Energy Demand Modeling

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Outline

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- Southern Regional Economic Assessment of Climate Policy Options and Review of Economic Studies of Climate Policy

Modeling Introduction

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- Energy Demand Model Introduction
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Introduction

Southern Regional Economic Assessment of Climate Policy Options and Review of Economic Studies of Climate Policy

White Paper Report

Prepared by the Center for Climate Strategies
for the Southern Governors' Association

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Options

Table 2-1. **Options Ranked in Descending Order of Cost-Effectiveness**

Sector	Climate Mitigation Actions	Estimated 2020 Annual GHG Reduction Potential (MMtCO2e)	Estimated Cost or Cost Savings per ton GHG Removed ($)
TLU-1	Anti-Idling Technologies and Practices	13.13	-$83.51
TLU-2	Vehicle Purchase Incentives, including rebates	59.04	-$70.85
RCI-3	Appliance standards	26.32	-$44.29
RCI-1	Demand Side Management Programs	201.94	-$40.33
RCI-2	High Performance Buildings (private and public sector)	108.33	-$36.05
TLU-3	Mode Shift from Truck to Rail	13.71	-$35.52
RCI-4	Building Codes	93.83	-$18.00
AFW-1	Soil Carbon Management	9.24	-$12.76
AFW-2	Nutrient Management	3.25	-$10.10
AFW-4	MSW Landfill Gas Management	20.81	-$0.42
TLU-5	Smart Growth/Land Use	33.02	$0.00
RCI-5	Combined heat and power	90.99	$1.61
ES-4	Coal Plant Efficiency Improvements and Repowering	80.04	$10.72

Options 2

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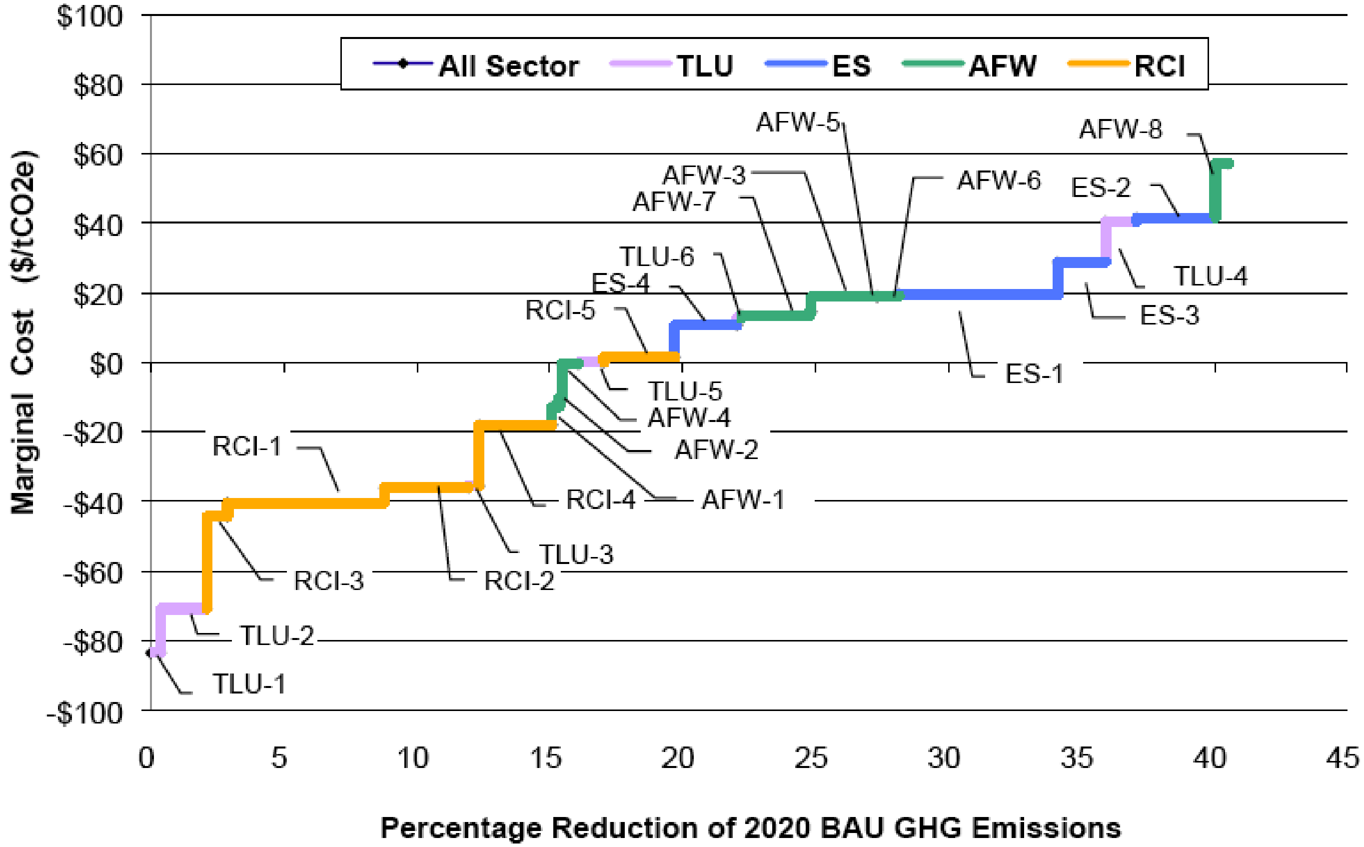
RCI-5	Combined heat and power	90.99	$1.61
ES-4	Coal Plant Efficiency Improvements and Repowering	80.04	$10.72
TLU-6	Transit	5.54	$12.73
AFW-7	Reforestation/Afforestation	87.89	$13.60
AFW-3	Livestock Manure - Anaerobic Digestion and Methane Utilization	2.53	$14.63
AFW-5	Enhanced Recycling of Municipal Solid Waste	84.03	$18.84
AFW-6	Forest Retention	28.22	$19.11
ES-1	Renewable Portfolio Standard	203.93	$19.62
ES-3	CCSR	61.45	$28.84
TLU-4	Renewable Fuel Standard (biofuels goals)	40.28	$40.51
ES-2	Nuclear	100.94	$41.55
AFW-8	Urban Forestry	16.75	$57.20

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; TLU = transportation and land use; AFW = agriculture, forestry, and waste management; RCI = residential, commercial, and industrial; ES = energy supply

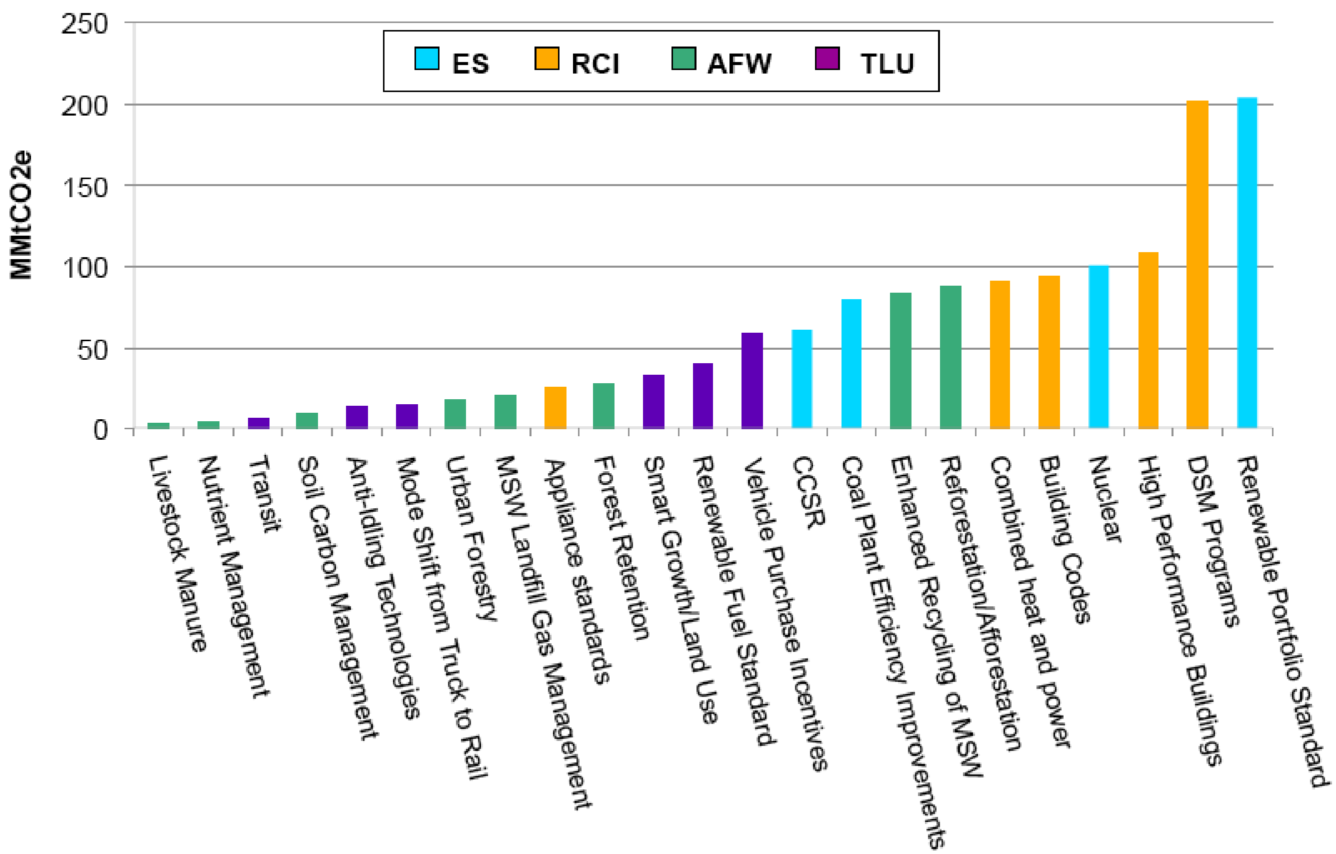
Cost Curve

Figure Ex-4. **SGA region economy-wide step-wise marginal cost curve, 2020.**



Reduction Potential

Figure 2-1. **Super options' regional GHG reduction potential, from smallest to largest.**



Modeling Introduction

- The goal is to simulate Annual Energy Demand.
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- Since one form of energy can be substituted for another,
- The model will consider all forms of energy:
- Solar Thermal, Solar Electric Passive Solar, Geothermal, Wind, Coal, Natural Gas, Oil, Nuclear,Hydro, etc.
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- Another model is required to simulate minute-by-minute Electricity Demand

Modeling Introduction 2

- 1. Energy is an intermediate good. It is consumed in machines that provide energy services. Examples of Energy services: heating, cooling, light, motors, transportation, and electronics.
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- 2. The machines that provide energy services last for years.
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- 3. Often, there are many alternatives when you buy a machine that provides energy services. Hummer versus Prius.
- Large house in suburbs versus small house in city.
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- 4. After purchase, the options are usually limited.

Modeling Introduction 3

- 5. Energy Efficiency versus Energy Conservation.
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- Energy efficiency is providing the same energy service using less energy.
- Geothermal heat pump versus gas furnace and electric air conditioner.
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- Energy Conservation is reducing consumption of energy service.
- Turn off lights. Raise temperature in summer and lower temperature in winter.
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Energy Demand Models

- Econometric Models
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- Engineering Process Models
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- Engineering-Economic Models

Econometric Models

- Time-series data. Choose function with parameters.
- Find parameters that provide best fit and use to estimate future.
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Engineering Process Models

- Define inputs and outputs of a collection of process options.
- Choose least cost options.
- Problem: fixed coefficients. Future process options are not known.
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Engineering-Economic Models

- Hybrid. Economic Theory of Production and Engineering Knowledge.
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- Investment Module, Energy Share Module, Efficiency Module, and Output Module.
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Model Objective and Scope.

- Discuss Model Objective and Scope for the IRP.

- We want a model to create scenarios for the TVA IRP.
- We want to know electricity demand in the TVA service area for a long time period (30 to 50 years).

- The model needs to consider all energy services. Space-heating, process-heating, and transportation can be provided by fuel or by electricity. The energy choice depends on the life-cycle costs of the various options.

Model Objective and Scope: Sectors

- We will divide the market into sectors.
- The number of sectors depends on the data that are available Energy data usually is divided into Residential, Commercial, Industrial, and Transportation.
- Each sector can be subdivided. The Residential sector could have single-family-low density and multi-family high density.

Model Objective and Scope: Energy Service Options

- Each sector will require a range of energy services.
- There will be a range of options that can provide the energy service.

Energy Service Options

- Each option will be described by its inputs and outputs.
- The inputs are: capital, labor, energy, goods and services purchased from all of the sectors of the economy.
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- We assume that the embodied environmental impacts of all of the inputs are included in their cost
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- The outputs are the energy service and the costs and quantities of all of the environmental impacts directly associated with the option. The environmental impacts can include air pollution, greenhouse gas emissions, solid-waste disposal, radioactive waste disposal, mining-accidents, and viewshed impacts of mining. Each input and output can be measured in an appropriate unit and has an appropriate price or cost that is measured in dollars per unit. It is convenient to choose a base year and use price indexes that start at 1.0 in the base year.

Price Responsive Tradeoffs

- There will be many technological tradeoffs for each option. If an input becomes expensive, the best choice will use less of the expensive input and more of the less expensive inputs.
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- This framework is very convenient for creating scenarios. You build a rich set of tradeoffs and vary prices to produce various scenarios.

Investment Module

- The inputs are Prices of goods, services, capital and labor for the time period of the model and Output for each sector.
- The outputs are the details of all vintages of capital stock and Output by Sector and Vintage.
- In each year, the Investment Module will determine the life cycle cost for each Option and chose a portfolio of options to invest in for each energy service in each sector.
- To determine the capacity of the vintage, Module needs to know the total amount of the energy service that will be required in the sector. There is an existing set of machines that provide the energy service and some of them will retire. Given the total demand and the retirements, the Module can determine how many new machines need to be installed each year.
- The Module will simulate major upgrades to existing capital stock.
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Energy Share Module

- The inputs are Prices and the active vintages of capital stock.
- The outputs are the energy required per unit of each energy service in each sector and the price of each energy service.
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- The model simulates the operating decisions for each year. Some sectors may have machines that can use several types of energy. A boiler might be able to burn oil, or natural gas, or coal, or wood. I had a house with a natural gas furnace, a wood stove, and electric resistance heaters.
- The Energy Share Module estimates the energy mix that will be used by each energy service in each sector and Vintage each year. The Module calculates the price of each energy service.

Efficiency Module

- The inputs are the inputs are Prices, the active vintages of capital stock, and the price of each energy service.
- The output of the Efficiency Module is the quantity of Energy Service per unit of Output for each Energy Service and each Sector by Vintage.
- This Module simulates short-run changes in demand for energy service.
- The changes can be due to efficiency, conservation, or maintenance.
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Output Module

- The Inputs are the outputs of the other Modules.
- The outputs are energy demand by Sector, Energy Service, and Vintage.
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- This Module does the bookkeeping to combine the results from the other Modules and forecast energy demand.
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- The Investment Module provides Output (Q) by Sector and Vintage.
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Output Module 2

- The Energy Share Module provides the energy (E) required per unit of each energy service in each sector by Vintage.
- The Efficiency Module provides the quantity of Energy Service (S) per unit of Output (Q) for each Energy Service and each Sector by Vintage.
- For each Sector and Vintage, Energy Service is: $S = (S/Q)*Q$.
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- Energy Demand is: $E = (E/S)*S$.
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- The Model forecasts detailed demand for Energy and Energy service.
- The forecasts can be summarized in many different reports.