

# **White Paper**

## **Development of a Nevada Energy Policy Computable General Equilibrium (CGE) Model: A Decision Support Tool**

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# **Development of a Nevada Energy Policy Computable General Equilibrium (CGE) Model: A Decision Support Tool**

## **Executive Summary**

The state of Nevada has adopted policies to encourage energy efficiency and renewable energy technologies. The state government is also active in promoting economic development. Energy policies have the potential to interact with economic development both positively and negatively. A computable general equilibrium model is a tool that could help decision makers explore the policy trade-offs between energy efficiency, renewable portfolio goals and economic development.

Because electrical energy is an input to all sectors in the economy as well as a good that is sold directly to consumers, changes in the price of electrical energy typically affect prices in all other sectors in the economy. To understand the complete consequences of policies that have major impacts on price in the electricity market, it is necessary to model indirect effects and feedbacks throughout the economy. Computable General Equilibrium (CGE) models are a good tool for modeling these types of energy policy changes.

One model currently used in Nevada to find the economic impacts of changes in energy policy is the input output model. This is a cost effective model when changes are small and do not impact other sectors. But the model assumes that supplies of labor, energy and capital are available in infinite supply. Prices are assumed to be fixed and there is no way to model sector response to price change. For larger changes in price these assumptions are unrealistic. In other cases, a Regional Economic Models, Inc. (REMI) analysis has been used. REMI allows for some indirect and feedback effects but because the model is proprietary, many of the assumptions and inner workings of the model are necessarily opaque. By contrast, a publicly funded CGE model could allow public access to all assumptions, equations and computer code, thereby encouraging questions about assumptions, and possibly even competing models.

Three different approaches to modeling are outlined: the minimal, higher risk and ultimate approaches. The minimal model would be the quickest and the cheapest to produce, the higher risk would cost more and the ultimate model would be the most expensive to produce. Where there are enough resources to build it, the 'ultimate' model would be able to provide the most sophisticated results, giving the best tool for exploring the effects of different energy policies on the Nevada economy and the best customization for Nevada. However, the minimal model and the more sophisticated

'higher risk' model would both allow an exploration of general equilibrium effects of different energy policies and build experience for future versions of the Nevada Energy Policy Computable General Equilibrium (NV EP CGE) model.

An appendix details the types of data needed for these models and likely sources for such data. Much of the data needed for all three approaches to the model is publicly available and can be downloaded from the Internet. Some of the required data can be estimated and updated when and if there is more exact data available. In the case of the ultimate model, capital and labor mobility in response to changes in electricity prices may not be known, so a sensitivity analysis may be necessary to test different values. For the ultimate model, it is not known to what extent complete information on each type of Nevada generating plant and transmission constraints may be readily available. However, it is likely at least some more detail can be added to the NV EP CGE model.

In a literature review of CGE models used for energy efficiency or renewable portfolio standards policy analysis, 13 models were located that are possible prototypes for the NV EP CGE model. Each of these prototypes has strengths and weaknesses that are assessed in Appendix A, with one complication being that some of the models are proprietary and therefore full documentation is unavailable. The strongest possibilities for prototypes for the NV EP CGE model are the Holland Washington State University (WSU) model and the State Tax Analysis Modeling Program (STAMP) model for the minimal model, the Sue Wing and Bohringer and Rutherford type model for the higher risk model, and the Coffman et al. model for the "ultimate" model. A version of the WSU model is readily available to download from WSU and represents a "top-down" regional model that is relatively easy to modify. Similarly, the STAMP model approach presents a way of modeling Renewable Portfolio Standards (RPS) but avoiding the elaboration of a detailed electricity sector with multiple generation technologies. The other three models incorporate detail on the electricity sector and allow for greater realism in specifying different renewable portfolio standards.

None of these are fully developed for the Nevada case. The other potential prototypes contain elements that are missing from the above listed strong contenders, so that an amalgam of existing models may be the best "prototype". Many of the economists using these models were contacted in the course of the literature review and several have already provided advice on the NV EP CGE model and offered to provide additional help in future development of the model.

The ideal model is the simplest model that can do the analysis required at hand. Energy policy in particular often requires a general equilibrium analysis because all sectors of the economy are affected by price changes in energy. CGE models are complex, but the wide-ranging effects they can model make them one of the best options for modeling the interaction of the economy at large with respect to changes in electricity prices. Because of their usefulness in policy analysis, CGE models have become widely used. To be truly useful, the creators of the NV EP CGE model must

explain the assumptions and results of the model clearly to non-economist policy makers. Because the CGE models are so popular, there are already published lessons on how to successfully explain results to the lay audience, as well as non technical explanations of the models available to the researcher. These can be used and incorporated into written and oral presentations of the NV EP CGE model.

## Introduction and Literature Review

### Introduction

*Rationales for government energy policy.*

The State of Nevada has adopted policies to encourage energy efficiency as well as renewable energy technologies such as solar and geothermal. Since the Great Recession, the state has also been active in promotion of economic development, targeting as a part of this effort jobs in clean energy. The development of a Nevada energy policy computable general equilibrium model (NV EP CGE) is one way to examine how such energy policies interact with job creation in the state, and how best to maximize policy effectiveness to meet goals of sustainability and economic recovery.

Many states have been active in encouraging energy efficiency programs and investment in renewable energy because it is widely believed that there is insufficient investment in and provision of these technologies as a result of a number of market failures (Gillingham et al., 2009). Among economists, there is ongoing debate over the extent of these market failures, and therefore the extent to which policy intervention is justified. Beyond this debate, other economists have maintained that there is an over-emphasis on finding 'market failures' to justify policies related to energy efficiency and renewable energy technology and believe that urgent sustainability concerns justify a broad-based set of policies that can change the underlying structure of the economy, a structure of preferences and industrial technologies that most analyses take for granted (Hanemann, 2008).

Environmental economists usually assume that a well-functioning market economy will lead to the most beneficial outcomes for society. However, market failures and externalities may interfere with optimal outcomes. Some of the market failures that have been postulated related to the energy efficiency investment gap are (Gillingham, Newell and Palmer, 2009, Howland et al., 2009):

- a. Split incentives: For example, a tenant pays for the utility bill so the building owner has little incentive to make energy efficiency investments to reduce a tenant's utility bills. Since energy efficient building improvements will accrue to the building owner, tenants have little incentive to invest in such improvements.
- b. Information problems: There are many possible information gaps. A building owner or business owner may simply not know that there are money saving efficiency upgrades available, or a consumer may not know the energy consumption of one appliance compared to another. New preferences for energy efficient equipment may develop as a positive

externality as business owners or consumers learn about and spread information about how to use a new technology such as a solar water heater.

- c. Behavioral problems: Numerous deviations from 'rational' decision making have been recognized by economists. One example of this is the 'salience effect' which causes decision-makers to overweight up-front investment costs of energy efficiency purchases.
- d. Liquidity constraints: Business owners may not have access to enough capital to make appropriate investments because of credit market failures or high transaction costs for small investments.

The list of market failures above can all prevent maximized levels of investment in energy efficiency even where there is a positive private return on investment. In addition to the above market failures there are many negative externalities associated with various types of energy use. These negative externalities related to greenhouse gas emissions, security, reliability, and risk reduction may all increase the societal return on investment when full costs and benefits of energy efficiency measures are taken into account. Many of these are cited as reasons for government intervention to encourage investment in renewable energy technology as well.

*Different types of evaluations of energy policy: return on investment, economic impacts and benefit-cost analysis.*

The simplest and most basic evaluation of energy efficiency policy is estimation of private returns on investment (ROI) for the type of projects to be encouraged by the policy. ROI is the net financial benefit divided by total cost and is typically measured from the perspective of a private business or individual rather than from a public perspective. Because many economists and policy makers believe there is an energy efficiency investment 'gap' created by market failures, it is possible that there are energy efficiency investment opportunities that are zero cost. That is, there are energy efficiency opportunities available to business owners and homeowners which have a positive private return on investment for those owners. Where these opportunities are found to exist they are 'no-brainers'. Much energy efficiency policy is developed in an effort to encourage these types of investments.

Complications may arise from investment in energy efficiency in terms of the return on investment at the utility scale. Businesses or households who use less energy effect the distribution of fixed costs in the system and may unfairly burden other rate-payers. In addition, energy efficiency may create rebound effects because the effective price of electricity decreases with the efficiency investment. Optimal investment levels in new renewable technologies may change also in relation to energy efficiency investment. A social return on investment would take into account these complicating factors.

A cost-benefit analysis is similar in spirit to calculating the return on investment, but from a large scale regional, national or world perspective. It attempts to measure total changes in society's well-being attributed to a change in policy or a project. In addition to measurement of the financial costs and benefits from the perspective of society as a whole, cost benefit analysis usually includes attempts to quantify difficult to measure benefits such as clean air and water, reduction in global warming or reduction in security costs due to lower energy use (Transportation Economics Committee, 2004).

A different type of evaluation that is often undertaken to describe regional results of a policy or project is the economic impact analysis. The economic impact analysis is typically carried out from the perspective of a smaller region such as a state or a county rather than from a national or international perspective. While a benefit-cost analysis is considered by economists to be the ultimate aid to policy decision makers, there is often interest within a region as to how a policy or project might increase or decrease local business activity, especially the number and quality of jobs. There is competition between regions for outside inflows of capital or government funds and the new jobs they can bring. The analysis attempts to find changes in economic activity due to the change from the baseline for jobs, employee compensation, value-added and fiscal impacts. In contrast to the cost-benefit analysis, there is not normally an attempt to measure environmental or other less tangible costs or benefits in financial terms, although a change in resource use or pollution emissions may sometimes be measured directly in non-dollar terms. Other benefits may not be counted that would be accounted for in a benefit-cost analysis. For example, if people are more comfortable in their homes because of increased insulation it produces an increase in their welfare. This type of welfare increase would not be accounted for in an economic impact statement. On the other hand, second round increases in employment and economic activity, referred to as indirect and induced effects, are not included in a benefit-cost analysis but are included in an economic impact analysis. The key difference is that benefit-cost analysis measures changes in human *welfare* due to a new policy or project from a broad-based national or international perspective, while economic impact analysis measures the change in economic *activity* at a regional level without reference to the change in welfare for regional households (Transportation Economics Committee, 2004). The economic impact results could be considered more descriptive than proscriptive.

## **Types of models**

Hundreds of studies have analyzed energy efficiency and renewable energy policies and projects for costs, benefits and economic impacts. These studies use a large variety of methods depending on the available data and expertise as well as the goals of and budget for the analysis. Measurement of capital investment costs incurred, and ongoing operations and maintenance costs versus the estimated energy generation or savings over the lifetime of the investment form the basic core of most studies and



correspond to the private, or part of the social, return on investment calculations. This core analysis is often extended for use in other types of models including input-output (I-O) models, the Regional Economic Models, Inc. (REMI) model – a commercially available economic impact and forecasting model, and computable general equilibrium (CGE) models, as well as others. Since I-O, REMI and CGE models are related to each other by an inner core of multi-sector inter-industry relationships, can produce similar types of results, and because CGE models are the ultimate interest of this review, I focus below on these three types of models and the differences between them. However, I first review several important national ‘bottom-up’ detailed engineering style models. Often these models, or their outputs, are combined in various ways with other national or regional input-output, REMI or CGE models.

### ***Some Prominent U.S. Models for Analysis of Energy Policy***

There are several large-scale models that have been used to analyze energy policy. These could be considered bottom-up engineering oriented models and contain a large amount of detail concerning generation capacity of many types of electricity plants as well as all types of constraints due to current and projected transmission capacities and much more. Three important well-known models are the NEMS model, the Haiku model, and the ReEDS model. Each has been used to study economic and environmental impacts of renewable portfolio standards. All three have been used to enrich CGE models either with data outputs or by embedding the entire model within a CGE model.

#### ***National Energy Modeling System (NEMS)***

This is a model used to predict energy production, consumption and prices for the U.S. as a whole and for the nine Census sub-regions 25 years into the future. It is a product of the Energy Information Administration of the U.S. Department of Energy. The model is also used to investigate energy policies such as National RPS or carbon taxes. One of the modules is the electricity market module. Bottom-up detailed demand and supply modules are linked in a system which allows for a general equilibrium type solution. See: <http://www.eia.gov/oiaf/aeo/overview/#oview> )

#### **HAIKU**

The HAIKU model focuses solely on electricity. It also contains rich detail on 21 U.S. regional electricity markets. It is a product of Resources for the Future, a think tank that produces research concerning interactions between the economy, energy, natural resources, and the environment. The purpose of the model is precisely to answer questions about electricity market policies such as renewable portfolio standards. The model is able to address such details as seasonal and daily timing of demand, inter-

regional power trading and transmission constraints, different types of generation technologies, investment in new technologies and retirement of old technologies.

See: <http://www.rff.org/RFF/Documents/RFF-Rpt-Haiku.v2.0.pdf>

### **Regional Energy Deployment System (ReEDS)**

This model is used to analyze electricity generation capacity expansion. The National Renewable Energy Laboratory maintains ReEDS. It involves the current and predicted costs of generating and delivering electricity with different technologies and is also used for energy policy investigations. Of the three models it is most closely associated with RPS and energy efficiency policy analysis, with special attention to problems with renewable energy such as the intermittent nature of wind and solar, transmission constraints and storage or back-up generation needs. Regional detail on 356 regions in a GIS database is part of the model.

See: <http://www.nrel.gov/analysis/reeds/description.html>

### **Input-output models**

Many studies use an I-O model to analyze the economic impacts of energy efficiency or RPS in a region. I-O models can be called a type of general equilibrium model which accounts for relationships throughout the entire economy: businesses, workers and capital owners, and consumers. One advantage of I-O models is the ability to include inter-sectoral industry analysis. Existing relationships between sectors through estimated purchases and receipts are used to estimate multiplier effects to a regional economy as new money from outside the region circulates. Thus I-O models include secondary indirect effects to the rest of a regional economy.

Some examples of energy efficiency I-O analysis include the SWEEP study (Geller, 2012), economic impact portion of the NERA report from NV Energy (Harrison et al., 2011), Kentucky report (Tharp and Quillen, 2009), Jobs and Economic Development Impact (JEDI) model reports (National Renewable Energy Laboratory, 2009) and a Department of Energy analysis (Scott et al., 2008). One meta-analysis of 15 such input-output studies concludes that energy efficiency programs – in addition to a 30 percent renewable portfolio standard requirement by 2030 – will create four million more job-years than gas and coal electricity generation would have (Wei, 2010).

I-O models assume an economy that does not face supply constraints for factor inputs. This can sometimes be a reasonable assumption for very open regional economies over a medium or long run where labor and capital can easily flow into the region from neighboring areas. It can also approximate the situation where there is high unemployment and idle capital. However, where there are opportunity costs for factor inputs, the model is not realistic.

## **REMI models**

Another very popular model used to analyze economic impacts of energy policy is the Regional Economic Models, Inc., or REMI, model. REMI is a commercially available model that combines an I-O component with an econometric forecasting model (John Cridfield and Harrison Campbell, 1991). REMI is capable of producing multi-year forecasts. Unlike the IMPLAN model, labor and capital supplies are constrained and relative prices change. Other regions compete for factor inputs and for export activity, adding more complexity and, potentially, more realism to the REMI model. The reporting of results and the use of the model tends to be for economic impact analysis and in that respect similar to results from I-O models. The REMI analysis results are often presented with reference to a base-case no-policy-action alternative. I-O analysis, in lieu of having a base case, may try to find a 'direct impact' that consists of 'new dollars' that would not be available to the regional economy without the policy or project under consideration.

Some examples of REMI model analyses applied to energy policy include the state of Michigan study of RPS and energy efficiency programs (Polich, 2007), a study of the state of Florida's climate action plan (Rose and Wei, 2008) and a study of energy efficiency investments for New England states done by Environment Northeast (Howland et al., 2009). In one case that is representative, Rose and Wei find that investing in a collection of 20 different greenhouse gas mitigation strategies for Florida results in a net present value impact of \$38 billion in gross state product. They find that these positive results stem from positive return on investment both in the case of the renewable energy technologies and energy efficiency projects. The Rose and Wei study in particular represents a prototype for a potential lower cost alternative for investigation of energy efficiency and renewable portfolio standards for the Nevada case if funding for a custom made CGE model is insufficient.

## **Computable general equilibrium models: introduction and comparison with I-O and REMI**

Computable general equilibrium (CGE) models have become perhaps the foremost model for investigating the economic and environmental results of various greenhouse gas mitigation measures, especially cap and trade policies for, or taxation of, carbon emissions (Sue Wing, 2009). As a part of these investigations, CGE models have been used to experiment with how energy efficiency and RPS standards in the electricity sector will affect the economy. CGE models are flexible and have been built to serve many purposes. The CGE umbrella is large enough that in a sense, one could consider I-O models and the REMI model a type of CGE model. They can be used to measure changes in jobs, employee compensation, value-added and fiscal impacts, but can take into account more complex price relationships. Generally, because of the complex functional relationships specified, more aggregated industry sector detail is used than in I-O models and REMI models. CGE models may have competition for

constrained factor inputs. Unlike REMI and I-O models, CGE models can sometimes be used to find measures of welfare (increases or decreases in public welfare) such as are used in cost benefit analyses. Like the REMI and I-O model, the inter-industry relationships at the core of the model allow tracking of pollution or resource use in connection with a perturbation of the initial conditions of the economy. However, CGE models are not typically well-equipped to incorporate the full benefits and costs of a cost-benefit analysis. For example, the many models used to investigate GHG mitigation normally do not attempt to find welfare changes due to changes in GHG emissions. Though they may specify various tax levels from GHG emissions, there is usually no attempt to link emission levels to a welfare measure. For some governments, CGE models have become such a popular decision making tool, that some complain that the traditional more complete cost-benefit analysis has been overthrown (Layman, 2004). For a fuller consideration of all the variables in a CGE setting, a multi-criterion analysis must be used. I return to a more in-depth review of CGE models below.

### **Critiques of I-O, REMI and CGE economic analyses**

I-O model studies of electrical energy efficiency programs have been particularly vulnerable to criticisms that they are overly optimistic (Croucher, 2012). One important point is whether or not an economic impact analysis correctly defines 'new dollars'. Some analyses do not count initial investments in energy efficient buildings or new more efficient appliances as a cost, even though these investments are paid for through local tax money or utility rate-payer dollars that clearly have an opportunity cost and cannot be considered new dollars to the region. REMI and CGE model analyses are also not immune to this type of problem (Stavins et al., 2007). Investment in energy efficiency should be seen as an expense.

Other problems that occur with economic analyses of energy efficiency programs:

- Measurement issues: engineering specifications may not always be perfectly met in real life situations, yet energy savings are usually estimated this way rather than from data collected on actual energy use in the field before and after installation. All types of analysis depend on accurate estimates of energy savings and can't be any more accurate than this data input.
- Rebound effects: if energy efficiency measures lower energy costs for a business or household, they may have more money to spend. Some of this money may be used to purchase more electricity. If energy efficiency causes the cost of electricity to drop, it will become even more desirable to substitute it for other factors of production. Thus energy efficiency programs can actually increase energy use. This is called the rebound effect. This is the type of complex general equilibrium effect is not well captured in an I-O analysis or REMI analysis but is easy to capture in a CGE model.

- Lumpy fixed capital: electricity production requires very large investment in generating plants and transmission lines. How these costs are spread over a customer base is a large issue in determining rates. Croucher and others point out that those customers who install energy efficient equipment and no longer have to pay as much for their electricity escape having to pay as much for these fixed plant and equipment costs. The same fixed costs still must be met just as they were before the energy savings occurred. Thus other rate-payers now must pick up these fixed costs. The opposite may be true where energy savings equipment allows all rate payers to avoid the cost of new plant and equipment. Because of this, one cannot use the retail electricity rates savings of a customer to calculate total societal savings. A good and careful analysis of capital infrastructure costs and savings is a difficult but important element in a good analysis of energy efficiency economics. In addition, these considerations may interact with adoption of new renewable technologies since energy efficiency can slow down the rate at which new generation capacity is needed.
- In economic impact studies, sometimes job increases are reported without any mention of job quality, i.e., how much annual compensation will be associated with those new jobs. Worse, some studies do not account for jobs lost in the traditional energy sector as demand decreases. These jobs are often high-paying jobs and will be replaced with lower paying service jobs.
- Baseline fuel prices: higher fossil fuel prices over the lifetime of the energy savings equipment will result in a higher level of private savings. Higher fuel prices will also create a greater incentive to adopt energy efficient devices and may negate the need for government intervention.
- Uncertainty: As Stavins et al. (2007) point out, costs and benefits of energy efficiency measures are not known with certainty. Instead of a point estimate, which is usually what is assumed for convenience, the reality is that there is a probability distribution of possible costs and benefits. Fuel price uncertainty adds another very large element of uncertainty. Depending on the time path of adjustment, fuel price increases could either obviate the need for energy efficiency policies, since the enhanced price signal will tend to drive energy efficiency measures by itself, or greatly increase the dividends of energy efficiency investments if a sudden price shock to the economy is averted.
- Inclusion of environmental costs and benefits: it is very difficult to measure costs and benefits of air pollution emission abatement, especially GHG emission abatement. It is also difficult to measure welfare impacts such as more stable and comfortable indoor air temperatures due to insulation, cluttering open space with giant windmills and transmission towers, impacts to wildlife from coal mining and so forth. As a result, these type of costs and benefits are often ignored. The lesson of environmental economics is that ignoring these types of costs and benefits will mean coming up with the wrong policy solution. Just because they are hard to evaluate does not make these costs and benefits any less real. However, most studies carried out do not attempt to quantify these. This last point is especially relevant for measuring the benefits and costs of RPS.

## Basic concepts for CGE<sup>1</sup>

Before turning to the literature, I briefly explain computable general equilibrium (CGE) models. CGE models are simplified representations of entire economies. One approach to constructing a CGE model is through the notion of the circular flow of the economy. Figure 1 presents the core of the conceptualized circular flow in a CGE model, adapted from Ghadimi (2007). First, we start with the producers. A CGE model contains multiple producing sectors such as the agricultural sector, the manufacturing sector, the trade sector, the services sector and the utilities sector. The number of sectors (and model complexity) could vary from only two sectors to hundreds, depending on the level of aggregation of industry activity needed for a particular policy analysis. Energy CGE models often have an elaborate nesting of energy inputs in the production function or a sub-model where different types of electricity production are chosen so as to optimize profit. Often other sectors are highly aggregated. Each industry sector is represented in the model in aggregate over all firms and therefore with a specific production function.

Producers in a CGE model typically purchase inputs to produce commodities to sell in the product market. For example, the electrical utility sector may purchase various fuels, parts, insurance and so forth from the product market. These are called inter-industry purchases. Producers also purchase the services of factors of production. The electrical utility sector, for example, purchases labor, capital and land from their owners. In the case of energy CGEs, energy resources may also be considered a factor of production.

In a CGE model, the owners of the factors of production are usually called households. Households may consist of a single representative household, or if different income levels, locations, ethnicities or other characteristics are of interest to the modeler, more than one representative household may be included. All factor income accrues to households as the ultimate owners of the factors. To complete the circle, households spend the income that they receive for the use of the factors they own in the product market. In energy CGEs one of the commodities purchased in the product market is electricity from the electric utility sector.

Three concepts from neoclassical theory link the firms and households in the circular flow and make up the core of the CGE model (Sue Wing 2011). These are:

1. Zero profit conditions. Because of constant returns to scale and competitive markets, producers do not make a profit. Total revenue is equal to total costs. All firm revenue is used to purchase intermediate inputs or to rent the factors of production from households.

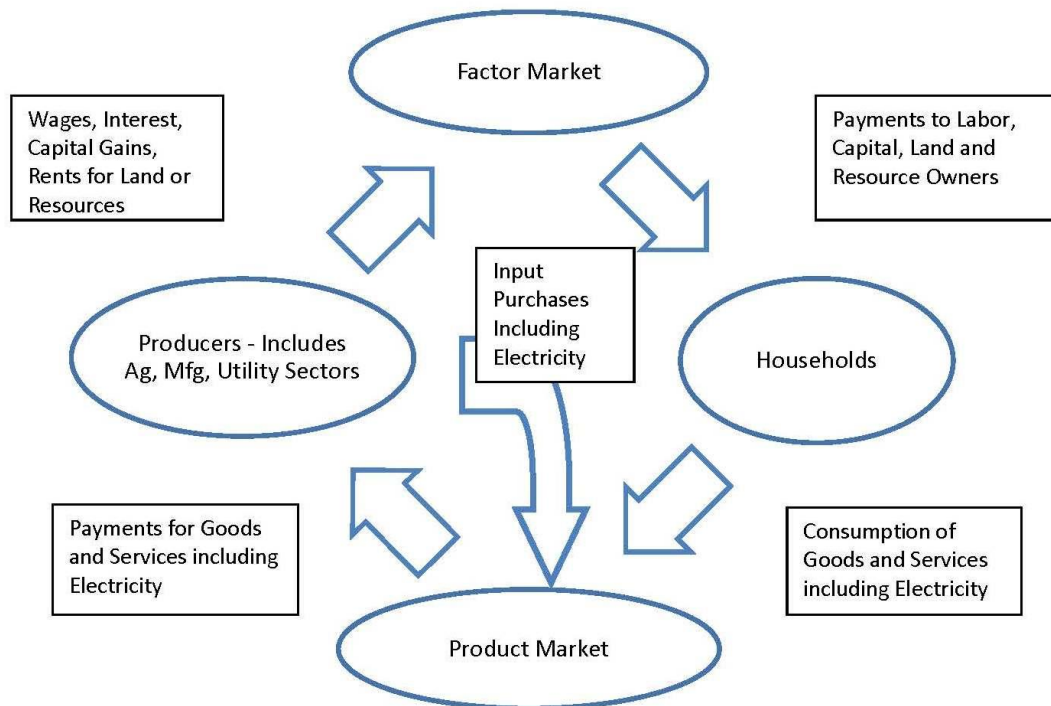
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<sup>1</sup> This section is adapted from **Fadali, Elizabeth; Kim Rollins and Shawn Stoddard**. 2012. "Determining Water Values with Computable General Equilibrium Models," Industrial Economics Inc., *The Importance of Water to the U.S. Economy: Technical Workshop*. Cambridge, MA:

2. Market clearance conditions. The value of a firm's output will be equal to the value of household and other firms' intermediate purchases. That is, in each market supply is equal to demand. This will also hold in the factor market.
3. Income balance conditions. In order to maximize utility, all the income that households earn by renting out factors will be spent on purchases of commodities from the product market.

While the above represents a basic description of the core of a CGE model, CGE models typically also contain representations of a government sector, investment and savings, and trade. The government sector may be used to model taxes and subsidies or other types of policies. Governments collect taxes, consume commodities and redistribute some taxes. Investment and savings specifications become important for dynamic CGE models in order to connect savings and investment in the initial time-period with capital formation. This can be especially important for dynamic energy-CGEs that consider policy questions about new infrastructure or the replacement of old infrastructure over time. Specification of trade flows with other regions are a standard part of CGE models and may also be important for modeling so-called leakage in energy policy models. Leakage occurs when one state's policies influence outcomes in other state markets that may feedback into the state and interfere with the first state's policy objectives. For example, if Nevada increases its RPS for renewables, but can satisfy the requirement with purchases of cheap hydro-electrical energy from Washington State, local alternative energy projects may not be funded as intended.

**Figure 1: Circular Flow of Income for a CGE**



The circular flow of the economy is represented in a CGE by a set of financial transactions referred to as a Social Accounting Matrix, or SAM. Table 1 illustrates a SAM. The SAM uses double-entry accounts. By convention, the rows are account receipts and columns are purchases. Total outlays (purchases) are equal to total receipts for each account. In Table 1, for example, reading down the first column, we see that the agricultural sector purchased \$1.3 million of agricultural commodity inputs, \$400,000 of trade commodities, \$700,000 from the manufacturing sector, and so on. The agricultural sector paid out \$1.3 million in wages to laborers. Another \$3.3 million represented returns to capital and depreciation. Total outlays were \$8 million dollars, exactly matching total receipts, which are found by reading across the row.

The producers are the “activity” accounts. The producers purchase inputs from other industries and pay wages and rents to the factors of production as well as indirect business taxes, such as sales taxes, to the government. In the factors columns, labor pays \$54 million in income to households as well as \$7 million in payroll taxes to governments, and money is allocated from the capital account to household owners of capital, to the government for capital gains taxes and for investment. Reading down the final demands sector columns, households and government, we once again close the circle with households spending income on purchases of commodities. Households also pay direct taxes to government, invest, and transfer money to other households.

Government purchases goods and services, transfers money back to households, and invests. The final column shows exports, the purchases of commodities made by parties outside of the region.

### **Implementation: The social accounting matrix (SAM) and energy accounts**

Figure 2 shows an overview of the CGE modeling process (Gillig and McCarl 2002). Computable general equilibrium models are referred to as computable because they are applied to economic data. Data for the SAM is collected and then adjusted and balanced so that total receipts are equal to total outlays for each account. The SAM data described in Table 1 represents the so-called benchmark general equilibrium. This data, along with specific assumptions regarding utility and production functions are assumed to represent one equilibrium solution of the economic model. An energy CGE model will usually include energy accounts and emissions accounts that accompany the SAM.

Since the benchmark is considered to represent an equilibrium solution, once specific functional forms are chosen, the benchmark data is used to calibrate the parameter values for the functional forms. Depending on the functional forms chosen for producers and consumers, some parameter values will not be supplied by the calibration and will have to be supplied exogenously. Values are either taken from the literature, or chosen using the modeler’s best judgment.



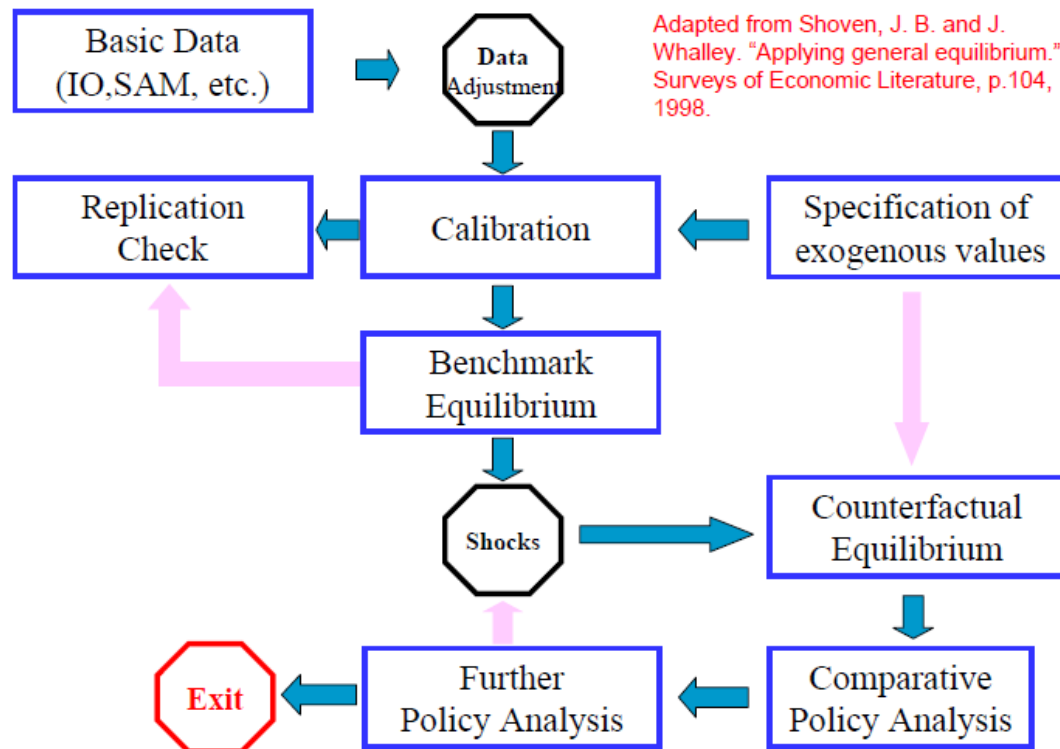
After calibration, the model is checked to see if it correctly replicates the baseline data in the SAM. After ensuring that the baseline data can be replicated, the model is “shocked”. For example, an increase in export demand may be imposed

**Table 1: Example of a Social Accounting Matrix (millions of \$)**

		Purchases ↓↓↓↓↓↓															
		Activities				Commodities				Factors				Final Demand			
		Ag	Trade	Mfg	Services	Ag	Trade	Mfg	Services	Labor	Capital	Taxes	Households	Govt	Investment	Trade	TOTAL
Activities	Ag					8	-	0	0								8
	Trade					-	30	-	1								30
	Mfg					0	-	25	0								25
	Services					-	0	-	120								121
Commodities	Ag	1.3	0.7	1	0.2								1	0	2	6	12
	Trade	0.4	2.7	2.1	5.3								17	2	1	7	38
	Mfg	0.7	1.8	7.9	6.1								15	8	8	11	59
	Services	0.7	5.2	3.4	29.3								54	19	1	37	149
Factor	Labor	1.3	10.8	6.6	42.3												61
	Capital	3.3	5.7	3.5	31.8												44
	Taxes	0.4	3.4	0.2	5.4												9
Final Demand	Households					-	-	-	1	54	16	-	2	3	23	2	100
	Govt					0	0	-	5	7	1	9	9	19	7	0	57
	Investment					0	0	0	1	-	29	-	2	6	6	7	52
	Trade					4	8	34	21	-	-1	-	0	0	4	0	70
	TOTAL	8	30	25	121	12	38	59	149	61	44	9	100	57	52	70	836

Figure 2. Diagram of CGE Modeling Process

## CGE Overview -- Steps in CGE Modeling



exogenously or a tax may be eliminated. The model is solved once again to find the "counterfactual" equilibrium set of prices and quantities for all sectors. These results can then be compared to the base solution or other counterfactual scenarios.

Because the CGE model is a representation of the entire economy, the output from the model gives a complete set of market-clearing prices and quantities in the product and factor markets. Thus, almost any economic variable of interest can be compared to the baseline: GDP, employment levels by sector, aggregate consumption, energy use by sector, electricity prices, emission shadow prices, and more. An explicit measure of welfare, the equivalent variation, may sometimes be calculated from the results so that the change in welfare for different simulations can be calculated.

### Dynamic CGE models

All CGE models implicitly incorporate time, in that conceptually an adjustment process takes place until markets clear (Ghadimi, 2007). Models may be designed to represent short-run changes, in which capital or other factors are not mobile between sectors or regions, or long-run changes that assume full mobility of factors. Most energy

CGE models incorporate a more explicit time element in order to observe the temporal effects of a policy adjustment.

Most energy policies are enacted over time and therefore have consequences that unfold over multiple time periods, or questions related to capital stock accumulation. One such important energy policy issue is to encourage the appropriate amount of investment in energy efficiency or renewable energy. This is an investment and capital stock decision. For this type of question a multi-period model is often used.

Ghadimi (2007) describes two basic types of dynamic CGE models:

1. recursive models that solve for a static equilibrium, update time-related variables and solve for the next time period equilibrium in sequence for the required number of time steps, and
2. models that incorporate inter-temporal optimizing behaviors based on expectations.

Either method is used in energy CGE models, although inter-temporal optimizing behaviors make the model more complex and harder to solve.

## **Literature Review of CGE models for electrical energy efficiency and renewable energy support**

Because energy is an input to all sectors in the economy as well as a part of the final demand of all institutions (households, governments, investment), it is a subject that is naturally suitable for general equilibrium analysis. The pervasive nature of energy use means that partial equilibrium analysis could rarely be sufficient to analyze any large changes in energy price or quantities. Changes in energy prices or quantities have the power to change relative prices for all types of commodities, factor inputs such as labor and capital, and thereby, household incomes, as well as taxes and transfers to and from governments. Tracking energy use through the economy to specific sectors is also desirable since energy policy can easily create winners and losers, or may need to be especially tailored for certain sectors or low-income households. For this reason, energy and CGE models are a natural fit. Worries about energy shortages or price increases have caused great interest in this topic amongst economists and researchers in many other fields as well. Furthermore, because in recent decades, greenhouse gas emissions have turned out to be perhaps the biggest environmental externality ever encountered by humankind, and because the economic ramifications of policies to mitigate the emissions are very large, there are hundreds of models made to analyze such policies in the economic literature. Many of these models contain components that analyze energy efficiency measures and renewable portfolio standards. The literature on the subject is vast.

In many respects, energy CGE models contain quite typical specifications. Income, consumption, savings, government, trade, macro-closures and dynamics are usually variations of standard CGE model specifications. Some special issues that arise in energy modeling are (Kuik et al., 2009):

- Top down, bottom up or hybrid models: The quintessential bottom up model would be a non-CGE engineering model with large amounts of technical detail on electricity production or energy sectors but less attention to macro-economic details whereas top down models, such as the typical CGE model, concentrate on macro-economic interaction but don't have detail on various types of electricity production and infrastructure. There are many attempts to combine the two approaches in a hybrid model (for example, see Bohringer and Rutherford, 2008).
- Determining baseline economic growth over time in a dynamic model.
- Types of energy sources to include in the model.
- Nesting and aggregation of energy inputs to production: For example, where energy is believed to be a complement to capital they would be nested together (Turner and Hanley, 2011).
- Recursive dynamic versus inter-temporal: Actual optimization behavior may be incorporated into a CGE model but other dynamic models use a step approach with exogenous changes in population, GDP, technical change and other parameters imposed on the current simulation solution, time period by time period.
- Malleability of capital: This is related to technical detail and dynamics. One must specify how fast capital can change from an old technology to newer technology. Depreciation, savings and investment are especially important in the capital intensive electricity sector. Some capital assets may have very long life in the energy sector.
- Endogeneity of technical change: Technical change may lower prices of technologies such as solar energy or energy efficiency measures. Some models simply impose a rate of change exogenously but there has been great interest in how policy variables, such as the imposition of GHG penalties or an increase in research and development investment, could endogenously change outcomes (Gillingham et al. 2009). Related to this is the notion of path-dependency (Kalkuhl et al., 2012).
- Elasticity of substitution of electrical energy with other inputs: If it is easy to substitute electricity for other inputs, this may increase the rebound effect if electrical power becomes cheaper because of energy efficiency measures. On the other hand, if it is hard to substitute other inputs for electricity and renewable portfolio standards make electricity more expensive, it will impact businesses more than if the elasticity of substitution is larger. Similarly, the ease with which consumers may substitute away from electricity will be influential.

- For the regional model, a question to be addressed is how electricity prices may influence capital and labor inflows from other regions. If electricity is cheaper it may positively affect business decisions to move to Nevada and vice versa.

Three examples of energy models are GTAP-Energy – the Global Trade Analysis Project model and data housed at Purdue University (Rutherford and Paltsev, 2000) and modified for investigation of energy use and GHG emissions policies; EPPA – the Emissions Prediction and Policy Analysis model housed at MIT (Paltsev et al., 2005); and GRACE-EL – the Global Responses for Anthropogenic Changes to the Environment model developed in Norway (Aaheim and Rive, 2005). However, these models are just representative of a very large field of work. For example, in their recent meta-analysis of GHG abatement costs, Kuik et al. list 20 different CGE models, but their list is not comprehensive (Kuik et al. 2009).

Sue Wing presents a detailed how-to for a hybrid electric energy CGE model (Sue Wing, 2006, 2008). The static model is purposely kept very simple and presented in a transparent way. The focus of these two papers is an elaboration of the electricity sector so as to include thirteen specific production technologies such as steam turbine coal production, geothermal or solar. Sue Wing details the changes needed in the social accounting matrix as well as the data necessary to disaggregate the electricity sector into the finer detail needed to distinguish between different modes of electricity generation. Although RPS are not addressed in this model, it might be a prototype for a NV EP CGE model.

### **Regional energy policy CGE models for analysis of RPS and energy efficiency**

Specific emphasis on energy efficiency or RPS and the economic impacts of such policies is more rare. Below, I focus on this smaller part of the literature. For Nevada, because it is a sub-national entity, the CGE model needs to take into account the openness of the economy to the rest of the nation as well as account for state trade with other states differently than foreign trade. Other sub-national models are the best templates for a Nevada model. In addition, the focus of the policies under investigation is specifically with the electricity sector, rather than with all types of energy use or GHG emissions in general. Thus, I examine models with these characteristics as their focus.

#### *Energy Efficiency*

There is a suite of papers using a Scottish model developed by Turner, Hanley, Allan and others that model energy efficiency policy in Scotland and the United Kingdom (Allan et al., 2007b, Hanley et al., 2009, Turner, 2009, Turner and Hanley, 2011). The level of detail in the production function might mean that the Scottish AMOSENVI model could be considered a hybrid model somewhere between the most general top down model and detailed engineering models. The production function involves seven levels of nesting. Intermediate inputs are approached differently depending on whether they

are an energy or a non-energy input, a common approach (Turner and Hanley, 2011). Electricity is modeled as a composite of renewable and non-renewable technologies.

These studies concentrate largely on the well-known rebound effect. When energy efficiency increases, its productivity increases, producing a fall in its effective price (Turner and Hanley, 2011). As the effective price falls, energy use is substituted for other inputs. In addition, energy intensive industries may become more competitive and increase production. Finally, there is an income effect as more money is now available to spend on non-energy commodities, increasing consumption. The rebound effect occurs when these interactions cause energy use to increase and the total initial energy savings decreases. Backfire occurs when this effect causes total energy use to increase in response to improved energy efficiency to the point that it outweighs the energy initially saved (Turner and Hanley, 2011). Energy efficiency and the rebound effect is also the subject of a literature survey (Greening et al., 2000). Allan et al. (2007) review eight papers that use CGE models to explore the rebound effect (Allan et al., 2007a).

The Berkeley Energy and Resources (BEAR) CGE model for analysis of California energy policy is documented in several reports (Beghin et al., 2002, Beghin et al., 1996, Roland-Holst, 2008a, b, 2009, Roland-Holst and Kahrl, 2009). The scenarios that are run and results that are produced with the BEAR model are almost exactly what would be appropriate for what has been envisioned for the NV EP CGE model, with a mix of energy efficiency and renewable portfolio standards policies run under several different assumptions about fuel prices. Output results give job and economic impacts.

Production function is a five level nest in the BEAR CGE model. An energy composite made up of different primary fuels is bundled with capital. There is a putty/semi-putty specification of technology. Unfortunately, there is no readily available technical documentation of how the detailed electricity sector is incorporated into the model. The model is proprietary and no peer-reviewed publications using this detailed module could be located.

Nasseri and Konan are developing a CGE model for Hawaii which will measure impacts of energy efficiency on sectoral GHG emissions and energy intensity (Nasseri and Konan, 2012). The model is a standard static CGE model that is augmented with data on energy use by sector and the accompanying GHG emissions of the energy use. They specify a Leontief production function for electricity inputs and other intermediate demands. Electricity inputs enter into the production function with an efficiency parameter that can be changed in order to shock the model with better efficiency. Efficiency improvements do not incur any cost.

### *Renewable Portfolio Standards*

A question that arises in energy policy models of the electricity sector is how to incorporate necessary engineering detail into a model that can also capture economy-

wide feedbacks such as the CGE model. Engineering models that incorporate rich detail about specific generation, transmission and distribution constraints constitute the so-called 'bottom-up' model while computable general equilibrium models with a single generic electricity sector are referred to as 'top-down' models. Top down models are able to model full effects of complex interactions between energy sectors, other industry sectors, labor, capital and natural resource demands and household incomes. The quest to have both the necessary detail and the full economy feedbacks has led to many types of hybrid models. In order to incorporate enough detail on the electricity sector to model renewable portfolio standards, some type of hybrid model is needed for the Nevada energy policy model. A range of methods is available; at one extreme modelers use the output of detailed partial equilibrium models to create exogenous inputs to a top-down CGE model; at the other extreme, a CGE model may be specified in such a way that the detailed electricity sector is fully incorporated into the CGE model. The incorporation of the detailed model into a CGE model is a more complicated undertaking. However, methods that merely incorporate many exogenously specified prices, demands and supplies into the CGE model can suffer from inconsistency.

One model that fully incorporates a more detailed electric sector to model RPS is demonstrated in Böhringer et al. (2013) which finds employment impacts in Germany due to subsidies for renewable energy generation. The model starts with a generic static energy policy CGE model which is demonstrated in Bohringer and Rutherford (2010) and more fully documented in Bohringer et al. (2009). The GAMS code for the 2010 'top-down' portion of the model is available upon request from the authors. The electricity sector of this general model is then extended with bottom-up detail necessary to specify different energy generation constraints. The general method used to extend the model is given in a 2008 Bohringer and Rutherford paper, which is primarily a pedagogic paper. The GAMS computer code for this 2008 model is also available. Also, the issue of combining the bottom-up and top-down models is discussed in another 2009 report (Bohringer and Rutherford, 2009). Similar techniques are used in several other RPS CGE models: Coffman et al. 2013, Davis and Balisteri, 2010, Morris et al. 2010, Rausch and Mowers, 2012.

At the other extreme is the STAMP model. The CGE model that is used appears to be a so called 'top-down' tax model. Beacon Hill uses the EIA data on levelized costs for various electricity generating technologies, EIA and other forecasts of future capital costs, forecasts of electricity demand, elasticities for electricity demand and other data to calculate RPS costs as a percentage price increase on electricity. The model represents a way around the difficulty of integrating the detailed bottom-up model into the CGE. However, it would appear that they may lose much of the value of a CGE model by imposing many prices and quantities exogenously rather than letting the model determine these.

Many partisan state or national level think tanks such as the American Tradition Institute and Minnesota Free Market Institute have hired Beacon Hill Institute to analyze

the economics of their state’s RPS and energy efficiency programs with a CGE model called State Tax Analysis Modeling Program, or STAMP (Ackerman et al., 2013). Some state examples are New Mexico, Minnesota and Oregon (Tuerck et al., 2011a, b, c). The details of the STAMP CGE program are proprietary and little is revealed in the reports. A report from an opposing environmentalist think tank, Civil Society Institute, has been published countering these studies (Ackerman et al., 2013). The STAMP results consistently find the RPS standards to be very costly as compared to a baseline of no RPS standards.

Table 2 includes a list of most papers that focus on energy efficiency and RPS. Additional information about models that were considered as a prototype for the NV EP CGE model are included in Appendix A.

**Table 2. Energy Efficiency and RPS Focused CGE Models**

<b>Authors and Year</b>	<b>Region &amp; Focus</b>	<b>Notes</b>
Ackerman et al., 2013	U.S. States and U.S., critique of Beacon Hill Institute studies	Report from environment advocacy group attacking anti-RPS studies
Allan et al., 2007a, Allan et al., 2007b, Hanley et al., 2009, Turner, 2009, Turner and Hanley, 2011	Scotland and U.K., regional CGE models used to study energy efficiency rebound effects	Most versions of the model and simulations find significant rebound effects; rebound effects are empirical question specific to each region
Beghin et al., 2002, Beghin et al., 1996, Roland-Holst, 2008a, b, 2009, Roland-Holst and Kahrl, 2009,	California BEAR regional CGE model used to study effects of energy efficiency and GHG abatement policies, Beghin et al. use a very similar model for ‘top-down’ portion.	Find that energy efficiency and RPS investment creates jobs and GDP growth. In contrast to most studies it finds the higher the RPS standards, the more jobs and GSP.
Tuerck et al., 2011a, b, c,	Beacon Hill Institute use regional CGE tax model to simulate RPS policies (and in one case energy efficiency)	Institutes that hire Beacon Hill appear to be highly partisan. Findings are that RPS is expensive drag on economy.
Böhringer et al., 2013, Bohringer and Rutherford, 2008, 2009, 2010	CGE model of Germany to investigate employment impacts of renewable energy subsidies.	Limited positive employment opportunities depending on funding mechanisms and subsidy rates.
Coffman and Bernstein 2013, Coffman et al., 2012	CGE model of Hawaiian RPS, partial equilibrium model of RPS versus Clean Energy Standards	Clean energy standards that give credit to lower GHG fuels of any type reduce costs of lowering GHG emissions compared to RPS



<b>Authors and Year</b>	<b>Region &amp; Focus</b>	<b>Notes</b>
Davis and Balistreri, 2010	An independent effort to evaluate RPS goals in Colorado with a regional CGE model.	Low levels of RPS are found to reduce leakage and emissions allowance costs but higher levels do not.
Fatai et al.	New Zealand CGE model finds economic impact of energy efficiency improvements.	Wages, GDP, employment are found to increase.
Kuster et al., 2007	CGE Model of EU and interactions of unemployment and renewable energy investments. Model uses skilled and unskilled labor inputs.	Inefficiencies in the energy market increase unemployment for both skilled and unskilled labor over no policy intervention. Emissions do not necessarily decrease.
Morris et al., 2010	MIT EPPA CGE model is used to compare GHG emissions cap and trade policy with and without RPS.	RPS is found to decrease welfare substantially but also decreases carbon allowance prices. Welfare losses are large in the early years of the RPS policy.
Nasseri and Konan, 2012	A regional CGE model is used to investigate Hawaii increasing energy efficiency. Improvements have no cost in the model. State and sector specific energy intensity and GHG emission intensity factors are developed.	Tourism is found to be more energy/GHG emissions intensive than most other sectors and holds the greatest potential for reductions from EE programs.
Pizer et al., 2003, 2006	U.S. CGE model used to compare RPS and GHG taxes, uses partial equilibrium models to calibrate CGE and equate RPS to taxes and subsidies	They find that RPS is a very expensive method to reduce GHG emissions because there is no incentive to move from coal to gas.
Rausch and Mowers, 2012	U.S. multi-regional CGE model is used to compare the efficiency of RPS and GHG emissions tax policy.	RPS is found to be inefficient and regressive.

## Conclusion

Electricity is a crucial element of any modern economy. In addition, electricity markets suffer from many types of market failures. Because of this, governments have intervened with many types of energy policies from monopoly regulation and oversight to creating cap and trade markets for air pollutants to setting of renewable portfolio standards and energy efficiency resource standards. In order to find the most efficient and effective government interventions, economists have created a wide variety of models used to investigate the anticipated economic impacts, as well as costs and benefits of these policy interventions. One very successful model in the realm of energy economic models is the computable general equilibrium model. The pervasiveness of energy in the economy and the complex interaction that can come about from a change in energy prices, taxes or availability make the computable general equilibrium model a natural match for investigating the big picture outcomes of policy interventions. Of relevance to economic development goals, CGE models can forecast economy-wide net job impacts from energy efficiency and renewable energy policy decisions and represent an improvement over traditional models which have typically focused only on gross job impacts.

Most energy CGE models of the current era are used to model GHG emissions and the policies proposed to regulate them, often the cap and trade of emissions or the taxation of emissions. However, a smaller number of models have been used to investigate the energy efficiency investment rebound effect and renewable portfolio standards that are a popular policy intervention in the electricity sector in the United States. Most energy efficiency models have found a rebound effect so that an increase in energy efficiency of a given percentage results in a smaller percentage decrease in emissions, or even sometimes, an increase in emissions. Renewable portfolio standards have been found to be expensive and not effective in decreasing emissions as compared to the cap and trade or taxation policies.

CGE models we have found have not been used to model how RPS may address market failures causing an underinvestment in renewable technologies given security risks or competition amongst states to create renewable energy clusters.

## Methods for Finishing a NV EP CGE Model

Because a search of the literature did not produce any prototypes that are either very close to what is needed for the Nevada model, or well documented enough to easily follow, building the model falls into the category of original research and may take extra time. Options include:

### 1. The Minimal Approach – ‘top-down’ CGE model:

This appears to be the most straightforward approach, with fewer modeling unknowns that could delay obtaining good results. Only the process of translating the data so that cost increases or decreases due to RPS as compared to a base case of no RPS is unknown and there is some description of this process in the Beacon Hill studies.

1. Stay with the existing ‘top-down’ Holland WSU model.
2. If possible, convert existing model to MPSGE, which would allow for easier nesting of CES production functions as well as flexibility in specifying substitutability between any inputs.
3. Change the model into a multi-period model by adding time subscripts, and specifying how the model steps forward to the next time period through changes in investment and exogenously imposed growth patterns for labor, projected fuel prices and so forth.
4. Obtain necessary information about energy efficiency project costs and predicted electricity savings.
5. Obtain necessary information to specify different RPS scenarios as an exogenous price increase in the electricity sector, following Beacon Hill Institute method but with the idea of creating a sensitivity analysis or other tests of the Beacon Hill method.
6. Run scenarios with varying amounts of RPS and energy efficiency.
7. Report results.

#### *Resources needed:*

3 months Post-Doc, energy professor or graduate student already knowledgeable about CGE models.

2 month graduate student labor to help collect data on energy efficiency, energy savings potential, renewable and conventional energy generation costs and forecasted costs, fuel price forecasts and so forth.

**Bae, Suho.** 2009. “The response of manufacturing businesses to geographical differences in energy prices.” *Annals of Regional Science*. 43, pp.453-472.

## **2. The Higher Risk Approach – incorporate simple ‘bottom-up’ linear programming model for electricity sector:**

Instead of following a method which uses only a top-down CGE model, a more detailed bottom-up linear or quadratic programming model of the electricity sector could be incorporated into the model. Alternatively, a few different generation technologies with associated constraints could possibly be built directly into the CGE model. This would mean substituting the following steps for step 5 above.

1. Write a linear programming model with generation costs of several different technologies and future technologies, RPS requirement constraints, exogenous input prices and electricity demand, minimum and maximum production constraints and so forth, following a model like Coffman et al. 2012. Or try to incorporate these constraints and technology choices directly into the CGE model, skipping step 2.
2. Following Bohringer and Rutherford’s methodology, find a way to iterate between the top down CGE model and the LP or quadratic programming model until convergence is achieved.
3. Data collection and organization would be somewhat different but similar in effort.

This method might take a similar amount of time as above, but is at “higher risk” for problems developing and might take much longer, perhaps double or triple the post-doc, energy professor or graduate student’s time. If it would be possible to hire an expert consultant knowledgeable about RPS CGE models, this might be helpful.

## **3. The “Ultimate Model” Approach:**

From the above approaches a basic no-frills model would result. There are many desirable features to incorporate into the model that present some added risk of using more labor hours and taking more time. Other important modeling considerations that could be built into the ultimate model, however, include:

1. Tracking of greenhouse gas emissions.
2. Monopoly specification of the electricity sector.
3. Adding a special retrofitting investment sector for energy efficiency.
4. Making sure that the exporting and importing of renewable and conventional electricity is realistically specified.
5. If possible, add a capital supply function which allows capital to migrate in or out of the region in response to electricity prices (use Bae, 2009).
6. Specification of labor mobility into and out of the state of Nevada such that it responds to electricity prices and/or wage differentials with other regions.
7. Incorporating a technology-by-technology or even plant-by-plant detailed LP model with transmission and other technical detail built-in.

*Resources needed for the “ultimate model”:*

Add 6 more months of time for the post-doc, energy professor, or graduate student who already is familiar with CGE models to refine the very basic model envisioned for the high and low risk efforts above.

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## **Appendix A: Possible Nevada Energy Policy Model Prototypes**

### **Contenders for RPS Electricity Model:**

#### **1. BEAR – Job and economic impacts of CA energy efficiency and RPS policy**

**Pluses:** Regional energy RPS CGE model with scenarios that we would like to run (energy efficiency, RPS investments and economic impacts thereof). Dynamic model with putty/semi-putty specification of capital vintages. This means that newer capital vintages can more easily be substituted for other factors of production such as labor than older vintages of capital.

**Disadvantages:** Cannot find any peer-reviewed publication of the energy policy aspects of this model. No documentation of integration of ‘bottom-up’ electricity sector into standard energy CGE model seems to be available – this is the most difficult aspect of the model to deal with. Nevada economy different than, lots smaller than, California.

**References:** (Beghin et al., 2002, Beghin et al., 1996, Roland-Holst, 2008a, b, 2009, Roland-Holst and Kahrl, 2009)

#### **2. Coffman and Hawaii RPS CGE model.**

**Pluses:** Sub-national model of RPS and energy efficiency. Coffman has submitted a paper about the model for publication. A bottom-up model paper is already published. She worked on an energy CGE model for her PhD dissertation. Her work uses the Bohringer/Rutherford type approach for integrating a bottom-up and top-down model.

Iman Nasseri’s unpublished work cited below is an energy efficiency CGE model. It is very simple but the contribution may be data development of the Hawaii specific energy intensity by industry. Konan was also Coffman’s advisor.

**Minuses:** The island economy is quite different to model than ours especially for electricity since imports and exports of electricity would be non-existent. The work on the Hawaii models has been very time intensive and detailed. It took two years with a operations research specialist in electricity to get the detailed bottom-up portion of the model done. There may be reasons that we could have a decent model without so much effort.

**References:** (Coffman, 2007, Coffman and Bernstein, 2013, Coffman et al., 2012, Nasseri and Konan, 2012)

### 3. Davis and Balistreri Colorado RPS CGE model.

**Pluses:** State model that finds economic impacts of RPS. Colorado might be similar to Nevada. Dynamic. Uses MPSGE and IMPLAN data.

**Minuses:** I cannot find any peer-reviewed publication of this model and have found insufficient documentation. Seems to use Rutherford/MIT standard set-up with NEMS forecasts – unclear how RPS are incorporated.

**References:** (*Davis and Balistreri, 2010*)

### 4. Bohringer et al. 2013 Rutherford lineage

**Pluses:** The Bohringer-Rutherford approach is used by most of the existing RPS models. They have extensively documented the general approach and have in one case applied it to RPS energy modeling. There is a simple educational model with GAMS code available online as well as code for a top-down bottom-up integration:

<http://www.mpsge.org/rps/>

[http://www.mpsge.org/td\\_bu.pdf](http://www.mpsge.org/td_bu.pdf)

<http://www.mpsge.org/mainpage/mpsge.htm>

Closest paper to our problem is: **Böhringer et al., 2013**. "Are Green Hopes Too Rosy? Employment and Welfare Impacts of Renewable Energy Promotion." *Energy Economics*, 36, pp. 277-85. This is a single region, static model of Germany with special emphasis on how RPS interacts with the job market. The model is only briefly documented in this paper however. They reference Bohringer and Rutherford 2010 for the top down CGE model portion and the incorporation of the bottom-up model is described in Bohringer and Rutherford 2008.

**Minuses:** The modeling approach seems to be set-up for a very detailed electricity sector. It may be too detailed for our project. Need to learn the MPSGE programming language – many of the energy models are written in MPSGE since it simplifies using multiple nests in the production function (it is part of GAMS so it just requires learning the particulars of the language, no purchase of software necessary). Experienced CGE modelers have had trouble implementing the approach.

**References:** (*Bohringer et al., 2009, Böhringer et al., 2013, Bohringer and Rutherford, 2008, 2010, Bohringer and Rutherford, 2009, Rutherford and Paltsev, 2000*)

## 5. Sue Wing model

**Pluses:** Ian Sue Wing has written very clearly about how to set up the data and model to synthesize the bottom-up and top-down portions of a CGE model for electric power technologies in peer-reviewed publications and books. His technique is very much related to the Bohringer and Rutherford approach, but seems to be simplified and more approachable.

**Minuses:** He does not have a model published specifically about RPS. His work describes national models, not regional.

**References:** (Ian Sue Wing, 2009, 2008a, 2006, 2008b)

## 6. STAMP model.

**Pluses:** This appears to be an ordinary ‘top-down’ CGE model. They have taken the output of the projected prices and sales for different types of energy from existing models at the DOE EIA, and boiled these down into a supposedly equivalent tax increase, or price increase on the electricity sector. This would potentially be easy to do: we could use existing Holland model, specify a tax increase in the electricity sector along with increased investment. The most difficult part is the data analysis to find the “tax” increase from RPS.

**Minuses:** It could be inconsistent to use the outputs of another model to find the ‘tax increase’. It doesn’t really use the capacities of a CGE model, or the connection between investment in renewable and their prices. There do not appear to be any peer-reviewed publications of this model used for RPS analysis. It is proprietary so full documentation is not available. It is clearly part of an ideological campaign. There are a series of these done for many states including Nevada by conservative organizations with a clear anti-RPS bias.

**References:** (David G. Tuerck et al., 2011a, b, c)

## 7. Rausch and Mowers, MIT US Regional Energy Policy Model and ReEDS

**Pluses:** Rausch and Mowers incorporate the ultimate “bottom-up” model (NREL’S ReEDS) into a multi-regional US CGE model (MIT US Regional Energy Policy model). They claim to have come up with a way to have “endogenously determined electricity demand, fuel prices, and goods and factor prices.” It is supposed to be a fully integrated top-down bottom up model. Rand M analyze RPS at national level (multi-regional). They discuss how to incorporate probably the ultimate “bottom up “ model, also using the

Rutherford and Bohringer paper. It is recursive dynamic. They have a literature review with papers that are partial equilibrium not CGE models, but which might provide insight to modeling RPS. Also they have a reference for a paper that tells specifically how they manage to get IMPLAN and state level EIA energy data to mesh. List of data may be of interest because they seem to have been able to do this very detailed electricity sector with publicly available datasources and the NREL ReEDS model.

**Minuses:** It seems very complex. The only way this could be useful as a prototype would be if they gave us the full model or could report results from a special run for Nevada policies. No peer-reviewed publication appears to be available.

**References: (Sebastian Rausch and Matthew Mowers, 2012) See also their lit review on pp. 4-5 and several additional references that document the pieces of their model.**

## **8. Pizer et al. Resources for the Future: HAIKU Results and CGE**

**Pluses:** Pizer et al. at Resources for the Future used a CGE model to evaluate state renewable portfolio standards, CAFÉ standards for vehicles as compared to a GHG tax or cap and trade policy. They find that RPS and CAFÉ at the state level or nationally costs ten times more than the GHG tax to reduce emissions by five percent. This is because RPS does not reward switching from coal to natural gas, one of the most cost effective methods of reducing GHG emissions.

One possibility with this model is that it might have some existing results for the mountain region that could be of interest. This is because they are using some models that have 17 regions. It seems to be more straightforward and possibly along the lines of the STAMP model in that it leans more heavily on the outputs from the national electricity sector models for electrical energy production forecasts. They discuss the technique for RPS standards modeling as a “shadow tax approach”. They use outputs of the detailed ‘bottom-up’ models like HAIKU to calibrate their CGE model. Then Pizer et al. change the incentives for electricity producers by taxing fossil fuels and subsidizing output so that no net revenue is generated. This changes relative prices, which produces an effect like, “Tax on fuel use, subsidy on capital”. These are estimated by using the partial equilibrium model results. There is a peer-reviewed publication of this modeling effort.

**Minuses:** The focus is on the cheapest way to achieve GHG reductions. It is a national model and deals with energy in general, not solely electricity. It is possibly easier than Rutherford type approach but still looks complicated. Complexities incorporated by using existing NEMS and HAIKU energy models.

**References: (William Pizer et al., 2006, 2003) more technical documentation available in Newell and Pizer 2003.**

## 9. Kuster et al. from Germany: GTAP-E Variant

**Pluses:** This paper focuses on employment impacts of renewable portfolio standards as well as other energy policies. It uses GTAP-E (it is a world model that is recursive dynamic – GTAP is the Global Trade Analysis Project at Purdue) and adapts it to add a labor specification with two skill types and labor markets that don't clear.

**Minuses:** There is no peer-reviewed publication. Some good documentation is in the paper but is not complete. Since research took place in Germany, some of the documentation is in German. This is not a single region model.

**References:** *(Robert Kuster et al., 2007) more documentation in Zurn et al. 2006 and a 2005 paper that is in German.*

## 10. Morris et al. using MIT EPPA

**Pluses:** CGE model used to examine RPS policy. The need for back-up generation capacity for renewables is included, although since NV renewables are mostly hydro and geothermal, this problem will be small for many years in our case. Uses MIT EPPA model as a base. This has a lot of documentation, and version 4 is available for download at <http://globalchange.mit.edu/research/IGSM/eppadl>. Seeing how the code for RPS is written might be of interest. Discusses changes needed to incorporate electricity sector detail. 2009 data on capital and fuel costs might be recent enough that we could use it. Gives EIA data reference for this and Lazard as reference for conventional electricity production. It appears to be a top down model that includes various electricity technologies in nests, but documentation in this paper is limited.

**Minuses:** EPPA model that they use as base is a recursive dynamic international model – not a good base for us generally and quite complex. No peer reviewed publication could be located.

**References:** *(Morris et al., 2010)*

## 11. Tuladhar et al. (2009) model. Charles River Associates model with NEEM.

**Pluses:** This is a peer-reviewed publication. It seems to be set up with state and regional information. Results could potentially be meaningful for Nevada. Could the model be modified to find Nevada specific results? The MRN (top-down portion) and NEEM (detailed bottom up electricity sector) models have been 15 and 20 years in development. Rutherford designed MRN. Ira Shavel developed the NEEM model. The

model is based on publicly available data from IMPLAN and EIA. IMPLAN data must be corrected to align with EIA state level data. CRA works with IMPLAN to create these energy accounts.

**Minuses:** Very little documentation is available in this paper and the model is for the U.S. not for a region. It is again a very complex model. They use the Rutherford-Bohringer approach to integrating the top down and bottom up model, so apparently not very different from alternatives listed above.

**References:** *(Sugandha D. Tuladhar et al., 2009) with further documentation in Smith (2007), congressional testimony. The short piece I was able to download did not seem to have documentation.*

## **12. Karen Turner and Nick Hanley: Scottish Energy Efficiency Models**

**Pluses:** This suite of models developed over many years are top-down regional CGE models used to model the energy efficiency and the rebound effect. The rebound effect where there is both an income and substitution effect in response to energy efficiency lowering effective prices of electricity, is the most interesting aspect of energy efficiency to model.

One specialty for this group would be multi-regional models that focus on trade effects of resource or pollution flows. Other than the BEAR model, none of the CGE models listed above try to model energy efficiency. Energy efficiency models tend to look at rebound effects and tend to be top-down CGE models. A good research area may be a model that shows interaction effects between the rebound effect of energy efficiency programs and RPS. There may be interesting implications for how this influences optimal timing for introducing new generating capacity or retiring old capacity.

**Minuses:** These models do not incorporate electric sector detail that can handle RPS scenarios. The group is in England, meaning it is more difficult to work with them. There are other energy efficiency CGE models available.

**References:** *(Grant Allan et al., 2007a, Grant Allan et al., 2007b, Nick Hanley et al., 2009, Karen Turner, 2009, Karen Turner and Nick Hanley, 2011)*

## **13. Holland WSU model.**

**Pluses:** This model is based on the CGE model and data I am most familiar with and examines energy issues. I have built a simple starter energy model that is similar that can model energy efficiency.

**Minuses:** It is focused only on a price increase in energy. There is no elaboration of electricity sector, energy efficiency or RPS. There are many energy CGE models since energy and CGE models naturally suit each other.

**References:** *(David Holland et al., 2007)*



## Data Needs for Nevada Energy Policy CGE Model

9/16/2013

- 1. Basic Data: Total quantity demanded and supplied, in dollars and in megawatt hours, exports and imports, electricity producers, commodities produced by electricity suppliers, types of fuel used.**

Data needs for the Nevada Energy Policy CGE model (NVEPCGE) depend on whether a more detailed model, a minimal model or something in-between is built. Data quality and quantity can be varied depending on the type of analysis. An example of a model with less detail would be the existing static model which uses default IMPLAN data for Nevada for 2011 to model changes in energy efficiency. An example of a very detailed state electricity model is given in Coffman et al. 2012 for the state of Hawaii. There is a relatively detailed discussion of the types of data necessary as well as the sources of this data in this paper (Makena Coffman et al., 2012).

The 2011 Nevada IMPLAN data is a large part of the default data for the model. According to other energy CGE modelers (see, for example, p. 6 (Sebastian Rausch and Matthew Mowers, 2012) the IMPLAN data does not well characterize the electricity sector or energy markets in general and should be adjusted to better fit with the information available in State Energy Data System from the Energy Information Administration. Verification of and guidance in using data from NV Energy and NV Public Utility Commission could help ensure data accurately reflects the NV electricity sector.

We have compared the 2010 and 2011 versions of IMPLAN for the electricity sector (see Table 9). Even for the basic data, the differences in the two years make it clear that it will be good to get confirmation from other available sources such as the EIA, NV Public Utility Commission or NV Energy, both for the current year of data we are working with (2011) and, ideally, several years of electricity sector data to understand any trends or major changes. EIA data and IRP filings may provide some of the data, but data reliability will be better and can be checked more quickly if contacts within NV Energy or the PUC who are already very familiar with the data are available to answer questions.

One of the most basic things to understand is both the physical quantity of electricity produced in Nevada and its value. IMPLAN values 2011 Nevada electricity generation, transmission and distribution services at \$2.4 billion (see Table 3). According to IMPLAN data, electricity is generated mainly by the electricity sector, but other sectors produce minor amounts of electricity as a 'by-product'. The IMPLAN data mirrors the national average data, and indicates that 97% (by value) of NV electricity is generated, transmitted and/or distributed by the electricity sector, nearly 3% by the gas distribution sector and a tiny fraction, 0.2% by local governments. Value of output includes transmission and distribution values. IMPLAN estimates that about \$308 million of electricity sector services are exported outside of Nevada (see Table 3).

State specific data from the EIA Form 923 says that 31.9 net MWH were generated in 2011 in Nevada and that 0.5% by number of net megawatts of production was generated by the mining sector (Barrick Goldstrike Mines), 0.1% by the federal government (solar facility on Nellis Air Force Base) and 0.2% by the hotel sector (Las Vegas casinos) and another 0.2% by the water utility sector. According to the detailed state data available from the EIA website, 68% of this electricity was generated using natural gas fuel, 17% from coal, 7% from conventional hydroelectric, 7% from geothermal and 1% from solar (see Table 4). According to the IMPLAN data and the EIA data, the cost of generating and delivering the average MWH is about \$75.

Electricity consumption both in dollar value and in MWH purchased is also a part of the basic data necessary for the model. Going back to Table 3, the IMPLAN estimate for the value of electric power generation, transmission and distribution services provided is \$3.6 billion, with about \$2 billion of this, or 56%, used by other industry sectors for inputs to their production and the remainder used by households, government and investment. Of the total \$3.6 billion, \$1.5 billion is imported from outside the state, according to IMPLAN estimates (Table 5).

In Table 6, EIA data shows that residential customers purchased 34% of the total megawatt hours sold in the state of Nevada. Total sales were 33.9 billion megawatt hours.

Additional data giving the share of electricity generation produced by entities other than NV Energy are also needed since the RPS do not apply to these entities. Some information on this was available in the Form 923 EIA data.

**Table 3 NV 2011 IMPLAN Commodity Summary for Commodity 3031, Electric Power Generation, Transmission and Distribution (2011 \$)**

Description	Industry Commodity Production	Net Commodity Supply	Intermediate Commodity Demand	Institutional Commodity Demand	Total Gross Commodity Demand
Electricity, and distribution services	2,405,632,080	2,400,258,789	1,991,878,906	1,600,214,600	3,592,093,506

Source: NV 2011 IMPLAN data, (Minnesota IMPLAN Group, 20012)

Note: Net commodity supply is industry commodity production minus foreign exports. Intermediate commodity demand is demand from other industry sectors while institutional commodity demand is final demand from households, government, investment and for export.

**Table 4 NV 2011 Total Electric Power Industry Power Generation (net MWH)**

Natural Gas	21,841,397	68%
Coal	5,407,304	17%
Hydroelectric Conventional	2,190,583	7%
Geothermal	2,146,119	7%
Solar Thermal and Photovoltaic	291,225	1%
Other	37,817	0%
Petroleum	14,213	0%
Other Gases	7,261	0%
<b>Total</b>	<b>31,935,919</b>	<b>100%</b>

Source: EIA Detailed State Data, Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923) <http://www.eia.gov/electricity/data/state/>

**Table 5 NV 2011 IMPLAN Commodity 3031 Trade (2011 \$)**

Description	Foreign Exports	Domestic Exports	Total Exports	Intermediate Imports	Institutional Imports	Total Imports
Electricity, and distribution services	5,373,260	303,278,564	308,651,825	829,066,589	666,046,753	1,495,113,281

Source: NV 2011 IMPLAN data, (Minnesota IMPLAN Group, 20012)

**Table 6. NV 2011 Retail Sales of Electricity (MWH)**

Residential Sales (Megawatt-hours)	Commercial Sales (Megawatt-hours)	Industrial Sales (Megawatt-hours)	Transportation Sales (Megawatt-hours)	Total Sales (Megawatt-hours)
11,493,279	8,995,162	13,419,961	8,077	33,916,479
33.9%	26.5%	39.6%	0.0%	100.0%

Source: EIA Detailed State Data, Retail Sales of Electricity by State by Sector by Provider (EIA-861), <http://www.eia.gov/electricity/data/state/>

In IMPLAN, industry sales are different than commodity sales. An industry may produce more than one commodity. IMPLAN estimates that sector 31 (electricity sector) output is \$2.4 billion and that it employs 2,841 people (Table 7). According to IMPLAN the electric power

sector produces some natural gas and distribution services and water, sewage treatment and other utility services as well as electricity and distribution services (Table 8).

**Table 7. NV 2011 IMPLAN Description of Electricity Sector 31**

Description	Jobs	Output	Employee Compensation	Proprietor Income	Other Property Type Income	Tax On Production And Imports
Electric power generation, transmission, and distribution	2,841	2,449,470,464	364,831,040	2,971,325	788,448,960	343,268,224

Source: NV 2011 IMPLAN data, (Minnesota IMPLAN Group, 2012)

**Table 8. NV 2011 IMPLAN – Commodities produced by the Electricity Industry Sector 31**

Electricity, and distribution services	95.2%
Natural gas, and distribution services	3.8%
Water, sewage treatment, and other utility services	0.1%

Source: NV 2011 IMPLAN data, (Minnesota IMPLAN Group, 2012)

**Table 9. Comparison of Default Nevada IMPLAN Electricity Sector (31) for 2010 and 2011**

	IMPLAN NV 2010	IMPLAN NV 2011
Total electricity demand for both industry and households and other institutions	\$ 2,800,000,000	\$ 2,450,000,000
Industry purchases in electricity sector	\$ 1,600,000,000	\$ 950,000,000
Industry purchases as a % of total regional sales in electricity sector	58%	39%
RPC: % of electricity supplied by sources within the state	57%	58%
Electricity exports	\$ 135,000,000	\$ 346,100,000

Source: NV 2010 and 2011 IMPLAN data, (Minnesota IMPLAN Group, 2012)

## **2. Cost shares for labor, capital, fuel costs and other intermediate inputs (“recipes”) by type of generation**

A fundamental part of the CGE model concerns how the electricity is made. A default version of the ‘top-down’ recipe for making electricity in Nevada is available in IMPLAN. See Table 8 to see a summarized version of this ‘recipe’ compared to one modified with EIA data on fuel use. The default IMPLAN recipe is heavily influenced by national average inputs to the electricity sector. For example, coal and oil are a bigger share of inputs than EIA data for Nevada indicate. Labor and capital inputs may need modification as well if better data is available.

**Table 10 Summary of electric sector (31) inputs from IMPLAN (2011) and using EIA data**

	<b>IMPLAN</b> (millions of \$)	<b>Modified with EIA for Fuel Inputs</b> (millions of \$)
Coal	98.60	86.00
Electricity	0.02	0.02
Gas	266.44	370.00
Refined Oil	92.09	1.80
Other Goods	492.13	492.13
Labor	364.83	364.83
Capital	791.42	791.42
Net Tax Payments	343.27	343.27
Total cost	2449.47	2449.47

Source: NV 2011 IMPLAN data, (Minnesota IMPLAN Group, 2012), EIA-Form 923)

<http://www.eia.gov/electricity/data/eia923/>

The data in Table 10 gives estimates of total inputs used by the Nevada electricity sector as a whole. In order to model different renewable portfolio standards, inputs for each type of production used to meet these standards is needed, as well as information about the share of total electricity generated by each type of technology. For RPS scenarios in Nevada, we need to know what the recipes are for coal, natural gas, solar, geothermal and hydro generation. A more detailed type of model could include generation recipes for different types of coal, natural gas or solar technologies. Figure 3 gives an example of this type of data from Ian Sue Wing's paper. This is national data for the year 2000 given in terms of cost shares for inputs to electricity generation. It includes estimated inputs for many detailed types of electricity generation plants such as internal combustion engines, gas turbines, steam turbines, solar, geothermal and so forth. As shown in the example, crucial elements are the cost shares for labor, capital and fuel. Also important would be a share for the remaining inputs. The net generation and average costs give total costs by generation technology, which can be used with the cost shares to find total dollar inputs. These two columns also allow calculation of the share of MWH produced by each type of technology as well as the share of total costs of generation.

**Table 11. Example using EIA and IMPLAN data to estimate inputs for NV technologies\*.**

Input/ Technology	Coal	Oil	Gas	Hydro	Geo- thermal	Total Gen- eration	Total Trans- mission	Total Electricity Sector
Coal	86.0000					86.00	0.00	86.00
Electricity	0.0031	0.0000	0.0108	0.0027	0.0025	0.02	0.00	0.02
Gas			370.0000			370.00	0.00	370.00
Crude Oil		0.0000				0.00	0.00	0.00
Refined Oil		1.8000				1.80	0.00	1.80
Other Goods	78.7410	0.0005	270.6722	68.8984	63.9771	482.29	9.84	492.13
Labor	58.3730	0.0004	200.6571	51.0763	47.4280	357.53	7.30	364.83
Capital	126.6272	0.0008	435.2812	110.7988	102.8846	775.59	15.83	791.42
Net Tax Payments	54.9229	0.0003	188.7975	48.0576	44.6249	336.40	6.87	343.27
<b>Total cost</b>	<b>404.6673</b>	<b>1.8020</b>	<b>1465.4188</b>	<b>278.8339</b>	<b>258.9172</b>	<b>2409.64</b>	<b>39.83</b>	<b>2449.47</b>

\*Solar is currently so small it is not included in this example, but would eventually be necessary since solar renewables are a key part of the RPS for Nevada.

**Figure 3. Sue Wing cost shares example (Ian Sue Wing, 2006).**

Technology	Cost shares		Generation characteristics (year 2000)					
	Labor	Capital	Coal	Oil	Nat. gas	Nat. res.	Net gen. (10 <sup>12</sup> kWh)	Avg. cost (cents/kWh)
<i>Coal</i>								
ST <sup>a</sup>	0.15	0.54	0.32	—	—	—	1.698	2.7
CC <sup>b</sup>	0.16	0.58	0.26	—	—	—	0.002	2.7
<i>Oil</i>								
IC <sup>c</sup>	0.09	0.11	—	0.80	—	—	0.001	4.0
GT <sup>d</sup>	0.08	0.09	—	0.83	—	—	0.005	4.0
ST <sup>a</sup>	0.09	0.11	—	0.80	—	—	0.062	4.3
CT <sup>e</sup>	0.09	0.11	—	0.81	—	—	0.001	4.0
CC <sup>b</sup>	0.07	0.15	—	0.78	—	—	1.5 × 10 <sup>-4</sup>	3.0
<i>Gas</i>								
IC <sup>c</sup>	0.07	0.12	—	—	0.80	—	5.1 × 10 <sup>-4</sup>	3.5
GT <sup>d</sup>	0.07	0.10	—	—	0.83	—	0.022	3.4
ST <sup>a</sup>	0.08	0.13	—	—	0.79	—	0.208	2.0
CT <sup>e</sup>	0.08	0.14	—	—	0.77	—	0.051	3.2
CC <sup>b</sup>	0.08	0.23	—	—	0.69	—	0.007	2.9
<i>Nuclear and renewables</i>								
Hydro	0.24	0.56	—	—	—	0.19	0.706	1.1
Nuclear	0.13	0.61	—	—	—	0.27	0.248	4.3
Wind	0.17	0.63	—	—	—	0.20	7.8 × 10 <sup>-6</sup>	3.0
Solar	0.07	0.73	—	—	—	0.20	2.5 × 10 <sup>-7</sup>	10.1
Biomass	0.18	0.61	—	—	—	0.21	0.001	3.6
Geothermal	0.24	0.56	—	—	—	0.20	6.5 × 10 <sup>-4</sup>	2.4
<i>All technologies</i>								
Total							3.01	2.5

Source: Sue Wing (forthcoming).  
<sup>a</sup>Internal combustion engines

Another simple example, this time using Nevada specific data, is given in Table 11. This table uses total electricity sector inputs from EIA and IMPLAN, and total generation by

technology as given in EIA data with the assumption that each technologies' total cost share is approximately the same as its' share of total generation.<sup>2</sup> This type of approach could be taken if no other data is available to refine these estimates. However, the assumption used implies similar costs for different types of generation as a base calibration. This is not ideal since the differences in costs are at the heart of the issues we are investigating.

More data about fuel inputs and their costs is available from the EIA Form 923 data and other detailed state data. It is possible that old Integrated Resource Planning documents have this type of information as well. Additional information about different generation technologies' inputs may be available from NREL JEDI models available at [http://www.nrel.gov/analysis/jedi/about\\_jedi.html](http://www.nrel.gov/analysis/jedi/about_jedi.html) or other sources.

Two other aspects of production function recipes may also be important to the CGE model. These are:

- 1) estimated recipes for future planned generation technologies and
- 2) types of technologies used to generate exported and imported electricity.

The future generation technologies are used when new demand in the model, which is envisioned to be a multi-time period model, grows beyond current generation capacities. Types of technologies used to generate exported and, especially, imported electricity are important because of their interaction with the RPS. In particular, if imports of electricity generated by renewable technologies count towards meeting renewable standards, then data regarding typical and feasible imports is needed for modeling the RPS.

### **3. Costs of energy efficiency retrofits and projected energy savings**

Energy efficiency can be modeled abstractly in the current version of the NV EP CGE. However, to better model the economic and energy impacts of energy savings projects in commercial buildings or in residential buildings, engineering estimates of material and labor

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<sup>2</sup> Credit for the underlying spreadsheet, which uses a simple method to estimate cost shares, go to Ian Sue Wing, 2013, personal communication.

costs and projected energy savings are needed. NV Energy IRP’s describe the projects they are planning. For example, see Section III, demand side summary, pp. 13 to 19 in volume V of the 2013 to 2015 plan (2012). The summary provides all necessary data except for a break-out of costs of the projects into labor and material. Energy efficiency can be modeled without this detail, or a vector of energy efficiency expenditures may be available from other sources. Synapse, Inc. Energy Economics has prepared energy efficiency vectors which may be of use (Elizabeth A. Stanton et al., 2013).

Any additional projects beyond the NV Energy plans need additional research.

**Figure 4. Example of Energy Efficiency Estimated Costs and Projected Savings**

Program	2013 Budget (\$)	2013 Energy Savings (KWh)	2013 Peak Year KW Impacts	2013 Rank Year (KW)	Life (Years)	TRC B/C Ratio	Lifetime Energy Savings (KWh) PortfolioPro
Commercial Incentives	\$9,700,000	64,000,000	8,831	2	13.1	1.83	2,280,087,750
Residential High Efficiency Air Conditioning	\$7,500,000	16,000,000	5,928	3	17.4	2.16	944,380,025
Residential Energy Efficient Lighting	\$1,300,000	11,300,000	1,147	5	9.0	1.35	265,531,776
Energy Efficient Pools and Spas	\$1,500,000	8,250,000	1,184	4	10.0	1.29	208,773,881
Demand Response	\$17,350,000	11,170,000	223,000	1	10.0	1.66	244,653,188
Second Refrigerator Collection and Recycling	\$1,200,000	6,200,000	910	6	8.0	1.42	126,929,500
Energy Smart Schools	\$1,300,000	6,000,000	907	7	9.6	1.75	284,702,760
Consumer Electronics and Plug Loads	\$1,000,000	4,500,000	602	8	10.0	1.42	37,033,268
Low Income Weatherization	\$500,000	500,000	171	10	17.5	1.04	27,309,522
Advanced Building Techniques	\$500,000	400,000	239	9	N/A	N/A	0
Non-Profit Agency Grants	\$100,000	240,000	33	11	12.0	1.85	8,893,500
Residential Solar Thermal Water Heating	\$250,000	180,000	15	12	20.0	0.31	11,250,000
Energy Plus New Homes	\$0	0	0	N/A	17.0	0.00	0
Energy Efficiency Measures Financing	\$0	0	0	N/A	N/A	N/A	0
Market and Technology Trials	\$400,000	0	0	N/A	N/A	N/A	0
Energy Education and Consultation	\$400,000	0	0	N/A	N/A	N/A	0

Source: Nevada Energy Integrated Resource Plan for 2013 to 2015, Volume 5.

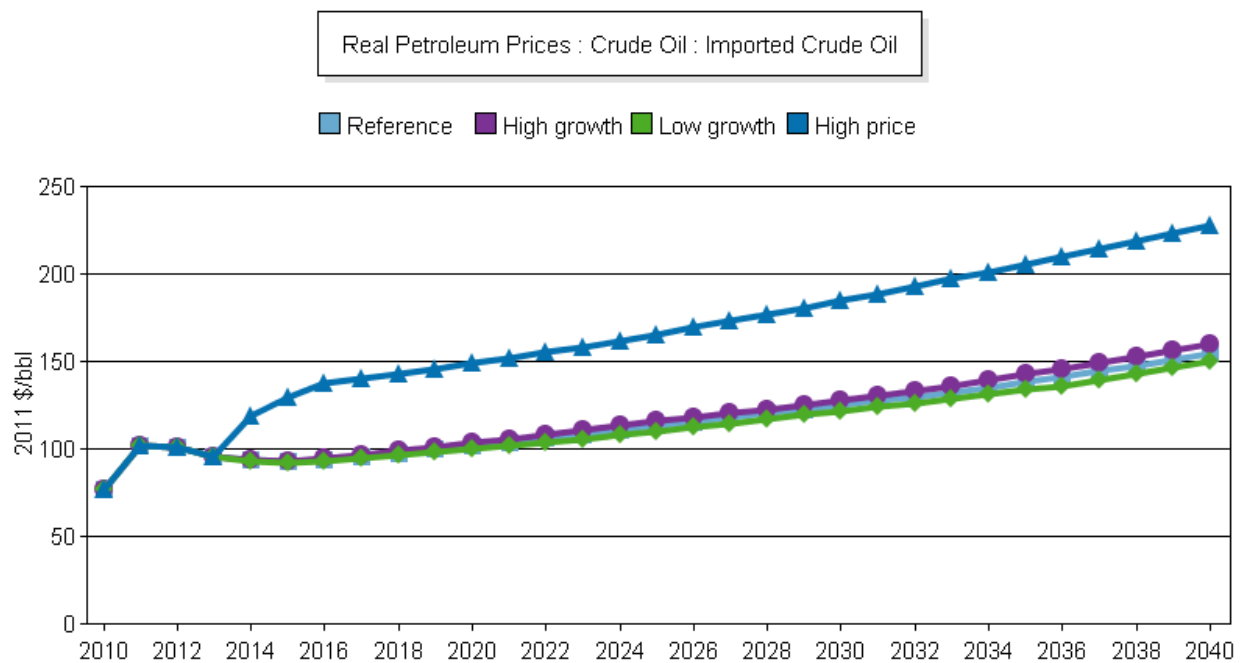
#### 4. Fuel prices.

The price of coal, natural gas and oil are very important in modeling electricity generation. For a multi-period CGE model price forecasts are likely necessary. Nevada is a small state, and does not produce large amounts of any of these fuels. Thus it has little influence on



most fuel prices. These prices are exogenous to the model and usually must be supplied from some other source for regional multi-year models. Many energy models use the fuel cost forecasts from EIA. The EIA produces low growth, high growth, high oil prices and reference fuel price forecasts which are readily available on the website as a part of the Annual Energy Outlook for petroleum products, natural gas and coal.<sup>3</sup> Mountain region forecasts are also available.

**Figure 5. Example of EIA Fuel Price Forecasts: Imported Crude Oil Prices per Barrel (2011 \$), 2010 to 2040.**



**5. Other useful data**

**a. Units of fuel and greenhouse gas emissions**

<sup>3</sup> For example, Annual Energy Outlook 2013, Petroleum Product Prices, High Economic Growth series: <http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2013&subject=0-AEO2013&table=12-AEO2013&region=0-0&cases=highmacro-d110912a>

To track fuel use as well as greenhouse gas emissions, data that gives physical quantities of energy inputs (i.e. tons of coal) per MWH of electricity generated and GHG output per unit of fuel is needed. The EIA Form 923 gives detailed information about Nevada electricity generation, fuel use and greenhouse gas emissions.

**b. Electrical energy intensive businesses in Nevada, sectors using the largest quantity of electricity, institutional electricity demand**

Which industry sectors care most about prices and efficiency? Sectors that are especially important can be left disaggregated in the CGE model for greater detail and focus. It would be good to know both existing and possible future sectors that are especially energy intensive. Similarly, it would be important to confirm which industry sectors use the largest amount of electricity. If differential impacts by household income are expected, confirmation of electricity demand by income level would be necessary. Tables 12, 13 and 14 contain the default IMPLAN data available in the NV 2011 model.

**Table 12. Nevada's Most Energy Intensive Sectors from Default IMPLAN Data**

<b>IMPLAN Sector</b>	<b>Electricity purchases as % of total outlay</b>	<b>Industry Rank by Value of Output</b>
Alumina refining and primary aluminum production	16%	318
Industrial gas manufacturing	15%	230
Alkalies and chlorine manufacturing	14%	135
Cement manufacturing	7%	219
All other basic inorganic chemical manufacturing	6%	141
Bowling centers	4%	307
Mineral wool manufacturing	4%	357
Private junior colleges, colleges, universities, and professional schools	4%	123
Other pressed and blown glass and glassware manufacturing	4%	337
Lime and gypsum product manufacturing	4%	98
Other accommodations	3%	183
Ground or treated mineral and earth manufacturing	3%	160
Ferrous metal foundries	3%	170
Mining copper, nickel, lead, and zinc	3%	83
Reconstituted wood product manufacturing	3%	234
Mining and quarrying other nonmetallic minerals	3%	155
Other Federal Government enterprises	3%	107
All other crop farming	3%	77
Hotels and motels, including casino hotels	3%	1
Fitness and recreational sports centers	3%	144
Mining and quarrying sand, gravel, clay, and ceramic and refractory minerals	3%	165
Museums, historical sites, zoos, and parks	3%	194
Primary smelting and refining of nonferrous metal (except copper and aluminum)	3%	176
Mining gold, silver, and other metal ore	3%	6
Plastics bottle manufacturing	3%	188

Source: NV 2010 IMPLAN

**Table 13. Nevada's Largest Purchaser's of Electricity from Default IMPLAN Data**

IMPLAN Sector	Regional Electricity Purchases 2011	% Total Electricity Sales	Industry Rank by Value of Output
Hotels and motels, including casino hotels	\$487,579,500	17.7%	1
Real estate establishments	\$169,724,900	7.1%	3
Food services and drinking places	\$92,099,930	3.8%	4
Mining gold, silver, and other metal ore	\$90,684,130	3.8%	6
Amusement parks, arcades, and gambling industries	\$51,744,680	2.2%	10
Private hospitals	\$24,834,530	1.0%	13
Wholesale trade businesses	\$16,105,800	0.7%	7
Management of companies and enterprises	\$15,696,640	0.7%	11
Retail Stores - Clothing and clothing accessories	\$14,406,390	0.6%	27
Mining copper, nickel, lead, and zinc	\$13,076,050	0.5%	215
<b>Total for top ten</b>	<b>\$793,721,650</b>	<b>33.0%</b>	-

Source: NV 2011 IMPLAN

**Table 14 NV 2011 institution demands for electricity (IMPLAN default)**

	Gross Demand	Regional Demand
Households LT10k	\$58,919,150	\$24,523,530
Households 10-15k	\$48,975,020	\$20,384,550
Households 15-25k	\$129,506,600	\$53,903,690
Households 25-35k	\$166,698,700	\$69,383,900
Households 35-50k	\$228,656,900	\$95,172,340
Households 50-75k	\$332,682,700	\$138,470,300
Households 75-100k	\$203,145,400	\$84,553,890
Households 100-150k	\$175,816,200	\$73,178,800
Households 150k+	\$150,479,100	\$62,632,930
Federal Government NonDefense	\$1,581,715	\$658,347
Federal Government Defense	\$20,460,370	\$8,516,084
Federal Government Investment	\$0	\$0
State/Local Govt NonEducation	\$67,234,180	\$27,984,440
State/Local Govt Education	\$16,058,570	\$6,683,953
State/Local Govt Investment	\$0	\$0
Capital	\$0	\$0
Inventory Additions/Deletions	\$0	\$0
Foreign Exports	\$5,373,261	\$5,373,261
Domestic Exports	\$303,279,100	\$303,279,100
<b>Total Institution Demand</b>	<b>\$1,908,866,966</b>	<b>\$974,699,115</b>

Source: NV 2011 IMPLAN