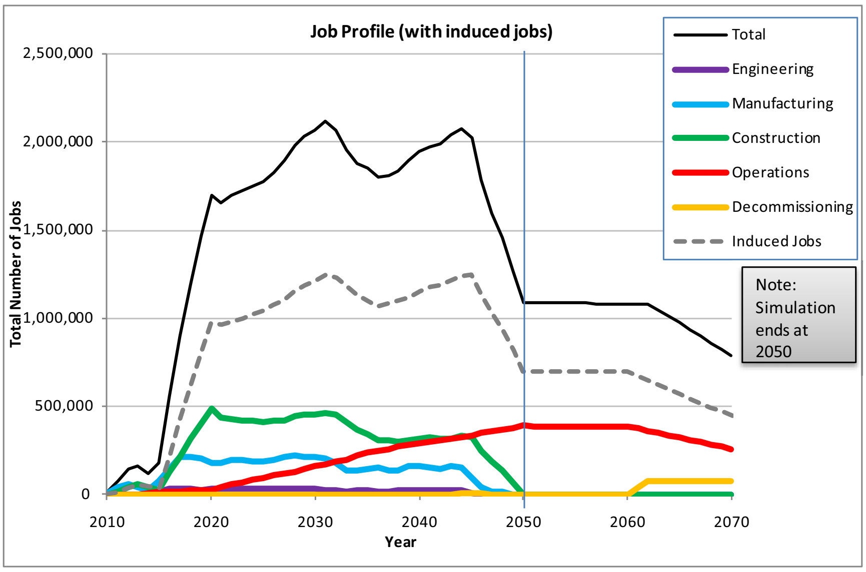

Figure 8. Future Job Profile Estimate Using the 2050 SIM.

Insights. By looking at various user specified scenarios, multiple insights can be gained as to the behavior of the U.S. energy system as a whole. For example, intuitively one would think that by changing 80% of the U.S. car and light truck fleet to plug in electric would decrease GHG emissions. However, if the current electricity generating mix (nuclear=21.2%, renewable=9.1%, coal=51.5%, natural gas=17.2%, and petroleum=1%) stays the same, this is not the case.

As more plug in cars are used, demand and use of petroleum does go down thereby decreasing emissions from petroleum use. Also, as more plug in cars are used, electricity demand and use goes up significantly. By keeping coal as a large portion of electricity generation, coal GHG emissions increase dramatically which more than offsets the decrease in emissions from petroleum. This is shown in Figures 9 and 10.

In order to decrease overall GHG emissions using electric cars, a major shift to "cleaner" electricity generation plants needs to be implemented in the U.S. (such as nuclear or renewable).

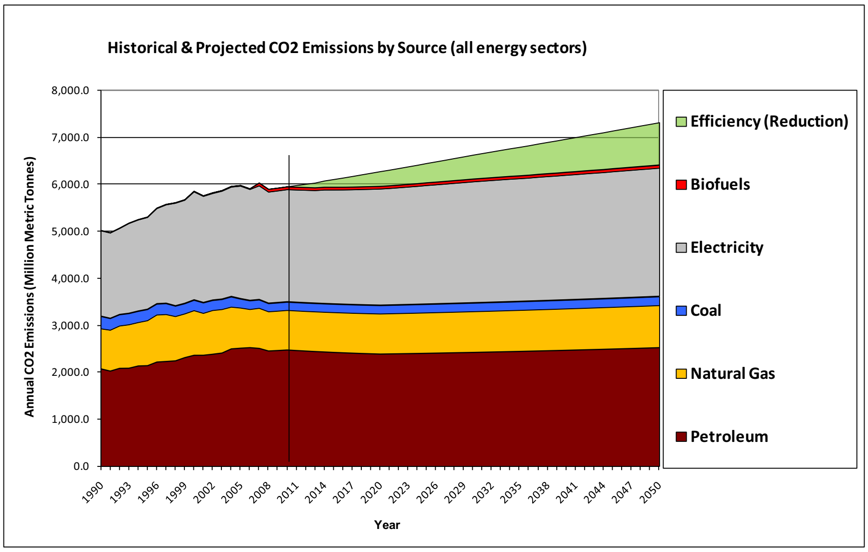

Figure 9. GHG Emissions for Baseline Scenario

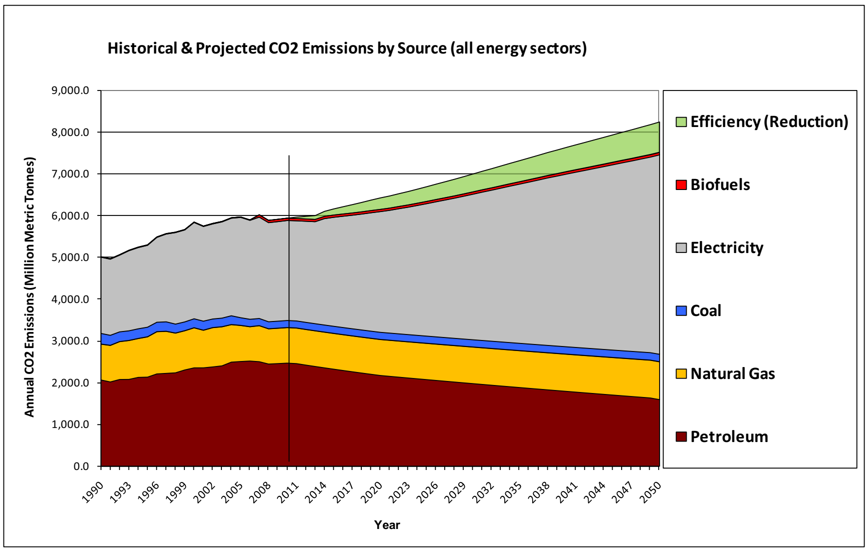

Figure 10. GHG Emissions for 80% Electric Car Scenario

Summary

The 2050 SIM is a simple, robust tool that allows users to analyze domestic energy scenarios and determine for themselves the best mix of scenarios for overcoming the vulnerabilities demonstrated by the U.S. energy infrastructure while realizing the important benefits to stakeholders. The systematic approach used in its creation with documented assumptions and rationale for each aspect adds to the model's rigor and gives confidence to the user in the results. With the model, the user can analyze the effects of overcoming U.S. energy infrastructure vulnerabilities with energy efficiency and conservations methods alone. The user can then add domestically produced transportation and power sources to witness the effect on vulnerabilities and the benefits realized. In addition, users can assess the potential benefits of nuclear power (particularly HTGRs) and renewables and the significant role each can play in transforming the U.S. energy infrastructure, reducing GHG emissions, stabilizing prices, achieving domestic energy independence, and creating jobs. In short, the 2050 S IM allows users to better understand the behavior of the U.S. energy system.

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Biography

John W. Collins, CSEP and Chief Systems Engineer at the Idaho National Laboratory for the Next Generation Nuclear Plant, started his career as a Technical Shift and Start-up Engineer. John led projects to retrofit analog instruments and controls to digital with computer automation and managed the defueling of reactors domestically and internationally. John, a Project Management Professional and Certified Systems Engineering Professional, has 26 years in project and program management, risk and requirements management, decision making, and strategic planning. A Chemical Engineer by education, John managed Electrical and Instrument/Controls, Engineering, Spent Nuclear Fuel, and Nuclear Material Consolidation Projects.

Layne F. Pincock, is a Systems Engineer at the Idaho National Laboratory for the Next Generation Nuclear Plant. Layne has participated in a wide variety of systems engineering projects during his 18 year career at the Idaho National Laboratory, including large integration projects across many Department of Energy Sites. Layne also worked on t he license application for the Yucca Mountain Project. Layne is a mechanical engineer by education.