# RENEWABLE ENERGY IN THE SOUTH

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## EXECUTIVE SUMMARY

Transitioning away from increasingly scarce, carbon-intensive and polluting fossil fuels is one of the key challenges facing modern society. Prominent among the energy supply options with inherently low life-cycle $CO_2$ emissions is a suite of renewable technologies. They also represent an opportunity to diversify energy resources while increasing reliance on domestic fuels.

Government policies can provide a strong impetus for constructing renewable generation facilities. Federal and state tax incentives, government procurement policies, statewide renewable electricity standards (RESs), and regional carbon cap and trade programs all encourage investments in renewable electricity. These policies, however, are not uniformly adopted throughout the country. While 29 states have an RES, only four of these states are located in the South (Delaware, Maryland, North Carolina, and Texas) plus the District of Columbia (Figure ES.1).

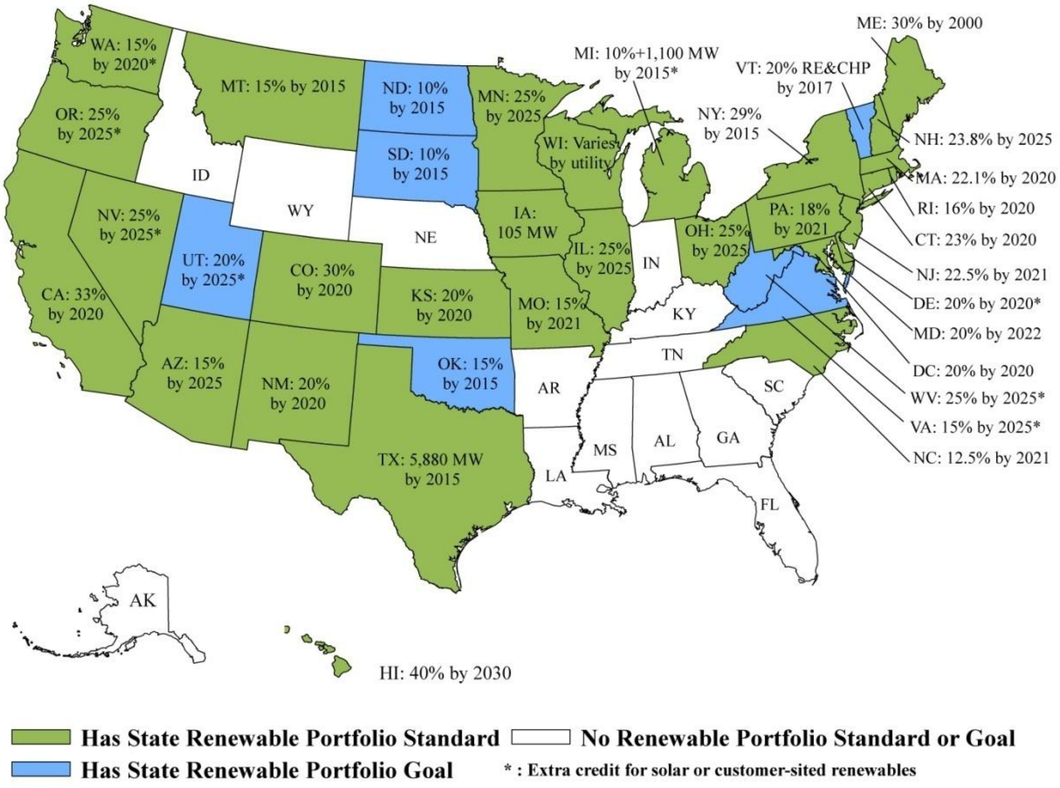

**Figure ES.1 States with Renewable Electricity Standards**

Source: Database of State Incentives for Renewable Energy (2010) http://www.dsireusa.org/. Accessed August 17, 2010

An RES is particularly influential for renewable markets because it provides a mandate requiring electricity suppliers to employ renewable resources to produce a certain amount or percentage of power by a fixed date. Typically, electric suppliers can either generate their own renewable energy, buy power from independent power producers, or buy renewable energy credits. Thus, this policy blends the benefits of a "command and control" regulatory paradigm with a free market approach to environmental protection.

Policy makers in some Southern states oppose renewable electricity standards because they believe their renewable resources are insufficient. The purpose of this report is to provide an up-to-date assessment of the economic potential for expanding renewable electricity generation in the South. We examine this economic potential by first incorporating new and improved estimates of hydropower and wind resources into our version of the National Energy Modeling System (NEMS). Then we adjust the cost forecast for solar resources to better reflect published estimates. Next we considered several policies – including accelerated R&D and extensions of tax credits – where increased renewable utilization is a policy goal. Finally, we examine the ability of renewable power generation to compete with traditional fossil and nuclear power options under two different federal policy scenarios: a national RES and a carbon-constrained future.

Customer-owned renewables are included in this assessment in addition to utility-scale renewables. While they are often not the focus of renewable policy debate, customer-owned renewables can achieve most of the same environmental and sustainability objectives that are the major drivers for increasing utility-scale renewables.

## The Current Status of Renewable Power in the South

The South (Figure ES.2), with its strong energy-intensive industrial base, accounts for 44% of the nation's total energy consumption, while it is home to only 36% of the U.S. population. Coal dominates electricity generation in the South, and renewables only provide 3.7% of its electricity generation. No state in the South exceeds the national average of 9.5% renewable electric power.

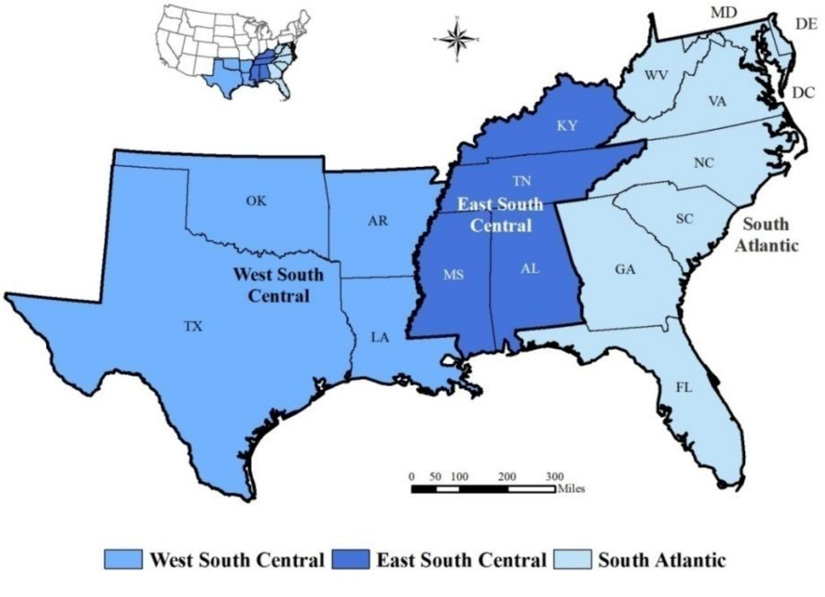

**Figure ES.2 The Census South Region and Its Three Divisions**[1]

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[1] Map and definition from U.S. Census Bureau document on Regions and Divisions of the United States *www.census.gov/geo/www/us_regdiv.pdf*

Hydropower represents nearly two-thirds of U.S. renewables, and it is also the largest renewable resource in the South accounting for 53% of the region's renewable electricity. Many Southern states produce hydropower, with Alabama, Tennessee, and Arkansas most notable among them (Table ES.1). Wind power is the second largest renewable source of electricity in the U.S. and in the South. Among the Southern states, Texas generates the largest quantity of wind power and Oklahoma also has a significant share. West Virginia and Tennessee are the only other two Southern states producing at least 1 TBtu of wind power. Biomass from wood and waste is the third largest renewable source of electricity both in the U.S. and the South. While Florida produces the largest quantity of biopower, other Southern states have significant quantities, as well, including Virginia, Maryland and the Carolinas. No state in the South produces more than 0.5 TBtu of geothermal or solar/PV electricity. In contrast, geothermal electricity comprised 8% of U.S. renewable generation in 2008, and solar power constituted 0.2%.

**Table ES.1 Consumption of Electric Power from Renewable Resources, by State in 2008 (Trillion Btu)**

| | Total Electricity | Renewable Share (%) | Renewable Power | Hydro | Wind | Biomass (Wood & Waste) | Geo-thermal | Solar & Photo-voltaic |
|---|---|---|---|---|---|---|---|---|
| Alabama | 1404 | 4.6% | 64 | 61 | 0 | 4 | 0 | 0 |
| Arkansas | 532 | 9.0% | 48 | 46 | 0 | 2 | 0 | 0 |
| Delaware | 73 | 2.7% | 2 | 0 | 0 | 2 | 0 | 0 |
| DC | 1 | 0.0% | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida | 2002 | 2.6% | 52 | 2 | 0 | 50 | 0 | 0 |
| Georgia | 1302 | 1.6% | 21 | 21 | 0 | 0 | 0 | 0 |
| Kentucky | 1030 | 1.9% | 20 | 19 | 0 | 1 | 0 | 0 |
| Louisiana | 701 | 1.7% | 12 | 11 | 0 | 1 | 0 | 0 |
| Maryland | 486 | 5.6% | 27 | 20 | 0 | 8 | 0 | 0 |
| Mississippi | 445 | 0.0% | 0 | 0 | 0 | 0 | 0 | 0 |
| North Carolina | 1253 | 3.0% | 38 | 30 | 0 | 8 | 0 | 0 |
| Oklahoma | 730 | 8.4% | 61 | 38 | 23 | 0 | 0 | 0 |
| South Carolina | 1024 | 1.8% | 18 | 11 | 0 | 7 | 0 | 0 |
| Tennessee | 911 | 6.2% | 56 | 56 | 1 | 0 | 0 | 0 |
| Texas | 3652 | 4.8% | 175 | 10 | 160 | 5 | 0 | 0 |
| Virginia | 742 | 3.5% | 26 | 10 | 0 | 16 | 0 | 0 |
| West Virginia | 907 | 1.3% | 12 | 8 | 4 | 0 | 0 | 0 |
| **Census South** | **17,200** | **3.7%** | **630** | **340** | **188** | **104** | **0** | **0** |
| (% of the South) | | | 3.7% | 2.0% | 1.1% | 0.6% | 0% | 0% |
| **United States** | **40,200** | **9.5%** | **3,800** | **2,500** | **550** | **440** | **310** | **9** |

In sum, the South's wind power is concentrated mostly in the West South Central states, while its biopower comes mostly from the South Atlantic region. Its hydropower is widely dispersed, but is particularly dominant in the East South Central states (Figure ES.3).

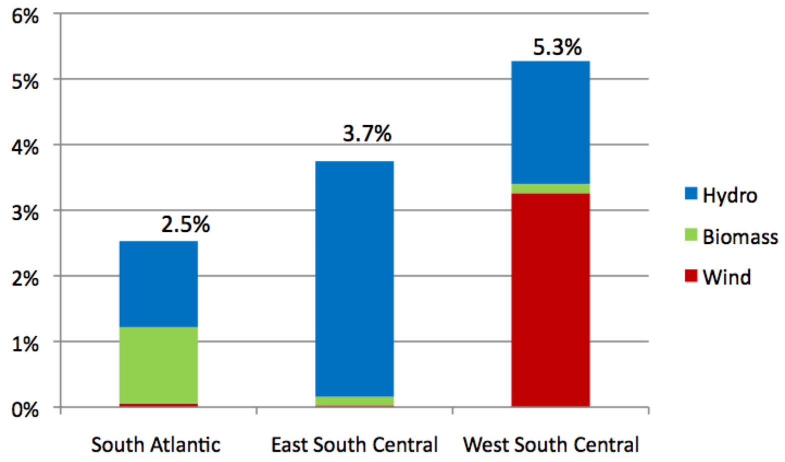

**Figure ES.3 Consumption of Electric Power from Renewable Resources, by Census Division in 2008 (as a Percent of Electric Power Consumption)**

Source: Energy Information Administration. 2010b. *State Energy Data System*. Retrieved on July 2, 2010 from: http://www.eia.doe.gov/emeu/states/_seds.html

## Notable Renewable Energy Projects in the South

The scarcity of renewable electricity standards in the South should not suggest that the region lacks renewable power activity. In fact, the potential for expansion of renewable energy in the South is being demonstrated by the growth of investments in renewable power projects throughout the region. SACE (2009) listed approximately a dozen activities in its report on renewable resources in the Southeast. Additional projects have been initiated recently with funding from the American Recovery and Reinvestment Act (ARRA). Solar projects have received the biggest financial boost from the ARRA, with more than $60 million spending on 14 programs. In addition, more than $10 million of ARRA funding supports biomass development, and about $20 million is being spent on hydropower projects. When these projects are completed, the South will have an additional 120 MW of solar power and 300-500 MW of biopower, more than doubling the current capacity of both. Investments in wind farms in the West South Central states have been significant, and Florida Power and Light is planning a 14 MW wind farm on Hutchinson Island.

## METHODOLOGY

Unlike most previous assessments of renewable electricity alternatives, this report includes ***both***: 1) utility-scale renewable generation and 2) customer-owned renewable resources. Utility-scale generators use wind, biomass, hydro, or solar energy to produce electricity. Customer-owned renewable resources include rooftop solar panels, industrial facilities that produce electricity from waste heat (called “combined heat and power” or CHP), and demand-side technologies such as heat pumps that use heat in the air, water, or ground to produce energy services that reduce the requirement to consume electricity.

Our assessment of renewable electricity resources in the South uses a version of NEMS, the U.S. Department of Energy's premier energy forecasting tool.[2] NEMS models U.S. energy markets and is the principal modeling tool used by the Energy Information Administration (EIA) to produce "reference forecasts" that are published each year in its *Annual Energy Outlook*. In this analysis, three scenarios of expanded renewables in the South are compared with the Reference forecast reflecting EIA's analysis of the Stimulus Bill and the 2008 economic downturn (EIA, 2009a):

- **Expanded Renewables:** Uses updated estimates of renewable resources in the South detailed in Volume II and other sources. In addition, it assumes a number of renewable policies such as an extension of R&D and tax subsidies, but no new state or Federal carbon pricing or renewable energy portfolio policies are enacted.
- **Expanded Renewables + Renewable Electricity Standard (RES):** Uses all of renewable policies and updated estimates of renewable resources from the **Expanded Renewables Scenario** along with a Federal requirement of 25% renewable electricity production by 2025. The scenario exempts small retailers from the RES mandate and excludes hydroelectric power and municipal solid waste from the sales baseline. An RES only scenario was also created in order to compare results.
- **Expanded Renewables + Carbon-Constrained Future (CCF):** Uses all of the renewable policies and updated estimates of renewable resources from the **Expanded Renewables Scenario** along with a carbon price of $15 (in $2005) per metric ton of carbon dioxide in 2012 growing annually at 7%. Allowances are redistributed to load serving entities as described above, and there are no carbon offsets. A CCF only scenario was also created in order to compare results.

The first scenario seeks to provide an improved forecast of the future growth of renewable energy. The two additional scenarios estimate what might happen to the future of renewable power in the South if a national RES or a national price on carbon were enacted.

## Updated Estimates of Renewable Resources

Recent assessments of renewable resources provide updated, more precise, and more expansive estimates of available renewable resources across the country. The updated estimates shown in Table ES.2 show potentials for five specific renewable resources in each of the 16 Southern states and the District of Columbia. These resource potentials are the basis for modeling the hydro and the wind power in the Expanded Renewables scenario described above, since they identify a greater physical resource than previous estimates. For the biomass, landfill gas, and solar, we use other data sources that provide more detailed supply curve estimates that are consistent with the averages shown in Table ES.2, as described in the full report.

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[2] SNUG-NEMS: Southeastern NEMS User Group version of NEMS.

**Table ES.2 Renewable Resource Potential, by State**

| | Low-Power and Small Hydro (MW of Feasible Projects) | Wind (km$^2$ of Developable Land) | Biomass Wood & Waste (Thousand tons/year)[3] | Methane from Waste (Thousand tons/year)[4] | Solar Radiative Forcing (kWh/m$^2$/day) |
|---|---|---|---|---|---|
| Alabama | 460 | 24 | 12,000 | 340 | 4.9 |
| Arkansas | 590 | 1,840 | 12,590 | 190 | 5.1 |
| Delaware | 6 | 1.9 | 420 | 60 | 4.6 |
| DC | N/A | N/A | 56 | 1 | 4.6 |
| Florida | 79 | 0.1 | 9,210 | 500 | 5.2 |
| Georgia | 230 | 26 | 14,450 | 350 | 5.1 |
| Kentucky | 520 | 12 | 7,540 | 290 | 4.5 |
| Louisiana | 310 | 82 | 12,880 | 180 | 5.0 |
| Maryland | 91 | 300 | 1,910 | 220 | 4.6 |
| Mississippi | 300 | 0.0 | 15,790 | 170 | 5.0 |
| North Carolina | 350 | 160 | 9,920 | 810 | 5.0 |
| Oklahoma | 350 | 103,400 | 3,740 | 210 | 5.0 |
| South Carolina | 210 | 37 | 6,100 | 220 | 5.0 |
| Tennessee | 660 | 62 | 6,440 | 300 | 4.7 |
| Texas | 330 | 380,300 | 13,260 | 940 | 5.4 |
| Virginia | 420 | 360 | 6,230 | 310 | 4.8 |
| West Virginia | 480 | 380 | 2,390 | 50 | 4.3 |
| **South Total** | **5,370** | **486,900** | **134,900** | **5,140** | **-** |
| **U.S. Total** | **29,400** | **2,091,800** | **408,000** | **15,030** | **-** |

Note: Numbers may not add up due to rounding. Source: Hall, et al. (2006) *Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants,* INL, Table B-1; NREL (2010) *Wind Powering America. Wind Resource Potential*. Retrieved on July 18, 2010 from: http://www.windpoweringamerica.gov/wind_maps.asp; Energy Information Administration. (2010b). *State Energy Data System*. Retrieved on July 2, 2010 from: http://www.eia.doe.gov/emeu/states/_seds.htm; Milbrandt, A. (2005)*A Geographic Perspective on the Current Biomass Resource Availability in the United States,*NREL,TP-560-39181,pg.49 (Table 10), December 2005.

The hydro resource data suggest the availability of significant small conventional and low-power hydro resources, above and beyond those previously modeled in NEMS. These resources are available across many states in the East South Central and South Atlantic regions, and they total more than five GW, or the equivalent of approximately five new coal or nuclear plants. The

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[3] Biomass Wood & Waste in Table 2 includes crop residues, switch grass, forest residues, mill residues, urban wood waste.

[4] Methane from Waste includes methane from landfills, manure waste, and domestic wastewater management.

latest wind resource data measured at 80-meter heights show a broader geography of wind resources relative to the resources previously modeled in NEMS. Prior estimates suggested more limited wind power resources in the South. The estimates of biomass resources and methane from waste broadly reflect the magnitudes modeled in NEMS, which recently updated its bioenergy supply curves. These resource estimates exceed those of other models that are not as current.

## RESULTS

### Utility-Scale and Customer-Owned Renewables

This section compares a Reference forecast with the three modeled scenarios previously described. Figure ES.4 displays the results in terms of the proportion of total electricity generation in the South that would come from renewable resources over the next twenty years. In the Expanded Renewables Scenario, renewable electricity generation doubles the output of the Reference forecast for the South. If a Federal RES is adopted or the policies represented by our CCF scenario are implemented, we estimate that 15% to 30% of the South's electricity could be generated from renewable sources.

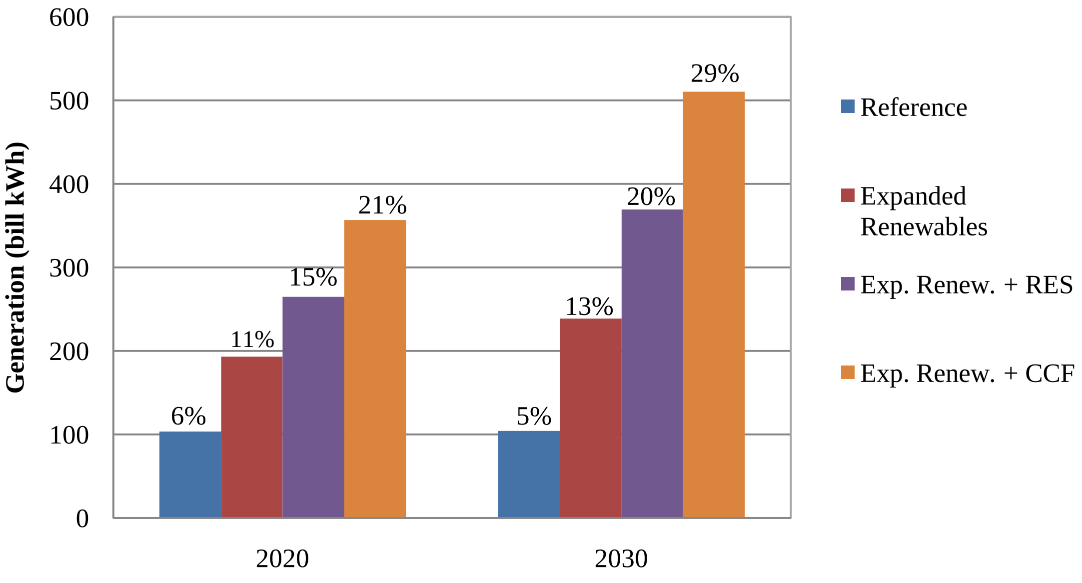

**Figure ES.4 Utility-Scale Renewable Generation in the South**
**(% of total generation)**

Table ES.3 shows the amounts of renewable electricity (in billion kilowatt hours –TWh), that would be generated under the three renewable-enhancing scenarios compared to the same scenarios without Expanded Renewables, including displaced electricity from customer-owned renewables. Most of the growth comes from wind, CHP and distributed solar as well as biomass.

The modeled scenarios reflect an environment in which renewable sources are increasingly economically competitive or mandated, as in the case of an RES. Of the utility-scale renewable sources, wind and biomass not only provide the most generation potential, but are also the least expensive. It appears that wind out-competes biomass as the integration of renewable sources expands through the modeled time horizon.

**Table ES.3 Renewable Generation and Customer-Owned Renewables in the South in 2030 (billion kWh)**

| | Utility-Scale Renewables | | | | | | |
|---|---|---|---|---|---|---|---|
| | Wind | Biopower | Municipal Waste | Hydro | Solar PV | **Total** | **% above Reference** |
| Reference Forecast | 39 | 19 | 4.3 | 42 | 0.2 | 104 | - |
| Expanded Renewables | 151 | 24 | 3.8 | 60 | 0.3 | 239 | 129% |
| Renewable Electricity Standard | 54 | 238 | 4.3 | 42 | 0.2 | 339 | 224% |
| + Renewable Electricity Standard | 224 | 82 | 3.8 | 60 | 0.3 | 370 | 254% |
| Carbon Constrained Future | 59 | 83 | 4.3 | 43 | 0.2 | 190 | 81% |
| + Carbon Constrained Future | 362 | 83 | 4.3 | 61 | 0.3 | 511 | 389% |
| | **Customer-Owned Renewables** | | | | | | |
| | CHP | Distributed Biopower | Heat Pump Water Heaters* | Solar Water Heaters* | Distributed Solar PV | **Total** | **% above Reference** |
| Reference Forecast | 102 | 37 | - | - | 10 | 149 | - |
| Expanded Renewables | 151 | 34 | 34 | 21 | 68 | 308 | 107% |
| Renewable Electricity Standard | 85 | 32 | -1.8 | 0 | 13 | 128 | -14% |
| + Renewable Electricity Standard | 145 | 32 | 33 | 21 | 69 | 300 | 101% |
| Carbon Constrained Future | 210 | 39 | 12 | 0.3 | 9 | 270 | 81% |
| + Carbon Constrained Future | 288 | 42 | 42 | 23 | 69 | 464 | 211% |

+ RES and + CCF include the Expanded Renewables scenario assumptions in addition to the RES and CCF scenarios.

*The heat pump and solar water heater numbers are the incremental difference between the reference forecast and each scenario. These numbers, though presented in billion kWh, differ from the other values presented in the table. Since the water heater technologies do not generate electricity, these numbers are the energy savings these technologies avoid. They can be interpreted as the avoided fossil-fuel generation attributed to heat pump and solar water heaters.

By definition, an RES must meet an increased renewable target by 2030. Placing a price on carbon, represented by our Exp. Renew. + CCF Scenario, unsurprisingly leads to marked increases in renewable uptake. Interestingly, the Exp. Renew. + CCF Scenario has about 150% more utility-scale renewable generation than the CCF only Scenario. These results suggest there is large, economically viable utility-scale renewable potential that is close in costs with the other major GHG emission free technology, nuclear. Table ES.3 also points out that customer-owned renewable sources are significant. This is particularly true in the case of CHP. Our study suggests that by 2030 CHP may displace as much as 288 TWh of electricity generation in the South.

Figure ES.5 portrays the generation results of the Expanded Renewables Scenario across the four National Energy Reliability Council regions that broadly cover the South:

- Electric Reliability Council of Texas (ERCOT),
- Florida Coordinating Council (FRCC),
- Southeast Electricity Reliability Council (SERC), and
- Southwest Power Pool (SPP).

We see that the western part of the region is dominated by wind. Wind is also heavily represented in Florida, due principally to wind imports. The contribution of biopower, while not insignificant, is attenuated by its higher cost when compared to wind.

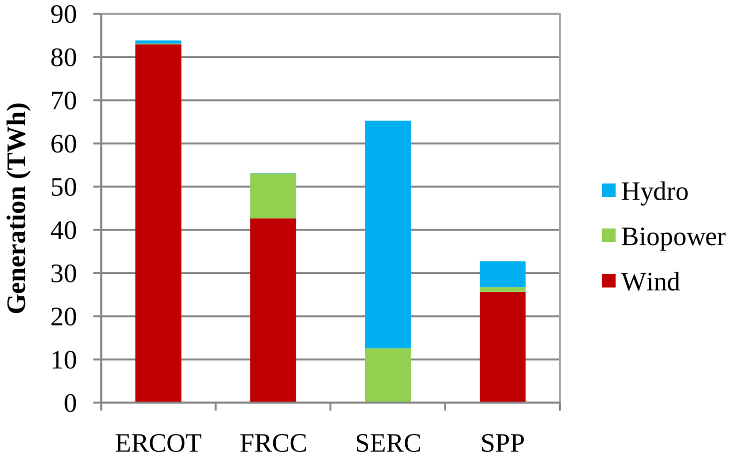

**Figure ES.5 Southern Renewable Distribution by NERC region in 2030 (Expanded Renewables Scenario)**

Figure ES.6 illustrates how much total renewable potential could be realized by 2030, considering both utility-scale and customer-owned renewables. Combined heat and power systems as well as solar and heat pump water heaters are classified as customer-owned resources that avoid fossil fuel generation. (The category "Demand-Side Solar" in Figure ES.6 includes distributed solar PV and solar water heating.) Adding customer-owned renewables to utility-scale renewables nearly doubles the potential of renewable generation in the South.

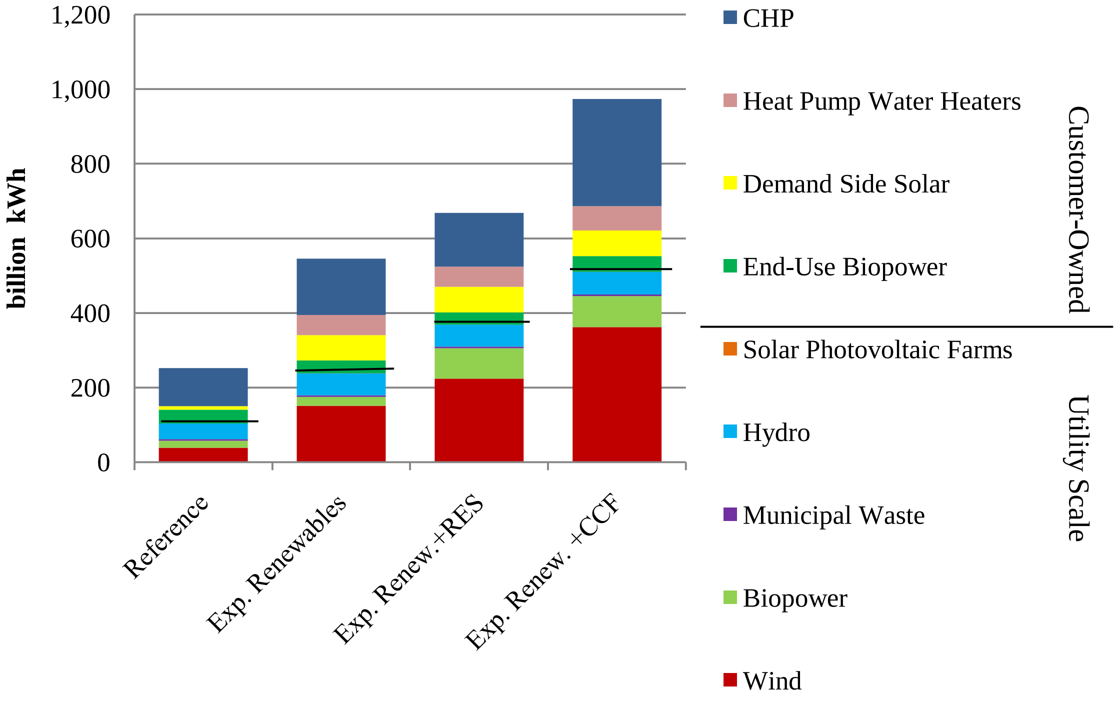

**Figure ES.6 Economic Potential for Utility-Scale and Customer-Owned Renewable Generation in 2030**

## Greenhouse Gas Emission Reductions

Figure ES.7 below shows the projected greenhouse gas emissions from electricity generation for the South, for each of the Expanded Renewable. scenarios. Not surprisingly, the carbon constrained future scenario results in the greatest reduction in emission. The avoided emissions from electricity shown in Figure ES.7 are similar to the overall avoided emissions for the South (shown in Table ES.4).

**Table ES.4 Emission Reductions from Reference (million tonnes $CO_{2e}$)**

| | Expanded Renewables | Renewable Electricity Standard | Exp. Renew. + RES | Carbon Constrained Future | Exp. Renew. + CCF |
|---|---|---|---|---|---|
| 2020 Avoided | 54 | 69 | 100 | 169 | 300 |
| 2030 Avoided | 84 | 160 | 160 | 553 | 710 |

Notably, renewable sources could be expected to help reduce electricity emissions in the South in 2030 between 7% (in the Expanded Renewables scenario) and 55% (in the Expanded Renewables + CCF).

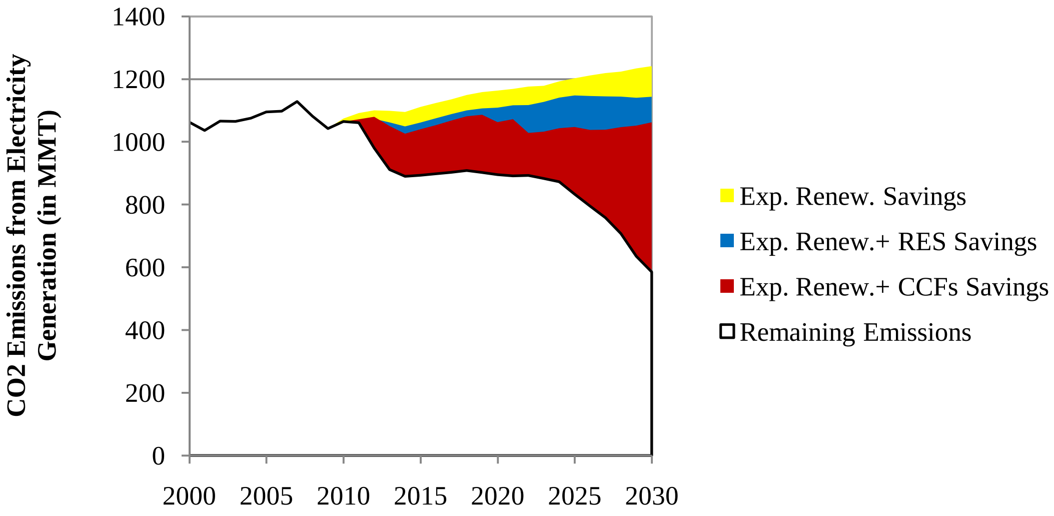

**Figure ES.7 Southern Electricity Carbon Dioxide Emissions Reductions, by Scenario**

## ECONOMICS OF RENEWABLE ENERGY IN THE SOUTH

The expanded tax credits, technology improvements, and updated renewable resource estimates that comprise the "Expanded Renewables" scenario would have favorable impacts on electricity rates and utility bills. As shown in Figure ES.8, average electricity rates in the South are forecast to rise for all users by 23% in the EIA Reference case (from 7.9¢/kWh in 2010 to 9.7¢/kWh in 2030). In contrast, the average electricity rate in the region in the Expanded Renewables scenario would rise by only 16% over the two decades, to 9.0¢/kWh. The escalation of rates associated with the RES and CCF policies is similarly dampened with the addition of the Expanded Renewables assumptions.

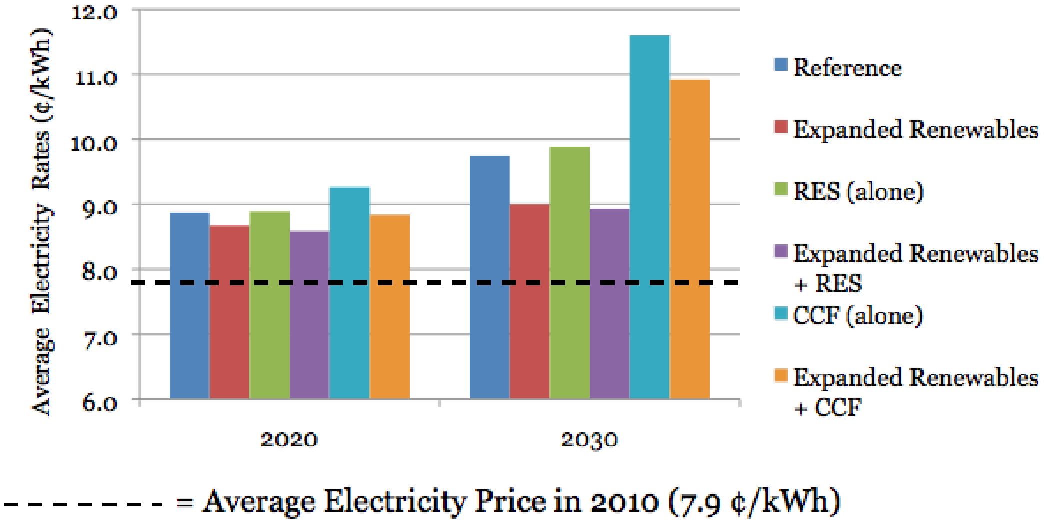

**Figure ES.8 Average Electricity Rates in the South under Alternative Scenarios**

The Expanded Renewable scenario has a similarly favorable impact on energy bills. In the Reference Case, the South's energy bill (across all fuels) would total $306 billion in 2020, and would rise to $341 billion in 2030 (in $2007). In the Expanded Renewables scenario, electricity bills would increase less—reaching an estimated $292 billion in 2020 and $318 billion in 2030 (7% less). Part of this reduced increase in energy bills is due to lower electricity rates (discussed above), but it is also a result of the inclusion of significant customer-owned renewables – especially CHP and solar and heat pump water heaters – that displace energy consumption in the industrial and residential sectors, in particular.

## CONCLUSIONS

By including a full-suite of renewable electricity sources, this report identifies a broad and diversified portfolio of renewable resources available for electric power generation in the South. Under realistic renewable expansion and policy scenarios, the region could economically supply a large proportion of its future electricity needs from both utility-scale and customer-owned renewable energy sources. The growth of customer-owned renewable generation in the South could well match that of utility generation. Additional renewable potential is likely to materialize over the next several decades, when solar becomes more cost-competitive, intermittent transmission barriers are overcome, and emerging technologies mature.

### Utility-Scale Renewables

With the inclusion of up-to-date data on wind resource availability (using 80-meter data), wind's lower levelized cost favors it in a regional analysis of utility power generation. As a result, our analysis suggests that wind will overwhelm biopower as a preferred renewable resource for the electric utility sector in the South. Onshore wind in the western part of the South is a low-cost resource that will make resolving transmission issues associated with wind highly desirable.

Previous EIA analysis using NEMS and lower altitude wind potential measurements found biopower to be the preferred renewable resource over wind (EIA, 2009). The real-world adjustments to these assumptions in our modeling resulted in the shift of emphasis between the two sources. In end-use applications, however, biopower continues to be cost-effective and has the potential to grow. Hydropower resources in the South are also shown to be significant with the potential for significant expansion.

While utility-scale solar resources are not forecast to meet even one percent of the South's electricity requirements over the next 20 years, solar projects have received more than $60 million of funding from the ARRA. These resources will be used to build an additional 120 MW of new solar capacity, which will expand its current capacity by more than 200%, and will bring solar workforce skills and supply chain infrastructure to the region. Future growth should be spawned from these investments, exceeding the SNUG-NEMS modeling estimates.

## Customer-Owned Renewables

On the customer side, CHP, for example, is a highly cost-effective source of electricity defined as renewable in the sense that it produces electric power from waste heat that would otherwise be vented to the atmosphere. Similarly, solar water heating offers a relatively inexpensive means of displacing the need for electricity production, as do heat pump water heaters. Under the Exp. Renew. + CCF Scenario, "distributed solar" provides 6.3% of total renewable electricity generation. These 'demand-side' renewables are not usually evaluated for meeting RES targets; nevertheless, the modeling shows that they would be significant low-cost contributors to the South's clean energy portfolio.

## Translating Renewable Energy Potential into Reality

Given the magnitude of the environmental and energy security challenges facing the nation, many different renewable resources and technologies need to be exploited, and every region of the country needs to contribute. Success will involve transforming and modernizing energy systems in fundamental ways. These transformations in many cases will involve more than just the next generation of technology. They will require paradigm shifts in how we generate and use energy today as well as acceptance of entirely new concepts such as complex integrated systems that optimize suites of technologies. Federal, state, and local public policies can accelerate this transition. The South has an abundance of renewable energy resource potential to help transition the nation away from increasingly scarce, carbon-intensive and polluting fossil fuels. With the commitment of policymakers, utilities, regulators, entrepreneurs, capital markets, and other stakeholders, this potential could be translated into a reality.

# 1. INTRODUCTION

Transitioning away from increasingly scarce, carbon-intensive and polluting fossil fuels is one of the key challenges facing modern society. Prominent among the energy supply options with inherently low life-cycle $CO_2$ emissions is a suite of renewable technologies. To the extent these technologies emit GHGs, the emissions generally occur during manufacturing and deployment and not during the combustion of fuels (National Research Council, 2009). They also represent an opportunity to diversify energy resources while also increasing reliance on domestic fuels with greater employment and economic growth multipliers relative to imported energy supplies.

The inherently low-carbon and local nature of these technologies comes from the fact that most renewable technologies are powered by the sun:

- Plants and algae require sunlight for photosynthesis before they can be converted to biofuels or biopower.
- Hydropower capitalizes on rain and snowfall from water evaporation and transpiration.
- Wind generates electricity directly by turning a turbine or indirectly in the form of ocean waves, but the wind itself is driven by the sun.
- Ocean thermal energy conversion uses the temperature differential between surface water warmed by the sun and cold deep water to drive a turbine and make electricity.

Tidal and geothermal energy are renewable energy resources that are not a direct product of solar energy. Tides go up and down due to the gravitational attraction between the oceans and the moon. The heat trapped in the earth, which results in geysers and other geothermal energy sources, is due to both leftover heat from formation of the planet and the radioactive decay of elements within the crust, such as uranium and thorium.

Increasing the contribution of renewables to the nation's energy portfolio will directly lower GHG emissions in proportion to the amount of carbon-emitting energy sources displaced.

The technologies in the suite of renewable options are in various states of market penetration or readiness. Within solar, wind, geothermal, ocean, biomass, and hydropower, each resource includes mature technologies that either have already been commercialized or are suitable for near-term commercialization. Each category also consists of many systems still in various stages of development, ranging from laboratory testing to prototype demonstrations.

Renewable energy production is expanding at double-digit rates across the globe (REN21, 2009). Although they are starting from a small base, renewables are the fastest growing energy source worldwide (EIA, 2009; Table 8). Much of the growth is in hydropower, solar photovoltaics, wind power and biomass (especially in OECD countries). Of the 3.3 trillion kWh of new U.S. renewable generation to be added to global energy production between 2006 and 2030, 54% is forecast to be hydropower and 33 percent wind power (REN21, 2009, Figure 17).

Many renewable technologies are unable to compete economically with fossil fuels under current pricing regimes. As a result, government policies and incentives typically are the primary drivers for the construction of renewable generation facilities (REN21, 2009, pp. 10-11). Industrialized countries across the globe have created government policies to encourage the construction of renewable electricity facilities, including feed-in tariffs, tax incentives, and renewable electricity standards (called market-share quotas in Europe). The extension of production tax credits in the 2005 U.S. Energy Policy Act along with the implementation of state renewable electricity standards and an array of other incentives are expected to accelerate growth in the use of U.S. renewable technologies.

## 1.1 THE CURRENT STATUS OF RENEWABLE POWER IN THE SOUTH

The renewable energy situation in the South is quite unique and is the focus of this report. To draw on a variety of data sources and to facilitate a broad array of data analysis, we find it beneficial to define the South to two different ways. We adopt the definition of the South provided by the U.S. Census Bureau for the purposes of data analysis that relies principally on Census statistics, state-based data from the Energy Information Administration (EIA), and energy end-use statistics from the EIA's National Energy Modeling System (NEMS). This definition of the South includes the District of Columbia and 16 States (Fig. 1.1), and it divides the region into three Census Divisions. The **South Atlantic** division is the largest both by population and geography, with eight states and the District of Columbia; all but West Virginia sit along the eastern seaboard. The **East South Central** division includes Alabama and three states with western borders that touch the Mississippi River. The **West South Central** division also includes four states, which all lie west of the Mississippi River. The South as defined by the U.S. Census Bureau is almost identical to the Region served by the Southern Governors' Association (SGA); it is slightly larger than the 11-state region served by the Southeast Energy Efficiency Alliance.

The South is also defined as a subset of four of the 13 regions defined by the National Energy Reliability Council (NERC) covering the continental United States (Fig. 1.2). The four NERC regions that are used to define the south are:

- Electric Reliability Council of Texas (ERCOT),
- Florida Coordinating Council (FRCC),
- Southeast Electricity Reliability Council (SERC), and
- Southwest Power Pool (SPP).

NERC's regions are the basis for managing the nation's electricity generation and are used in the electricity market module of NEMS.

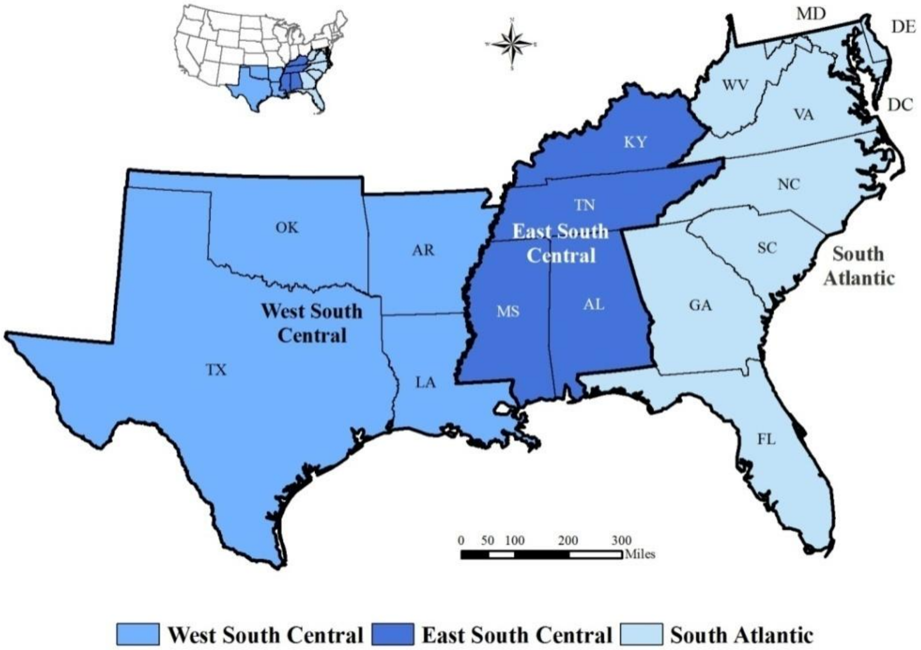

Figure 1.1 The Census South Region and Its Three Divisions[5]

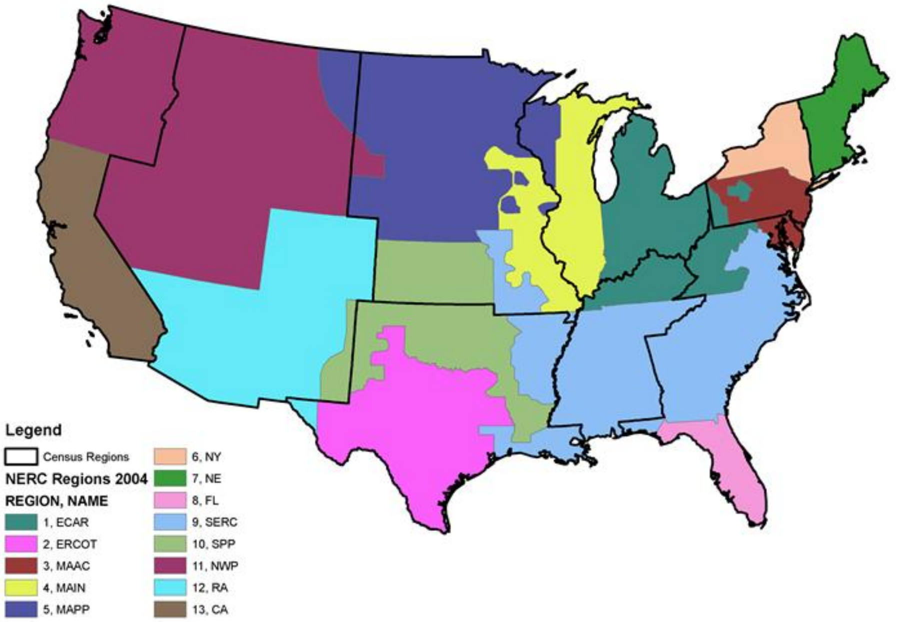

Figure 1.2 Overlapping Census and NERC Regions

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[5] Map and definition from U.S. Census Bureau document on Regions and Divisions of the United States *www.census.gov/geo/www/us_regdiv.pdf*

The overlap between these four NERC regions and the three Census divisions is approximate. Some of the notable disagreements between the two regions are the inclusion of Kansas in the NERC South and its exclusion from the Census South and the inclusion of West Virginia, Kentucky, and part of North Carolina in the Census South, but their exclusion from the NERC South. To facilitate the easy identification of each definition, we distinguish between the "Census South" and the "NERC South" regions.

With 36% of the country's population in 2009, the Census South is the most populous of the four census regions of the United States (U.S. Bureau of the Census, 2009). It includes two of the most populous states in the country – Texas and Florida – and it leads the nation not only in population but also in in-migration and population growth.[6]As the nation's largest and fastest growing region, the South has experienced a 20% population growth over the past decade, and this rapid expansion is expected to continue.

The South accounted for 44% of the nation's total energy consumption in 2008, considerably more than its share of the country's population of 36%. Its higher-than-average per capita energy consumption is true for each of the major end-use sectors: residential buildings (39%), commercial buildings (38%), industry (51%), and transportation (41%), and for electric power (43%).

As Table 1.1 shows, coal dominates electricity generation in the South, accounting for 53-54% in 2008, which is slightly higher than the U.S. average of 51%. In contrast, the South depends less on renewable sources of electricity than any other region. As a result of its heavy reliance on fossil fuels, the Census South accounts for 41% of U.S. carbon emissions. These regional averages mask a great deal of state-by-state diversity. Three states in the South rely primarily on natural gas for power production, and one state (South Carolina) relies primarily on nuclear power. In 2008, no state in the South exceeded the national average of 9.5% renewable electric power.

**Table 1.1 Energy Consumption for Electric Power in the South and the U.S., in 2008**

| | Coal | Renewables | Petroleum | Natural Gas | Nuclear | Imports |
|---|---|---|---|---|---|---|
| U.S. | 51.1% | 9.5% | 1.2% | 17.1% | 21.0% | 0.3% |
| Census South | 53.5% | 3.7% | 1.3% | 20.6% | 21.0% | 0.0% |
| NERC South | 53.1% | 3.5% | 1.4% | 20.0% | 22.1% | 0.0% |

Source: http://www.eia.doe.gov/emeu/states/sep_sum/html/pdf/sum_btu_eu.pdf

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[6] The South has the highest in-migration and population growth in persons, but the West leads the nation in growth rate on a percentage basis. For the period from 2000 to 2008, population growth for the whole U.S. was estimated at 7.8% with growth for the South at 11.1% and the West at 11.7%; over the same time, the average annual population growth rate for the whole U.S. was 0.94% with average annual population growth rates for the South at 1.32% and West at 1.39% (U.S. Bureau of the Census, 2008).

In 2008, eleven of the states in the Census South imported electricity, and only six southern states exported electricity. The largest importers of electricity were Virginia (443 TBtu imported), Florida (432 TBtu imported), and Tennessee (210 TBtu imported). The three largest exporters of electricity were West Virginia (539 TBtu exported), Alabama (438 TBtu exported), and South Carolina (156 TBtu exported) (SEDS, 2010). The electricity sales into Tennessee and out of Alabama are partly a function of the unified system of public power managed across seven states by the Tennessee Valley Authority.

In some cases, state electricity imports are purchased from renewable energy sources located in other southern states or situated outside of the South. For instance, the Tennessee Valley Authority contracted with Horizon Wind Energy LLC, a wind farm in Iowa, to purchase up to 115 MW of wind energy for 20 years (TVA, 2010).

In other instances, utility companies forgo importing electricity into the South and pursue renewable projects outside the South. Southern Company and Turner Renewable Energy jointly acquired a 30 MW solar facility in New Mexico. The power generated by the facility will be sold to customers in Colorado, Nebraska, New Mexico, and Wyoming (Renewable Energy World, 2010). Duke Energy has acquired interests in several wind farms throughout the U.S. It owns eight wind farms (a total of 703 MW) located in Colorado, Pennsylvania, Texas and Wyoming. It also owns a 283 MW interest in the 585 MW Sweetwater Wind Farm in Texas (Duke Energy, 2010d). Many such transactions are quite recent and are not reflected in Table 1.1.

EIA (2009c) forecasts that energy consumption for electric power generation in the South will grow from 17 quads in 2010 to 20 quads in 2030. Renewable utility generation is forecast to grow from less than 4% currently to 5% of total electric power generation by 2030 (Fig. 1.3). Petroleum use remains constant and small, but coal, natural gas, and nuclear are forecasted to increase in nearly equal proportions.

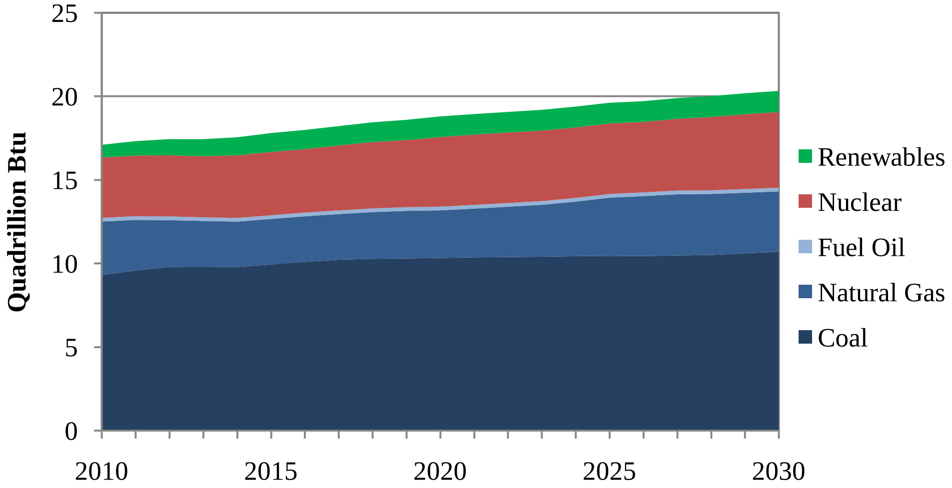

**Figure 1.3 Energy Consumption for Electric Power Generation in the Census South, 2007-2030 (EIA, 2009)**

Energy in the South is relatively cheap, and EIA forecasts that this comparative advantage will continue through 2030. Table 1.2 compares U.S. and Southern average electricity prices.

**Table 1.2 Average Electricity Prices to All Users in the Census South and the United States**

| Cost per Unit Energy | United States | | | The Census South | | |
|---|---|---|---|---|---|---|
| | 2007 | 2020 | 2030 | 2007 | 2020 | 2030 |
| 2007 ¢/ kWh | 8.27 | 9.24 | 10.04 | 7.77 | 8.71 | 9.61 |
| 2007 $/ MBtu | 24.3 | 27.1 | 29.4 | 22.8 | 25.5 | 28.2 |

Source: EIA, 2009c

The South consumes nearly 43% of U.S. electricity, but it consumes only 16.6% of the renewable power generated in the U.S. While 9.5% of U.S. electricity consumed in the country as a whole comes from renewable resources, only 3.7% of the utility electricity consumed in the Census South is renewable (Fig. 1.4). (The percentage of renewables is slightly smaller in the NERC South at 3.5%.)

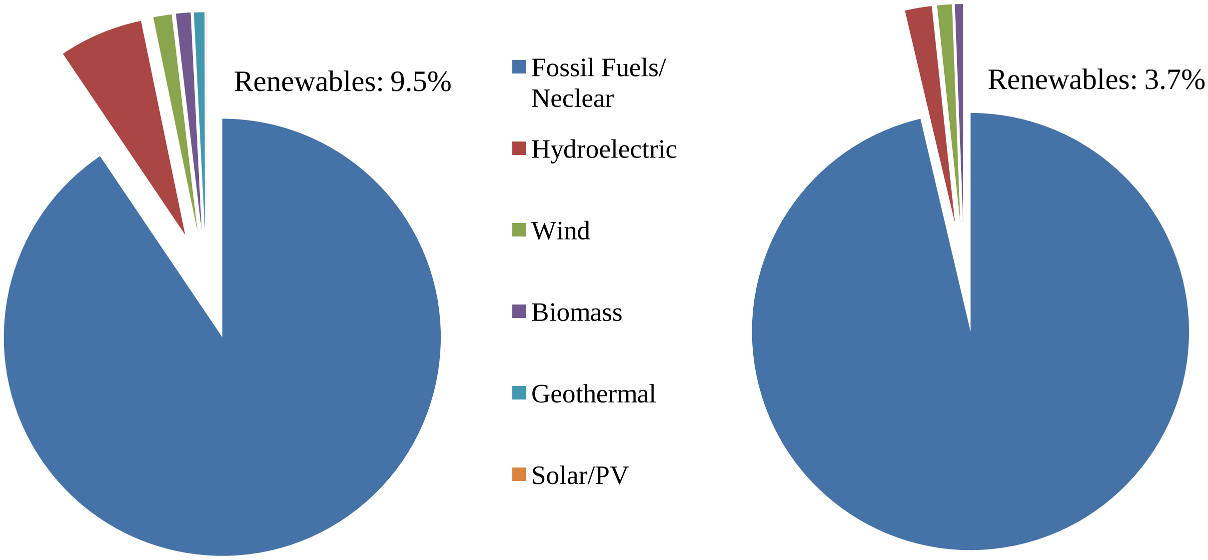

**Figure 1.4 Source of Electric Power in the U.S. and the Census South, in 2008**
Source: Energy Information Administration. (2010h).

Hydropower represents nearly two-thirds of U.S. renewables, and is also the largest renewable resource in the South accounting for 53% of the region's renewable electricity. Yet in the Census South, at 2% of generation, hydropower is considerably smaller than the 8% national average. The District of Columbia, Delaware and Mississippi do not produce any hydropower, while Alabama, Tennessee, and Arkansas are the largest hydropower producers (Table 1.3).

**Table 1.3 Consumption of Electric Power from Renewable Resources, by State in 2008 (Trillion Btu)**

| | Total Electricity | Renewable Share (%) | Renewable Power | Hydro | Wind | Biomass (Wood & Waste) | Geo-thermal | Solar & Photo-voltaic |
|---|---|---|---|---|---|---|---|---|
| Alabama | 1404 | 4.56 | 64 | 61 | 0 | 4 | 0 | 0 |
| Arkansas | 532 | 9.02 | 48 | 46 | 0 | 2 | 0 | 0 |
| Delaware | 73 | 2.74 | 2 | 0 | 0 | 2 | 0 | 0 |
| DC | 1 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 |
| Florida | 2002 | 2.60 | 52 | 2 | 0 | 50 | 0 | 0 |
| Georgia | 1302 | 1.61 | 21 | 21 | 0 | 0 | 0 | 0 |
| Kentucky | 1030 | 1.94 | 20 | 19 | 0 | 1 | 0 | 0 |
| Louisiana | 701 | 1.71 | 12 | 11 | 0 | 1 | 0 | 0 |
| Maryland | 486 | 5.56 | 27 | 20 | 0 | 8 | 0 | 0 |
| Mississippi | 445 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 |
| North Carolina | 1253 | 3.03 | 38 | 30 | 0 | 8 | 0 | 0 |
| Oklahoma | 730 | 8.36 | 61 | 38 | 23 | 0 | 0 | 0 |
| South Carolina | 1024 | 1.76 | 18 | 11 | 0 | 7 | 0 | 0 |
| Tennessee | 911 | 6.15 | 56 | 56 | 1 | 0 | 0 | 0 |
| Texas | 3652 | 4.79 | 175 | 10 | 160 | 5 | 0 | 0 |
| Virginia | 742 | 3.50 | 26 | 10 | 0 | 16 | 0 | 0 |
| West Virginia | 907 | 1.32 | 12 | 8 | 4 | 0 | 0 | 0 |
| **Census South** | **17,200** | **3.7%** | **630** | **340** | **188** | **104** | **0** | **0** |
| (% of the South) | | | 3.7% | 2.0% | 1.1% | 0.6% | 0% | 0% |
| **United States** | **40,200** | **9.5%** | **3,800** | **2,500** | **550** | **440** | **310** | **9** |
| (South as % of U.S.) | 43% | | 17% | 14% | 34% | 24% | 0% | 0% |

Source: Energy Information Administration. (2010h).

Wind power is the second largest renewable source of electricity in the U.S. and in the South. Among the Southern states, Texas generates the largest quantity of wind power and Oklahoma also has a significant share. West Virginia and Tennessee are the only other southern States producing at least one TBtu of wind power.

Biomass from wood and waste is the third largest renewable source of electricity both in the U.S. and the South. While Florida produces the largest quantity of biopower (50 TBtu in 2008), other Southern states, including Virginia, Maryland, and the Carolinas, also produce significant quantities. However, eight southern States produces one TBtu of biopower or less (Table. 1.3).

Completing the inventory of renewable resources for electricity production, no state in the South produces more than 0.5 TBtu of geothermal or solar/PV electricity. In contrast, the United States generated 314 TBtu of geothermal electricity comprised in 2008 (or 8% of U.S. renewable generation), and solar power generated 9 TBtu (constituting 0.2% of U.S. renewable generation).

In sum, the South’s hydropower is widely dispersed and variable across the region (Fig. 1.5). Its wind power is concentrated mostly in the West South Central division, while its biopower comes mostly from the South Atlantic region. The most populous Census Division in the South (South Atlantic) consumes the lowest percentage of power from renewable sources (Table 1.4). Its wind production is concentrated in West Virginia, and its hydro and biomass resources are small and dispersed. In contrast, the West South Central division derives more than 5% of its electricity from renewable resources, particularly from wind projects in Texas and Oklahoma.

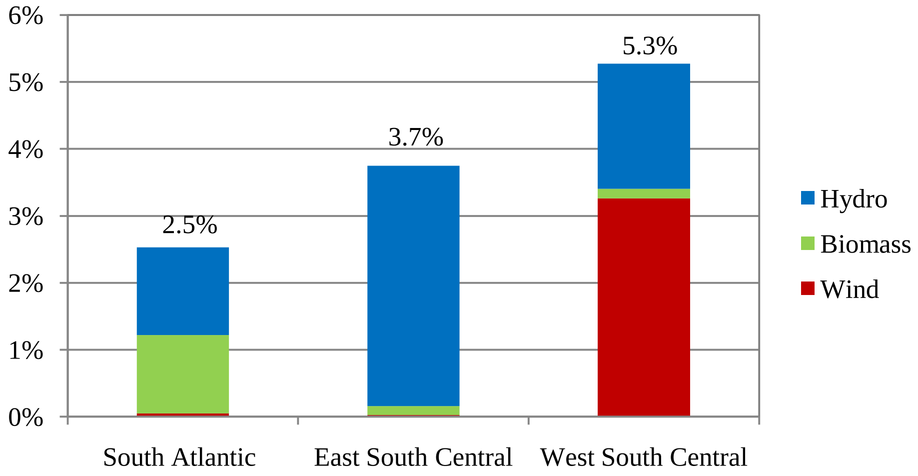

**Figure 1.5 Consumption of Electric Power from Renewable Resources, by Census Division in 2008 (as a Percent of Electric Power Consumption)**
Source: Energy Information Administration. (2010h)

**Table 1.4 Consumption of Electric Power from Renewable Resources, by Census Division in 2008 (Trillion Btu)**

| | Total Electricity | Renewable Power | Hydro-electric Power | Wind | Biomass (Wood & Waste) |
|---|---|---|---|---|---|
| South Atlantic Division | 7,790 | 196 | 102 | 4 | 91 |
| East South Central | 3,790 | 140 | 136 | 1 | 5 |
| West South Central | 5,615 | 296 | 105 | 183 | 8 |
| **Census South** | **17,195** | **632** | **341** | **188** | **104** |
| **United States** | **40,163** | **3,798** | **2,494** | **546** | **435** |

Source: Energy Information Administration. (2010h).

Recent assessments of renewable resources provide updated and more precise estimates of the cost and availability of renewable resources across the country. Table 1.5 provides updated estimates of potentials for five renewable resources in each of the 16 Southern states and the District of Columbia.

**Table 1.5. Renewable Resource Potential, by State**

| | Low-Power and Small Hydro (MW of Feasible Projects) | Wind ($km^2$ of Developable Land) | Biomass Wood & Waste (Thousand tons/year)[7] | Methane from Waste (Thousand tons/year)[8] | Solar Radiative Forcing ($kWh/m^2/day$) |
|---|---|---|---|---|---|
| Alabama | 460 | 24 | 12,000 | 340 | 4.9 |
| Arkansas | 590 | 1,840 | 12,590 | 190 | 5.1 |
| Delaware | 6 | 1.9 | 420 | 60 | 4.6 |
| DC | N/A | N/A | 56 | 1 | 4.6 |
| Florida | 79 | 0.1 | 9,210 | 500 | 5.2 |
| Georgia | 230 | 26 | 14,450 | 350 | 5.1 |
| Kentucky | 520 | 12 | 7,540 | 290 | 4.5 |
| Louisiana | 310 | 82 | 12,880 | 180 | 5.0 |
| Maryland | 91 | 300 | 1,910 | 220 | 4.6 |
| Mississippi | 300 | 0.0 | 15,790 | 170 | 5.0 |
| North Carolina | 350 | 160 | 9,920 | 810 | 5.0 |
| Oklahoma | 350 | 103,400 | 3,740 | 210 | 5.0 |
| South Carolina | 210 | 37 | 6,100 | 220 | 5.0 |
| Tennessee | 660 | 62 | 6,440 | 300 | 4.7 |
| Texas | 330 | 380,300 | 13,260 | 940 | 5.4 |
| Virginia | 420 | 360 | 6,230 | 310 | 4.8 |
| West Virginia | 480 | 380 | 2,390 | 50 | 4.3 |
| **South Total** | **5,370** | **486,900** | **134,900** | **5,140** | **-** |
| **U.S. Total** | **29,400** | **2,091,800** | **408,000** | **15,030** | **-** |
| (South as % of U.S.) | 18% | 23% | 33% | 34% | - |

Note: Numbers may not add up due to rounding.

Source: Hall, A.et al. (2006); NREL (2010d); EIA (2010h); Milbrandt, A. (2005); NREL (2010b)

## 1.2 RENEWABLE ENERGY PROGRAMS AND POLICIES IN THE SOUTH

Statewide renewable electricity standards (RES) are one of the strongest policy instruments supporting renewable power in the United States to date (REN21, 2010, p. 32; EIA, 2010i, p. 2; EIA, 2010j, p. 130). An RES is a legislative mandate requiring electricity suppliers (often referred to as “load serving entities”) in an area to employ renewable resources to produce a certain amount or percentage of power by a fixed date. Typically, electric suppliers can either generate their own renewable energy or buy renewable energy credits. This policy therefore blends the benefits of a “command and control” regulatory paradigm with a free market approach

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[7] Biomass Wood & Waste in Table 2 includes crop residues, switch grass, forest residues, mill residues, urban wood waste.

[8] Methane from Waste includes methane from landfills, manure waste, and domestic wastewater management.

to environmental protection. As of August 2010, 29 states along with the District of Columbia have an RES and an additional six states have renewable energy goals.[9]

There is no universal definition of a renewable resource. Eligible sources typically include wind, solar, ocean, tidal, geothermal, biomass, landfill gas, and small hydro. However, waste coal generation qualifies as a renewable resource in the state of Pennsylvania, and subsets of solar technologies are disallowed in other states. Several states have expanded the scope of their qualifying energy resources to include energy efficiency, and some of these allow combined heat and power (CHP) and other technologies that reuse waste heat.

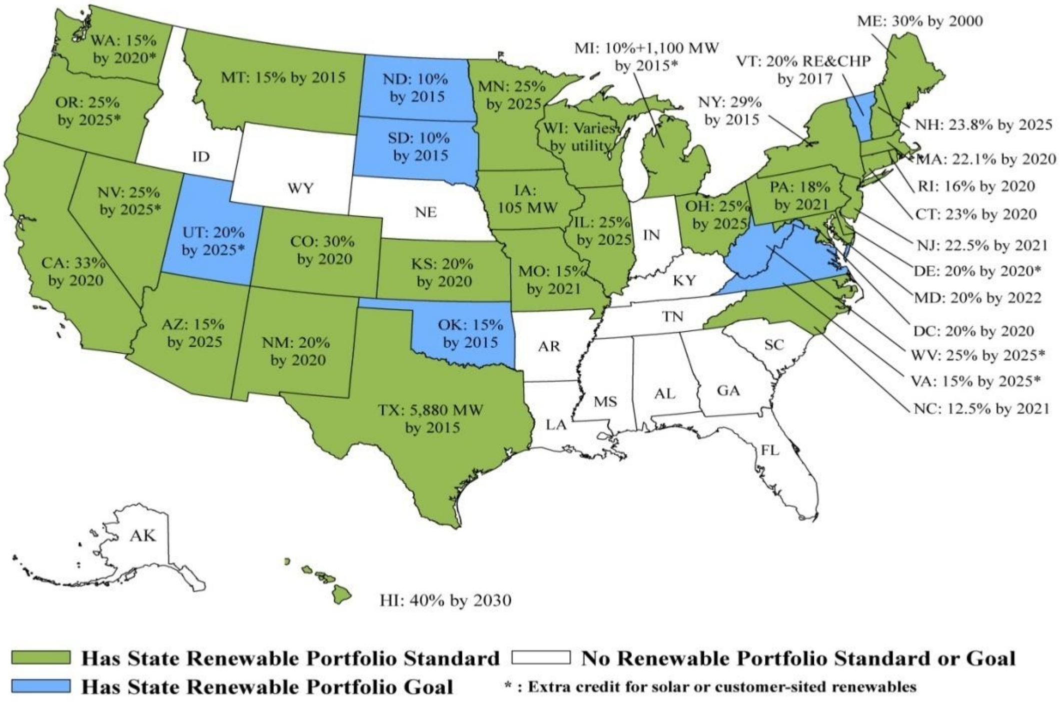

**Figure 1.6 States with Renewable Electricity Standards**

Source: Database of State Incentives for Renewable Energy (2010) http://www.dsireusa.org/.
Accessed August 17, 2010

Four states in the South along with the District of Columbia have an RES: Delaware, Maryland, North Carolina, and Texas. Oklahoma, Virginia, and West Virginia have also set voluntary renewable energy goals, as shown in Figure 1.6. The remaining nine Census South states represent the largest contiguous block of states without goals or standards for renewable power.

A Federal renewable electricity standard could reduce the regulatory confusion and administrative burdens that have resulted from the patchwork of state regulations. A Federal RES would produce a standardized regulatory environment that would provide manufacturers and

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[9] www.desireusa.org

industry with consistent and predictable business rules that are important when attempting to create national markets for green technologies.

Several recent U.S. House and Senate bills have proposed establishing a Federal RES. The American Clean Energy and Security Act of 2009 (ACESA) would require electricity providers to meet a combined renewable energy and energy efficiency standard, gradually increasing to 20% by 2020. Up to 5% can be achieved through energy efficiency, or with a governor's petition up to 8% for utilities in that state. The American Clean Energy Leadership Act of 2009 (ACELA) would require electricity providers to meet a combined 15% renewable energy and energy-efficiency standard by 2021; up to 4% can be met through energy efficiency in a given state if a governor petitions for it.

Some cities in the South have also implemented incentives for renewable power. For example, Gainesville Regional Utilities has developed a solar photovoltaic "feed-in tariff" (GRU, 2008). SHINE (Sustainable Home Initiative in the New Economy) is a residential weatherization rebate program offering City of Atlanta homeowners (single-family) the ability to receive up to a $2,000 rebate towards qualifying improvements. LEAP (Local Energy Alliance Program) is a community-based nonprofit based in North Carolina that operates a "Home Performance with Energy Star" program for the participating communities. Customer-owned renewables are promoted through these efforts.

## 1.3 NOTABLE RENEWABLE ENERGY PROJECTS AND PROGRAMS IN THE SOUTH

There is substantial development activity for renewables in the South despite the relative scarcity of renewable electricity standards. In fact, the potential for expansion of renewable energy in the South is being demonstrated by the growth of investments in renewable power projects throughout the region. SACE (2009) listed approximately a dozen activities in its report on renewable resources in the Southeast.

Additional projects have been initiated recently with funding from the American Recovery and Reinvestment Act (ARRA). An estimated $154 million of funding is dedicated to solar energy development in the South. About $5 million of funding supports wind energy development, while $14.7 million of funding is to support bioenergy developments in the South. Geothermal heat pumps have over $3 million of dedicated funding. Programs supporting multiple renewable energy technologies have over $79 million of funding. Most of the funding for these programs is due to ARRA funds. Appendix A provides a list of recent renewable energy funding programs in the South and their funding levels.

When these projects are completed, the South will have at least an additional 120 MW of solar power and 300-500 MW of biopower, more than doubling the current capacity of both. Investments in wind farms in the West South Central states have been significant, and Florida Power and Light is planning a 14 MW wind farm on Hutchinson Island. Appendix A also provides a list of existing renewable energy projects in the South, such as the world's largest wind farm, Roscoe Wind Farm, in Texas.

## 1.4 BARRIERS TO RENEWABLE ENERGY IN THE SOUTH

Despite advances in technologies, renewable power and fuels only make up about 9.5% of the nation's energy supply and only 3.2% when hydropower is excluded (EIA 2010b). While many renewable power technologies are available, the following barriers illustrate significant challenges that currently impede their full deployment. While generalizations are being made to the technology sector as a whole, the relative importance of barriers is highly variable across this diverse suite of technologies, as explained in subsequent sections of this report.

- Renewable technologies provide ***external benefits*** such as low carbon emissions and pollution that are not currently recognized in the market. Some utilities offer "green power" programs to consumers, allowing them to pay a premium to help the utility buy renewable generation. One example is TVA's Green Power Switch Program.

- Most renewable energy technologies have ***high (up-front capital) costs*** and lower (or zero) fuel costs compared to fossil fuel technologies. Capital costs for renewable energy technologies have declined considerably over the past decades, but remain a constraint to widespread market penetration. While the cost-effectiveness of renewable energy technologies does not depend integrally on fuel costs (except for biomass technologies), this risk-reduction benefit is often missing from economic comparisons (Painuly 2001).

- The dynamic environment of rapidly changing technology and energy resource costs leads to ***market risks*** associated with uncertain economics of any particular renewable technology relative to competitors. This market risk is compounded by uncertainties associated with the possible implementation of a carbon tax or national GHG cap and trade program.

- Renewable power technologies face ***infrastructure limitations*** in the form of supply chain gaps and complementary technology shortages. For example, with PV systems there is a lack of purchasing channels and trained installers. PV products are difficult to find and are often not available as complete, certified, and guaranteed systems; PV systems would benefit in the market if they could be purchased, installed, and serviced by nationwide retailers. Expansion of renewable sources for electricity production, such as wind power, will require parallel expansion in transmission capability and a general improvement in the operation of the country's electrical infrastructure.

- On-again/off-again tax credits contribute to ***fiscal uncertainty***, which could negatively reduce the incentives to boost production. In certain scenarios, developers are more likely to focus on an accelerated timetable instead of optimizing production over the long run by, for instance, investing in longer-term facility scale-up needs, systems, and personnel training. Specifically, the renewable production tax credit (PTC), which provides a tax credit for each kWh of electricity generated by qualified wind, solar, geothermal, closed-loop biomass, or poultry waste resources, has been available for the first 10 years of operation for all qualifying plants that entered service from 1992 through mid-1999. It was later extended to 2001 and 2003. With the EPAct, it was once again extended to 2007, subsequently to 2009 and now 2016.

***Interconnection requirements*** have been reformed in some states, but many states and utilities still have high backup or standby rates for small electric generating units and expensive equipment and inspection requirements that undermine these efforts. Time of use rates and other mechanisms to compensate PV and other technologies for generating electricity or reducing demand during peak periods when their generation is most valuable are not widely used.

- Renewable technologies also face ***imbalance tariffs***. The existing electric grid and utility infrastructure assume large generation sources and wide load balancing areas – making inclusion of smaller, non-continuous generation sources problematic. Imbalance penalties (tariffs) are charged by existing utilities to offset costs associated with the variability of wind and solar resources. These tariffs pose challenges to renewable power profitability.

- Renewable electricity standards that create markets for renewable energy exist in some states, but vary widely in the amount of renewable energy required and the qualifying renewable technologies – for example some recognize solar water heating and combined heat and power, while others do not. This ***uneven regulation*** can inhibit the creation of national markets for renewable technologies.

- Only nine states (including Delaware and Maryland in the South) have instituted ***rate structures*** that decouple utility compensation from the volume of their electricity sales. Without decoupling, utilities have limited financial incentives to encourage customer-owned renewable power installations – including rooftop solar photovoltaics and combined heat and power. Under traditional rate-of-return regulation, a utility's rates are based on an estimation of costs of providing service over some period of time (including an allowed rate of return) divided by an assumed amount of electricity and/or natural gas sales over that period. If actual sales are less than projected, the utility will earn a smaller return on investment and in fact could fail to recover all of its fixed costs. Thus, financial incentives favor expanding energy sales and traditional utility-scale supply-side infrastructure.

- Decision makers and the general public face ***incomplete and imperfect information*** and remain largely unfamiliar with renewable power technologies as well as their uses and benefits. Without more trustworthy information, it may be difficult to move these technologies out of niche markets.

The U.S. strategy for accelerating the deployment of renewable power and fuels reflects a mix of broad-based policies and programs as well as technology and application-specific activities. These activities include voluntary as well as regulatory approaches, and they focus on commercialization and deployment in both the government and the private sector.

Nearly 100 Federal government programs and policies encourage the deployment of renewable power and fuels in the marketplace (CCCSTI, 2009, Figure 3-7, p. 60). These activities involve tax policies and other financial incentives, reflecting the importance of external costs and upfront capital expenses in this sector. Because the rapid and large-scale penetration of renewable resources will require the close cooperation and buy-in of numerous public- and private-sector stakeholders, the strategy also includes a great deal of information outreach and partnership development: specifically, in 2008 the Federal government operated 39 labeling and information dissemination activities, 30 education, training and workforce development activities, and 27 policies and programs that involve coalition building and partnership. Market conditioning programs are also strongly represented, especially government procurement requirements. There are also 21 Federal programs that support technology demonstrations.

Based on the modest status of renewables in the South, and acknowledging all of the barriers and drivers for expanding renewables in this region, quantifiying the potential for Southern renewable electricity to grow is indeed a complicated task. Currently stimulus (ARRA) funds for renewable energy projects, utility renewable procurements, and end-use renewable projects are all growing. The ability to sustain and accelerate this progress is going to depend on societal pressures and goals associated with greater clean energy adoption, which makes exploration of the potential for expanded renewables in the South a compelling and important endeavor.

# 2. METHODOLOGY

## 2.1 MODELING RENEWABLE ENERGY RESOURCES IN THE SOUTH

Unlike most previous assessments of renewable electricity alternatives, this report includes both utility-scale and customer-owned renewable resources. Utility-scale resources are generally "dispatchable" and include generators that use wind, biomass, hydro, or solar energy to produce electricity.[10] These resources are typically integrated into the utility dispatch systems and are turned on or off depending on the system-wide demands and the economics of each resource. Customer-owned resources, in contrast, are power options that are not generally controlled by utility schedulers and dispatchers. They include power production technologies that are distributed and managed by individual power producers such as homeowners with building integrated photovoltaic arrays and industrial facilities that co-produce electricity along with thermal energy. Also included in our definition of customer-owned resources are demand-side technologies such as heat pumps that use renewable resources (such as heat in the air or ground) to produce energy services that reduce the requirement to consume electricity.

The inclusion of utility-scale and customer-owned resources distinguishes our assessment of renewable electricity potential in the South from the previous literature, which has taken a more traditional and narrower view of renewable electricity resources. To complete our assessment, we summarize the status of an array of emerging technologies that would appear to have particularly strong applicability to States in the South. These three types of renewable resources are listed in Table 2.1.

**Table 2.1 Portfolio of Renewable Energy Resources**

| Utility-Scale Resources | Customer-Owned Resources |
|---|---|
| Wind Power | Combined Heat and Power |
| Biopower | Distributed Biopower |
| Landfill Gas | Heat Pump Water Heaters |
| Hydropower | Solar Water Heaters |
| Utility-Scale Solar Power | Distributed Solar PV |

## 2.2 NATIONAL ENERGY MODELING SYSTEM (NEMS)

Our assessment of renewable electricity resources in the South uses a version of the National Energy Modeling System (NEMS). NEMS models U.S. energy markets and is the principal modeling tool used by EIA and DOE. It consists of four supply-side modules, four demand-side modules, two conversion modules, two exogenous modules, and one integrating module (Figure 2.2). NEMS is one of the most credible national modeling systems used to forecast the impacts of energy, economic, and environmental policies on the supply and demand of energy sources

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[10] Wind, run-of-river hydro, and solar are not "dispatchable" but they are integrated into grid operations as must-take resources.

and end-use sectors. Its "reference case" forecasts are based on federal, state, and local laws and regulations in affect at the time of the prediction. The baseline projections developed by NEMS are published annually in *the Annual Energy Outlook*, which is regarded as a reliable reference in the field of energy and climate policy. It is also widely utilized to conduct the sensitivity analyses of alternative energy policies and to validate research findings conducted by other government agencies including the Environmental Protection Agency, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and the Pacific Northwest National Laboratory.

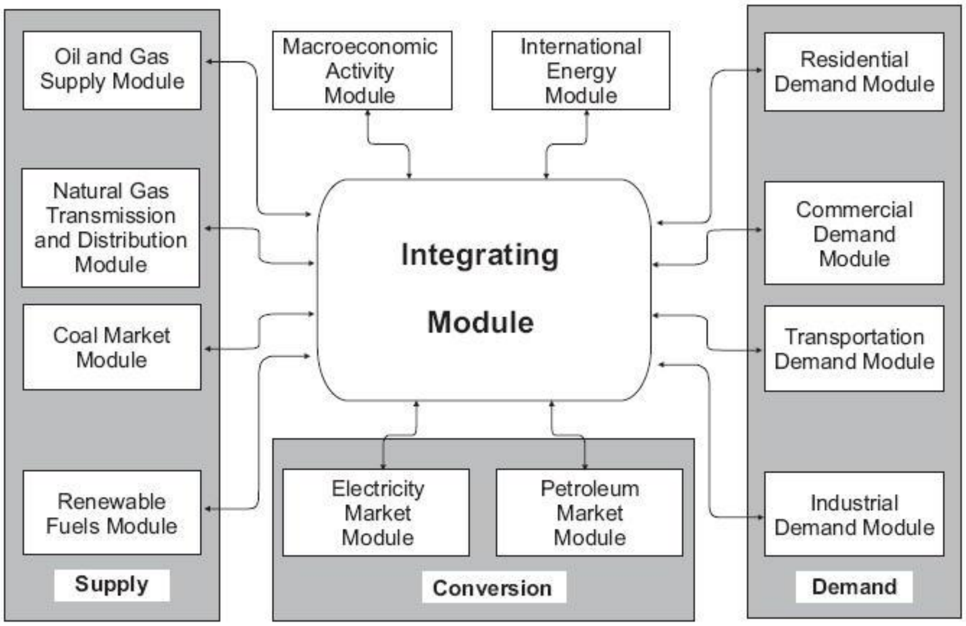

**Figure 2.2 National Energy Modeling System (NEMS)**
(EIA, 2003)

The version of NEMS used for this modeling is SNUG-NEMS, which is short for Southeast NEMS Users Group. Duke and Georgia Tech have calibrated SNUG-NEMS to the stimulus release of NEMS, in March 2009. Any references to "NEMS" in this report indicate generic attributes of EIA's model. The distinction of SNUG-NEMS is that while it uses all the same initial data as NEMS, SNUG-NEMS incorporates changes specified for this study and does not run on EIA's system.

### 2.2.1 The Reference Scenario

The starting point of our analysis is the baseline forecast (henceforth called Reference Scenario) of energy consumption for the South. This Reference Scenario for this study is derived from the updated *Annual Energy Outlook 2009* (EIA, 2009c)[11] reference projections. This Reference Scenario forecast takes into account the 2009 stimulus bill and the economic downturn in 2008 (EIA, 2009c).

This Reference Scenario portrays the South in 2030, much as it is today. It assumes that over the next 20 years, the nation remains uncommitted to climate policy, and coal continues to be an economically competitive energy resource. As such, renewable energy is expected to carry the external benefits of reduced greenhouse gas emissions and improved energy security.

Because the *AEO* 2009 includes several strong renewable energy policies promulgated in the Energy Independence and Security Act of 2007 (EISA, 2007), the American Recovery and Reinvestment Act of 2009 (ARRA, 2009), and the Troubled Asset Relief Program (TARP), it includes more naturally occurring renewable energy resources than was forecast in the *AEO* 2007. In addition, the *AEO* 2009 uses higher energy prices and a slower GDP growth rate.

## 2.3 DEFINITION OF RENEWABLE RESOURCE POTENTIAL

When evaluating the potential for any energy alternative to be deployed in future years, several types of estimates are generally used (Rufo and Coito, 2002; NYSERDA, 2003; Eldridge, Elliott, Neubauer, 2008). *Technical potential* refers to the complete penetration of all renewable resources that are technologically feasible, regardless of economic cost-effectiveness. *Economic potential* is defined as that portion of the technical potential that is judged cost-effective. While this is a useful way to frame the current potential, it includes investments that will not occur because decision-makers cannot be assumed to make optimal decisions every time a technology or practice is selected. *Program achievable potential* is defined as the amount of cost-effective (economic) potential that would occur in response to specific policies such as subsidies and information dissemination. It recognizes that the full economic potential is difficult to achieve, but that effective policies and programs can cause much of the cost-effective potential to be realized. As such, program achievable potential is the focus of our analysis.

The nature of the policies assumed for each renewable resource is described in each of the following chapters and is summarized in Table 2.1. In general, the customer-owned renewable resources were incentivized by providing the equivalent of a 30% investment tax credit (ITC), providing them with a subsidy analogous to the production tax credit that incentivizes many of the utility-scale renewable electricity technologies.

### 2.3.1 Levelized Costs and other Cost-Effectiveness Tests

A number of economic approaches have been used to measure the cost-effectiveness of renewable electricity options. One common test is levelized cost, which allows demand- and supply side options to be compared on an equivalent economic basis. It also allows the results of this study to be compared with the findings of the levelized cost of conventional sources of electricity, as estimated by Borin, Levin, and Thomas (2010).

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[11] The AEO 2009 was released three times. The final version, the "updated AEO 2009" is the one that will be discussed as the basis for the Baseline Scenario throughout this document.

## 2.4 SCENARIOS

The four scenarios used for the integrated analysis include the following:

- **Reference Scenario:** The baseline forecast consistent with EIA's stimulus data setup.
- **Expanded Renewables:** This scenario uses updated estimates of wind and hydropower renewable resources, more realistic cost trajectories for solar PV systems, accelerated R&D, and extensions of renewable tax credits.
- **Renewable Electricity Standard (RES):** This scenario models a Federal requirement of 25% renewable electricity production by 2025. The scenario exempts small retailers from the RES mandate and excludes hydroelectric power and municipal solid waste from the sales baseline.
- **Carbon-Constrained Future (CCF):** This scenario adjusts the Reference Scenario by adding a carbon price of $15 (in $2005) per metric ton of carbon dioxide in 2012 growing annually at 7%. Allowances are redistributed to load serving entities as described below, and there are no carbon offsets.

Each of these scenarios is discussed in more detail below. In addition to analyzing the four scenarios individually, we combine the RES and CCF scenarios in combination with the Expanded Renewables scenario in order to examine how they might operate together. These are called the +RES and +CCF scenarios.

## 2.5 SCENARIO: EXPANDED RENEWABLES

This scenario uses updated estimates of wind and hydropower renewable resources in the South drawn from McConnell, Hadley, and Yu (2010) and other sources. It also adjusts the cost forecast for solar resources to better reflect published estimates. In addition, it considers several policies – including accelerated R&D and extensions of tax credits – where increased renewable utilization is a policy goal. Additional information on the "Expanded Renewables" scenario can be found in the individual chapters. Specifically, Chapter 3 on "Wind Power" describes the Expanded Wind scenario, Chapter 4 on "Biopower" describes the Expanded Biopower scenario, etc. When each of these individual enhanced renewable scenarios are put together, they comprise the "Expanded Renewables" scenario. Table 2.2 summarizes the assumptions that are specific to each renewable resource.

| **Table 2.2 Expanded Renewable Scenario Assumptions & Resource Updates*** |
|---|
| **Wind**<br>• Increased wind resource availability by updating wind resources to those measured at 80-meter heights instead of those at 50-meter heights used in NEMS. |
| **Biopower**<br>• State sales tax exemption for biomass.<br>• A Production Tax Credit (PTC) of 0.9¢/kWh for biopower is extended from 2011 to 2030.<br>• Heat rate of the biomass integrated gasification combined cycle (BIGCC) decreases by 1.76% year over year until 2030, rather than only until 2022. |
| **Municipal Waste**<br>• Starting at 50% in 2010, the recycling rate of the municipal waste is assumed to increase an additional 1% annually between 2011 and 2030. |
| **Hydropower**<br>• The levelized cost is assumed to be 10¢/kWh for every feasible hydro project in each state.<br>• Enhanced resource availability based on INEL report. |
| **Residential and Commercial Solar Photovoltaic Systems**<br>• Reduced capital cost for PV modules and investment for rooftop PV systems relative to NEMS assumptions.  From 2011 to 2030, the residential system costs decrease by 53% while the commercial system costs decrease by 57% in SNUG-NEMS.<br>• A 30% tax credit, expiring in 2016, is extended to 2030 for rooftop PV. |
| **Utility-Scale Solar**<br>• The efficiency (sunlight to electricity conversion rate) increases by an additional 2% every five years from 2011 to 2030. |
| **Solar Water Heaters**<br>• A 30% tax credit, expiring in 2016, is extended to 2030. |
| **Heat Pump Water Heaters**<br>• A 30% tax credit, expiring in 2010, is extended to 2030. |
| **Combined Heat and Power**<br>• A 30% Investment Tax Credit (ITC), higher than the current 10% ITC expiring in 2016, extended to 2030.<br>• The overall efficiency of CHP systems improved by an additional 0.7% annually (without any additional increase in installation costs). For instance, a new 25 MW gas turbine running a combined cycle mode is assumed to improve to 77% efficiency in 2020 and 82% in 2030. Additional R&D funding annually for 10 years beginning in 2011. |

*The basis of these assumptions is described in subsequent, technology-specific chapters.

## 2.6 SCENARIO: RENEWABLE ELECTRICITY STANDARD

In the U.S., renewable electricity standards are mandated on a state-by-state basis. As of June 2010, 29 states along with the District of Columbia have an RES and an additional seven states have voluntary renewable energy goals as opposed to strict requirements.[12] Contrary to enabling a well-functioning national renewable energy market, however, inconsistencies between states over what counts as renewable energy, when it has to come online, how large it has to be, where it must be delivered, and how it may be traded complicate the renewable energy market. Studies have shown that while some state RES policies have shortcomings, they have on average had a significant positive impact on total in-state renewable electricity investment and generation (Carley 2009; Yin and Powers 2010).

To reduce state-by-state inconsistencies and further accelerate the growth of renewable power production, the U.S. Congress is considering implementation of a national standard. Recent Congressional proposals tend to be consistent with President Obama's campaign platform in 2008, which included a commitment to 25% renewable electricity production by 2025. Responding to requests from Chairman Edward Markey, for an analysis of a 25% Federal RES, the EIA released a report in 2009 entitled "Impacts of a 25-Percent Renewable Electricity Standard as Proposed in the American Clean Energy and Security Act Discussion Draft" in 2009. The EIA's scenario for the analysis exempted small retailers from the RES mandate and excluded hydroelectric power and municipal solid waste from the sales baseline. We use the same code for modeling a national RES as was used in this EIA (2009) report.

## 2.7 SCENARIO: CARBON CONSTRAINED FUTURE

We approximate the impact of a carbon constraint by adjusting several parameters in SNUG-NEMS. First, after examining the allowance price projections estimated by the Energy Information Administration (EIA), Congressional Budget Office (CBO), Environmental Protection Agency (EPA), and Natural Resource Defense Council (NRDC), we set a carbon price starting at $15 per ton of carbon dioxide (2005 dollars) in 2012, growing at 7% annually, and reaching $51 per ton in 2030.

Since completing our analysis using these values, EPA (2010a) has published a report on the "social cost of carbon" (SCC) – that is, an estimate of the monetized damages caused by each incremental ton of $CO_2$ emitted. The SCC values described in this EPA report are central value estimates of the U.S. Government Interagency Working Group on the Social Cost of Carbon. These central value estimates range from $23/metric ton of $CO_2$ in 2011 to $34/metric ton and $47/metric ton in 2030 and 2050, respectively (all values are in 2008 dollars). Interestingly, these SCC values are similar to the allowance price projections that we used, based on the Energy Information Administration (EIA, 2009) estimates of allowance prices.

We implemented an allowance redistribution system that gives 34% of allowances to local distribution companies (LDCs) starting in 2013, this share decreases linearly to 26% until 2026. From 2027 on, this share drops by 5% annually. In 2030, which is the last year of our study

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[12] www.dsireusa.org

horizon, the allowances allocated to LDCs are 5%.[13] The allowances given to the LDC are assumed to be passed through to consumers and reduce the escalation of retail electricity prices. Table B.1 in Appendix B specifies the annual share of allowances that are given to LDC.

We do not model the impact of domestic and international carbon offsets, but if they were to be included, the cost of the CCF scenario would be lower. Therefore, we must note that this CCF scenario measures the modeling effect of combining expanded renewables with a carbon constraint, but does not capture increased investment or public interest in renewable resources that would likely accompany a mandated constraint on carbon emissions.

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[13] This allowance allocation was suggested by EIA and is similar to their approach for current legislative analyses.

## 3. WIND POWER

This chapter takes an isolated view of wind potential in the South. Wind will be discussed in the context of all of the renewable fuels in the integrated chapter, chapter 10.

### 3.1 INTRODUCTION

Wind is a renewable resource that can be converted into useful forms of energy, as in the case of using a turbine to generate electricity. Wind energy has demonstrated robust market growth in recent years: from 2004 to 2008, global wind capacity grew by 250 percent. In 2009, the United States led the world in added and total wind power capacity, surpassing long-time wind power leader, Germany. Net installed capacity of wind power in the U.S. increased by 39 percent in 2009, equal to nearly 10 gigawatts.[14] In 2009, the USA and China together represented 38% of the global wind capacity in the world, and the top five countries (USA, China, Germany, Spain and India) represented 73% (WWEA, 2010).

In considering the potential for expanding these wind resources, it is important to note that wind is only economically extractable at a site where the wind exceeds certain threshold speeds. The U.S. Department of Energy states that for an area to be suitable for wind energy development, it must have an average annual wind speed of at least 6.5 m/s at a height of 80 meters above the ground (U.S. Department of Energy 2010d).

***Box 3.1 Roscoe Wind Farm- Texas***

**Capacity:** **781.5 MW**
**Location:** **Roscoe, Texas**
**Operating Since: 2009**

Since October 2009, the largest wind farm in the world has been operating in Roscoe, Texas, about 200 miles west of Fort Worth. The farm covers nearly 100,000 acres, contains 627 turbines, and produces enough power for about 250,000 homes.

Picture from Roscoe Wind Council, 2007

Sources: Renewable Energy World, 2009; Reuters, 2009

### 3.2 WIND POWER IN THE SOUTH

In 2007, wind generated 12 billion kWh in the NERC South, which was 28% of the total electricity generated from renewable resources in the region that year (EIA, 2009). This makes wind the second largest renewable resource, after conventional hydropower, in this area. The Energy Information Administration (EIA) projects wind power in the South to expand to 39 billion kWh in 2020 and to remain constant through the following decade. The total electricity generated from wind in the U.S. is projected to increase rapidly from 112 billion kWh in 2010 to 200 billion kWh in 2020, followed by a modest increase to 205 billion kWh in 2030.

The EIA projection also suggests that wind energy generation in the South does not grow as fast as it

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[14] "U.S. Wind Energy Industry Breaks All Records,
Installs Nearly 10,000 MW in 2009," American Wind Energy Association (January 26, 2010), web site www.awea.org/newsroom/releases/01-26-10_AWEA_Q4_and_Year-End_Report_Release.html.

does in the rest of the country. In 2007, 37% of the national total electricity generated from wind (32 billion kWh) is from the South. However, the South's share decreases to 20% in 2020.

Existing and developing wind energy projects in the South are located mostly in Texas, Oklahoma, and Missouri. However, there are plans for wind development in the Southeast. For example, Florida Power and Light is planning a 14 MW wind farm on Hutchinson Island (SACE 2009). Section 1.4 of Appendix A describes several other current wind projects in the South.

U.S. Secretary of the Interior Ken Salazar and the governors of ten East Coast states recently signed a Memorandum of Understanding, establishing an Atlantic Offshore Wind Energy Consortium in order to promote the development of wind resources on the Outer Continental Shelf. The ten states are Maine, New Hampshire, Massachusetts, Rhode Island, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina (U.S. Department of Interior, 2010). In addition, the University of Delaware and the National Renewable Energy Laboratory are developing a research site for offshore wind, where companies can build and test emerging offshore wind technologies. The test site will likely be developed within three miles of the Delaware coast, in state-administered waters,[15] near to NRG Bluewater Wind's proposed offshore wind park.[16]

## 3.3 BARRIERS, DRIVERS, AND POLICIES

The potential for growth in electricity generation from wind power depends on a variety of factors, including capital costs, pricing rules, technology improvements, access to transmission grids, public concerns about environmental and other impacts, and the future of the federal PTC for wind. The PTC provides an income tax credit of 2.1 cents/kWh for utility-scale wind production, through the end of 2012. State policies also have a tremendous effect on the economic viability of wind generation. One of the biggest drivers to date of wind development has been the state level RES. In the last ten years, 61% of the wind power capacity built has been in states with an RES policy. Mandating that a portion of electricity generation come from renewable sources clearly provides a boost for wind energy development (Bolinger, Wiser 2010). However, as noted in Chapter 1, of the 29 states with an RES, only four of them are in the South.

This section focuses on the numerous barriers that impede the development of wind energy. At the same time, it is important to note that many factors are causing wind power to succeed in the market. Even utilities not subject to mandates are buying wind power, as in Oklahoma and Tennessee, because it offers stable pricing, a hedge against fuel price risk, can be added quickly in small increments, can be sold into voluntary green power markets, creates carbon reduction credits, and is good for marketing. In addition, as we will see, the cost premium for wind is not large relative to the cost of conventional electricity resources that bring their own development risks.

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[15] http://www.offshorewind.biz/2010/06/14/university-of-delaware-and-national-renewable-energy-laboratory-to-develop-research-site-for-offshore-wind-energy-usa/

[16] bluewaterwind.com/delaware.htm

### *Box 3.2 Proposed Off-shore Wind Project: Bluewater Wind - Delaware*

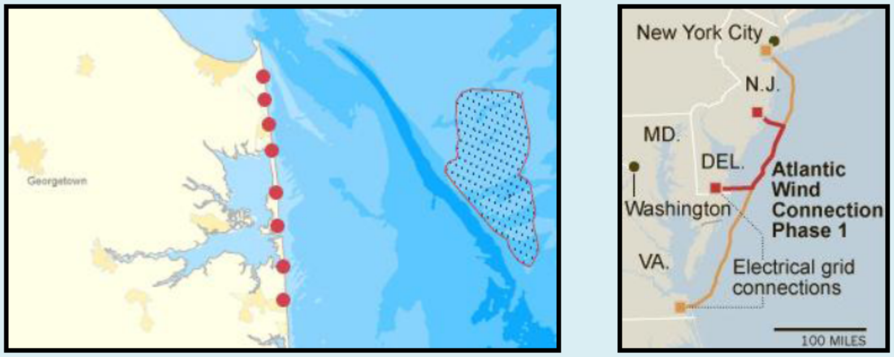
**Nameplate Capacity:** **450 MW**
**Location:** **13 miles off Delaware's shore**
**Estimated Operation:** **May 2016**

In 2008, Bluewater Wind signed a power purchase agreement with Delmarva Power for 200 MW of capacity and stable priced electricity for 25 years. It is the only off-shore wind project that has sought permission to build in federal waters.

The wind park is planned to be located 13 miles offshore, east of the Delaware Seashore State Park (See figure below to the left). The development would provide enough electricity to supply up to 100,000 Delaware households.

The 28 U.S. coastal states consume 78% of the nation's electricity. Off-shore wind projects allow electricity generation to be close to the area of greatest use, reducing the need for long transmission lines. This project in Delaware would have similar benefits in overcoming transmission barriers.

The proposed Atlantic Wind Connection, a five billion dollar project to create a transmission "spine" for off-shore wind farms along the Atlantic coast, could further address transmission issues for off-shore wind farms. Current plans propose a backbone cable with a transmission capacity of 6,000 MW that runs from northern New Jersey to Norfolk, Virginia (See figure below to the right). It would connect to off-shore projects along the way, likely including the Bluewater Wind park in Delaware. The red highlighted section between northern New Jersey and Rehoboth Beach, Delaware, is the proposed first phase of the project to be completed as early as 2016.



Pictures from NRG Bluewater Wind, 2010; NYTimes, 2010
Sources: Hanes, 2010; NRG Bluewater Wind, 2010; NYTimes, 2010; Delaware Offshore, 2008

**Initial Capital Cost.** Like many forms of renewable energy, most of the costs are capital rather than fuel based. Even though avoided fuel costs and low operating costs may make wind energy cost-competitive on a life-cycle basis, the higher initial capital costs may prevent more investment from flowing to the wind sector (Beck, Martinot 2004). However, as political and social support for renewable energy sources gains momentum, investments in wind power should continue to increase. As demand grows for wind, economies of scale and technological breakthroughs are expected to bring down the capital costs.

**Unfavorable Pricing Rules.** Wind energy may be charged higher transmission costs than conventional technologies or may be subject to other discriminatory grid policies. A system that requires generators to reserve a block of capacity in advance may force intermittent generators, like wind, to pay for the maximum output they can generate at any moment. However, a wind farm produces, on average, only about a third of the time. Wind generators could have to pay three times more per kilowatt hour transmitted than a conventional plant designed to generate at full capacity all the time (Nogee et al., 1999).

Also, because of wind's intermittency, utilities cannot count on the power at any given time and therefore offer a lower capacity payment for wind. One of two payment strategies is usually followed by utilities. They either only pay the wind energy generator for the "energy value", but not the "capacity value" of the generation, or pay an average price at peak times, which understates the value of the power (Beck, Martinot 2004). Although wind can bid into the real time market and potentially receive peak prices, they usually are relegated to these payment types.

**Transmission Barriers.** Unlike conventional sources of energy that can be transported from location to location, such as coal, petroleum or natural gas, wind must be harnessed where it can be found. This is often in remote areas. This makes wind power heavily dependent on transmission lines. However, historically the transmission systems have been built and transmission policies have been written to deliver power from conventional resources (American Wind Energy Association, 2000). Building new transmission capacity to connect often remote wind generation facilities is very capital intensive. In addition, most of the existing transmission policies assume that the generators are able to predict and control their generation. This is extremely hard for wind power generators due to the intermittent nature of wind. For these reasons, the existing transmission system is not structured to provide favorable transmission access for wind energy providers.

**Legal and Regulatory Barriers.** Wind turbines may be subject to building restrictions due to concerns related to height, aesthetics, and/or the environmental concerns related to siting along migratory birds path and coastal areas (Beck and Martinot, 2004). Land use issues are often brought up when construction of a wind farm competes with agricultural, recreational and scenic interests. In conjunction with these issues, urban planners may not be familiar with wind farm development. As such, well designed siting and permitting procedures have yet to be established in many areas.

## 3.4 EXPANDED WIND

### 3.4.1 The Case for Expanded Wind

In this study we are calling our wind focused modeling the "Expanded Wind" scenario. This scenario assumes that the wind resource available for development is larger than has been previously recognized by EIA. We assume hub-heights of 80 meters. However, there are no changes to policy or regulation assumed in our scenario. It is simply an expansion of the windy land area available for development due to advancements in wind generation technology.

The Expanded Wind scenario reflects the vision that all new wind installations are built upon an industry standard that takes advantage of the most advanced and efficient wind generation technology available, including turbines with hub heights of 80 meters or higher. Turbines of this size are now standard in the industry. According to the Department of Defense 2009 *Wind Technologies Market Report,* "…average hub heights and rotor diameters have also scaled with time, to 78.8 and 81.6 meters, respectively, in 2009. Since 1998-99, the average turbine hub height has increased by 40%, while the average rotor diameter has increased by 69%" (Bolinger and Wiser 2010). The hub height is the distance from the ground to the center-line of the turbine rotor. These large turbines incur higher construction costs than do smaller scale wind generation technologies, but they also generate more electricity. This is because wind speed is higher and blows more consistently at higher hub heights. This relationship results in similar per kW costs for larger turbines at higher elevation as for smaller, lower wind turbines.

It is important to note that our Expanded Wind scenario does not address the economic viability of offshore wind. Global offshore wind capacity reached only 1.5 GW in 2008, virtually all of it in Europe and none in the United States. Nevertheless, offshore wind is experiencing strong growth, with 200 megawatts (MW) added globally in 2007 and 360 MW in 2008 (REN21, 2009). Experts and advocates have argued that offshore wind possesses important advantages: wind turbines can be placed out of sight, with minimal noise obstruction, where winds blow faster, and near to urban markets. At the same time, offshore development faces the challenge of inadequate and costly deep-water substructures and service environments that are challenged by severe ocean conditions, as well as expensive, high-voltage underwater transmission cables. Offshore wind also faces numerous regulatory issues dealing with siting and imbalance penalties in the United States (Snyder and Keiser, 2009). While deep-water costs may remain noncompetitive over the next decade or two, shallow water wind farms have been forecast to reach grid parity in 2020 (Musial and Butterfield, 2004; Musial, Butterfield, and Ram, 2006).

The reference SNUG-NEMS forecast suggests that offshore wind is too expensive to be developed in any capacity over the next twenty years. Therefore, we do not attempt to model any policies or incentives in our Expanded Wind scenario that might bring down the costs of offshore wind. Nonetheless, other studies have stated that the electricity generation potential of offshore wind along the Southeast coastline is very large, and that costs are coming down. This optimism is reflected in a Memorandum of Understanding recently signed by U.S. Secretary of the Interior Ken Salazar and the governors of ten East Coast states recognize this potential and. The MOU establishes an Atlantic Offshore Wind Energy Consortium in order to promote the development of wind resources on the Outer Continental Shelf (U.S. Department of Interior, 2010). In addition, the University of Delaware and the National Renewable Energy Laboratory are developing a research site for offshore wind, where companies can build and test emerging offshore wind technologies. The test site will likely be developed within three miles of the Delaware coast, in state-administered waters,[17] near to NRG Bluewater Wind's proposed offshore wind park.[18]

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[17] http://www.offshorewind.biz/2010/06/14/university-of-delaware-and-national-renewable-energy-laboratory-to-develop-research-site-for-offshore-wind-energy-usa/

[18] bluewaterwind.com/delaware.htm

### 3.4.2 Modeling Scenario Assumptions

The EIA uses NEMS to forecast renewable energy resource levels, as well as electricity generation and generating capacity. The Wind Energy Submodule (WES) within the Renewable Fuels Module in NEMS uses an input file called *wesarea*. This file contains, for each NERC region, the amount of windy land area (in km$^2$) available for wind development in wind classes 4, 5 and 6.[19] The windy area included in these three wind classes is considered economical for development because the wind is consistent enough and the speed is fast enough to turn a turbine to generate electricity. The EIA's data is based on a wind turbine hub height of 50 meters. However, as mentioned previously, the current utility scale wind turbine sits 80 meters or more above the ground. It is well established that as elevation above the ground increases, so does the velocity of the wind (on average), and the power produced by wind is a function of this velocity cubed. Therefore, land area that is unsuitable for wind development using 50 meter turbines may in fact be viable using 80 meter turbines. As such, the EIA's available windy land data is very likely underestimating the availability of wind resources, not only in the South but across the country.

The National Renewable Energy Laboratory (NREL) and AWS Truewind Co. have developed a new dataset that examines the wind resource at 80 meters. Significantly more windy land becomes available in the new dataset due to the increased elevation. For the Expanded Wind scenario, we update EIA's current assumption about available windy area in the SNUG-NEMS input file using this new dataset. Appendix C describes the methodology of updating the windy area inputs. Table 3.1 compares the available windy area data at 50 and 80 meters. With the exception of Florida, all Southern NERC regions see orders of magnitude increases of available windy land area suitable for economical development, across each wind class. The sole exception is class 4 wind in the Southern Power Pool (SPP). Here, most of the windy land EIA labels class 4 is upgraded to higher classes, resulting in a decrease in the class 4 area available.

**Table 3.1 Windy Area in the South with 50-meter and 80-meter data (km$^2$)**

| NERC Region | Class 4 | | Class 5 | | Class 6 | |
|---|---|---|---|---|---|---|
| | 50m | 80m | 50m | 80m | 50m | 80m |
| **ERCOT** | 200 | 101,000 | 680 | 91,000 | 260 | 108,000 |
| **FL** | 0 | 0 | 0 | 0 | 0 | 0 |
| **SERC** | 380 | 18,000 | 100 | 6,600 | 74 | 1,300 |
| **SPP** | 118,000 | 44,000 | 110 | 80,000 | 7 | 218,000 |
| **Total[20] (km$^2$)** | 119,000 | 163,000 | 900 | 117,000 | 340 | 328,000 |

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[19] See Appendix C for a description of wind classes 4, 5, and 6.

[20] Columns may not sum to total due to rounding.

## 3.5 EXPANDED WIND SCENARIO RESULTS

Increasing the available windy land area has a dramatic affect on the amount of wind generation forecast by SNUG-NEMS. Figure 3.1 below shows that our Expanded Wind scenario predicts a marked increase in wind generation for all the Southern NERC regions but SERC in 2030. One thing to note is that Florida is expected to get over 20% of its electricity from wind generation, even though there is no windy land area suitable for development in Florida (see Table 3.1). This is due to the fact that it is less expensive for Florida to import electricity generated from wind than it is to generate its own electricity from natural gas or coal. Wind in SERC cannot compete with cheap coal, except in the case where it is exported to Florida. Figure 3.1 shows that the Expanded Wind scenario leads to as much as 12% of electricity generated in the South coming from wind in 2030, as opposed to the 2% forecast in the reference case.

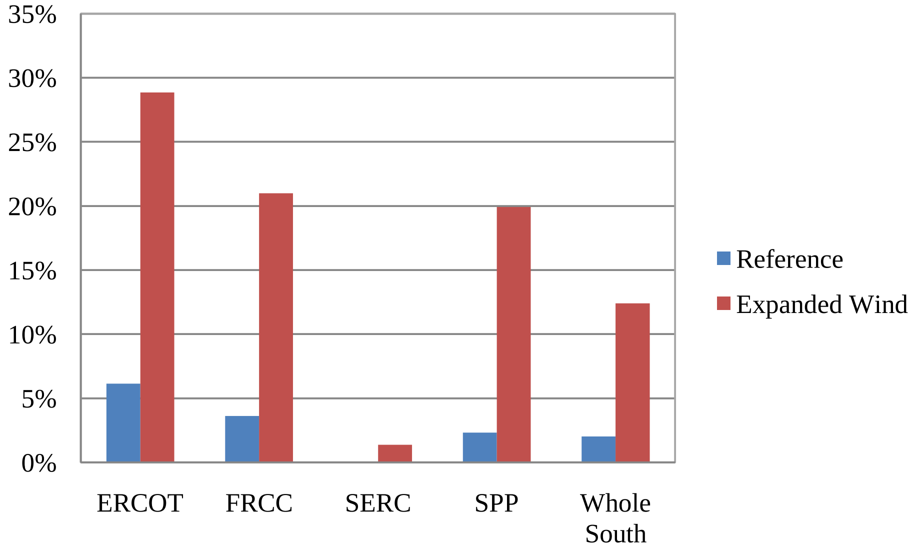

**Figure 3.1 Wind as Percent of Total Electricity Generation in 2030**

Figure 3.2 below depicts the regional distribution of wind resources in the South and the resulting generation forecast in our Expanded Wind scenario. Most of the wind resource is in the western South, particularly in Texas. The figure shows that in 2030 Texas could provide over 110 billion kWh of wind generation. This is roughly five times the generation forecast in the reference scenario.

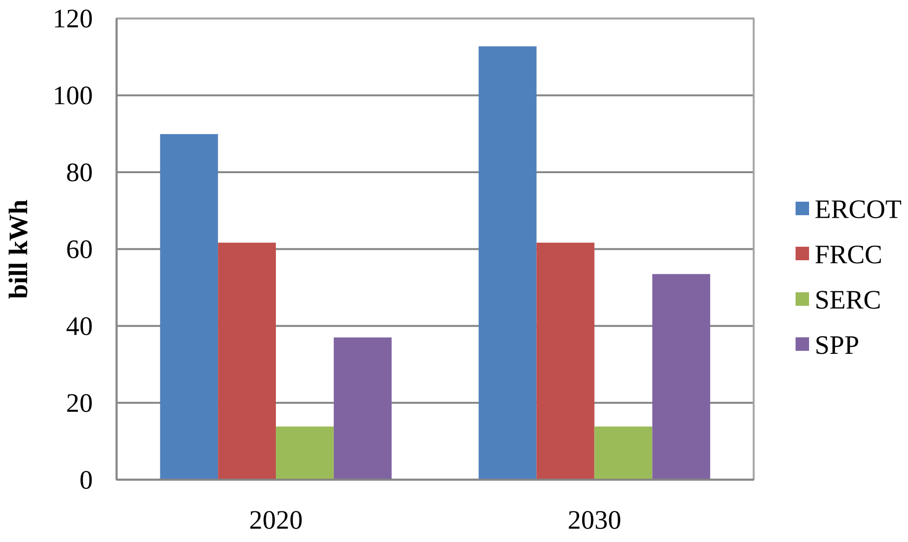

**Figure 3.2 Expanded Wind Generation in 2030**

The absolute changes for each region can be seen in Table 3.2 below. It shows that wind could comprise nearly 30% of electricity generation in Texas, up from 6% forecast in the reference scenario. Two of the three other regions could also experience large increases in the relative amount of wind generation.

**Table 3.2 Wind as Percentage of Generation in 2030**

| | Reference (billion kWh) | | | Expanded Wind (billion kWh) | | |
|---|---|---|---|---|---|---|
| NERC Region | Total | Wind | Percent | Total | Wind | Percent |
| ERCOT | 373 | 23 | 6% | 391 | 113 | 29% |
| FRCC | 292 | 11 | 4% | 293 | 62 | 21% |
| SERC | 1018 | 0 | 0% | 997 | 14 | 1% |
| SPP | 230 | 5 | 2% | 269 | 54 | 20% |

## 3.6 COST EFFECTIVENESS

SNUG-NEMS considers alternative generation sources when choosing which and how much of each renewable source will be developed. Whether renewable or fossil based, each generation type must be cost-competitive to be selected by the model, given the supply and demand constraints of the system. We have calculated the levelized cost of electricity (LCOE) for new wind turbines in our Expanded Wind scenario. Our study finds that the LCOE for wind generation in the South ranges from 6.1 to 8.5 cents/kWh. This range represents the differences in capacity factors realized, and capital costs required, for wind projects in the different regions of the South. For wind power generation, capacity factor is the ratio of actual power generated over a time interval to the power that would be produced if the turbine operated at maximum output 100% of that time interval (AWEA 2010). Capital costs also vary, but the difference in levelized cost is attributable mainly to capacity factor. These cost estimates include the current federal production tax credit, which is set to expire on December 31, 2012. When comparing the cost range for wind to the LCOE of other renewable sources (see Chapter 10), we see that wind generation is relatively inexpensive. The relatively low cost of wind generation makes it a logical choice for expansion of renewable generation by the model.

## 3.7 CONCLUSIONS

This chapter has examined expanded wind power in the South in an isolated scenario. This expansion results in large increases in forecasted wind generation in the South, particularly in the western portion of the region. For example, Texas could supply nearly 30% of its total electricity generation by wind in 2030. This is up from 6% in the reference forecast. Similar gains are possible in the SPP NERC region and in Florida. These updated estimates reflect the reality that wind generation technology has advanced beyond the levels upon which previous assessments were based. We have illustrated here that there is a large, inexpensive wind resource in the South. But the potential of this resource can only be realized if the barriers laid out in this chapter are effectively addressed. In particular, transmission limitations are likely to be the largest hurdle to be overcome.

While our analysis doesn’t address offshore wind, we recognize that this is an emerging resource that may become very important in the near future. The reference forecast shows no offshore wind generation before 2030, suggesting that it is simply too expensive to compete with other fuels. However, EIA assumptions about the costs associated with development of offshore wind may be outdated. We briefly explore the topic of offshore wind in Appendix B, and it is also discussed in McConnell, Hadley, and Xu (2010) and SACE (2009).

It is important to note that the results presented here are based upon an expansion of wind that does not consider the interactive effects related to growing markets for other renewable resources. For further analysis of how wind fares when part of an integrated portfolio of expanded renewable fuels, please see Chapter 10.

# 4. BIOPOWER

## 4.1 INTRODUCTION

Biomass as a renewable energy resource has received increased attention in the search for clean, renewable energy alternatives. Worldwide, biomass combustion (including cogeneration) accounts for approximately 52 GW of electric power capacity, and both large and small-scale systems have been expanding, with 2 GW of power capacity added in 2008 (REN21, 2009, Table R1).

Biomass can be (1) used as fuel for direct combustion or cofired with coal, (2) gasified, or (3) used in biochemical conversions. Because of the wide range of feedstocks, biomass has a broad geographic distribution. If a national RES target were to be set, some estimate that a majority of the growth in renewable electricity would come from electricity generated from wood and other biomass (Brown and Baek, 2010; EIA, 2009b). However, other analysis shows very little biopower growth, relative to wind (NREL, 2010f). The possible dominance of biomass is due to its dispatchability and the relatively low capital and operating costs it requires to generate electricity. In addition, compared to other renewable resources, the feedstock is readily provided in terms of gross supply and ease of delivery. Regionally, the South has a potential to supply over 35% of the nation's biomass energy resource[21]. However, while biopower provided 1.1% of the total national electricity generation in 2008, the South produced only 0.6% of its total electricity from biomass.

## 4.2 BIOPOWER IN THE SOUTH

The current availability of biomass resources in the South is shown in Figure 4.1. Clearly, solid waste from mill, forest, and agricultural sources is dominant. The mill and forest residues account for 50% of biomass resources, and supply biomass stably with less seasonal variations than energy crops and agricultural residues. Some industries such as the pulp and paper industry operate their own electricity generators to recycle their waste and produce electricity on site. The electricity generation from the landfill gas is analyzed separately in Chapter 5.

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[21] Approximated by the authors with data from Milbrant, A. (2005)

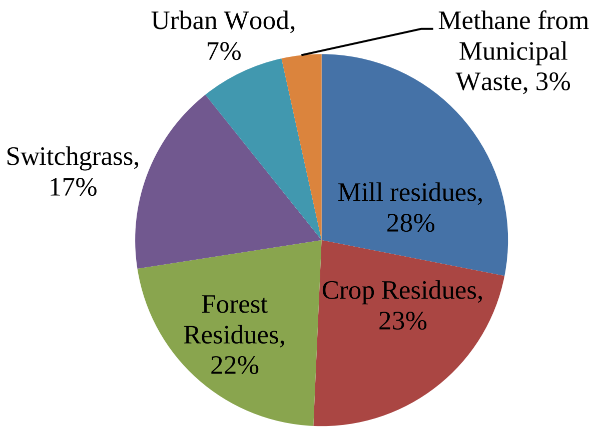

**Figure 4.1 Southern States' Biomass Availabilities (Source: Milbrandt, A., 2005)**

Using heat content values from best engineering estimates for heat rates and a 70% capacity factor, the maximum achievable potential of biopower is approximated with data of Milbrant A. (2005) by Ben McConnell at Oak Ridge National Laboratory. Figure 4.2 shows that the maximum achievable potential of biopower in the South is 165 TWh. Clearly, not all available biomass would be used for power generation, but in keeping with the national goals set by the Biomass R&D Technical Advisory Committee, about 5% of electricity generation in the South is approximated to be met using biomass as a primary fuel.

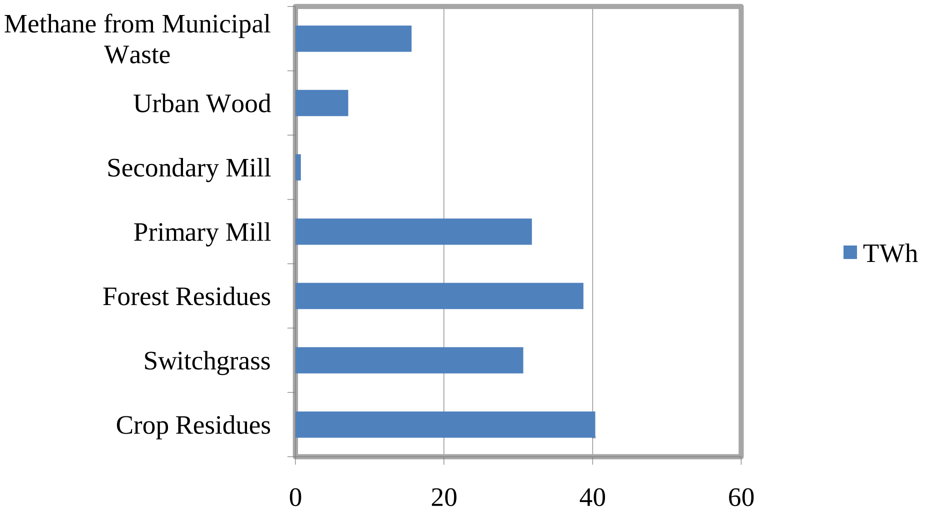

**Figure 4.2 Approximation of Biopower Potential by Source in the South**

***Box 4.1 ADAGE Biopower Facility***

**Nameplate Capacity:** **50MW**
**Location:** **Hamilton County, Florida**
**Estimated Operation:** **Mid 2012**

In 2009, ADAGE LLC, a joint venture between AREVA SA and Duke Energy Company, announced their plans to construct the first of a series of 50 MW biopower plants in Hamilton County, Florida. The site will use wood waste to generate electricity.

ADAGE has secured a 215-acre site in Hamilton County and received its air resource permit from the Florida Department of Environmental Protection.

Construction on the project is expected to begin in 2010 and require 24-30 months for completion. Due to the planned technologies, the site would use 90% less water and produce fewer emissions than other biopower plants in the nation once complete.

The facility is expected to create approximately 400 jobs during construction and 120 facility and fuel-related jobs during operation. The plant would provide renewable electricity to around 40,000 households in Florida once generation begins.

Picture from ADAGE, 2009 Sources: ADAGE, 2009; AREVA, 2009

## 4.3 BARRIERS, DRIVERS, AND POLICIES

A major limitation of agricultural residues is the limited collection season. They are usually collected over the course of a few months after grain harvest. For that reason, storage of up to ten months is generally required for year-round utilization. In addition to the storage issue, loading and transportation costs affect market prices of feedstock. Compared to the amount of all available resources, the amount of resources available for power generation is limited by the economical transportation range surrounding the power plant.

It is well known that one of the advantages of the use of biomass is the relatively low capital and operational costs for biomass-cofiring and direct combustion. However, there are still technical issues associated with cofiring such as limits to the percentage of biomass that can be cofired. The current biomass integrated gasification combined cycle (BIGCC) technology requires high costs for installation and maintenance, while its performance is better than the conventional options. Therefore, the BIGCC option still has potential to be improved technologically and economically by active R&D and demonstration. In addition, relative to wind, the level of PTC for biopower is low (as discussed later in this chapter).

Unlike other renewable resources, biomass is regulated by the Environmental Protection Agency (EPA) tailoring rule. It is tailoring the applicability criteria that determine which stationary sources and modification projects become subject to permitting requirements for greenhouse gas

(GHG) emissions under the Prevention of Significant Deterioration (PSD) and Title V programs of the Clean Air Act (CAA) (EPA, 2010b). The EPA's final Tailoring Rule, which does not exempt biomass power producers from GHG permitting requirements despite past EPA affirmations that biomass is carbon neutral. Instead, biomass power producers are required to maintain the same GHG reporting obligations as fossil fuel consumers (Nelson, 2010). In addition, there are controversies around defining “sustainable” harvest of biomass, and conflicts over feedstock use with other applications such as cellulosic ethanol, wood products, paper, and chemicals as well as wood pellets for export to Europe. Lastly, the relatively small scale of viable biopower plants prevents them from enjoying the economies of scale that large solid fuel (coal) plants enjoy.

To develop realistic and feasible scenarios for biopower in the South, this study reviewed policies promulgated in southern states. Georgia enacted legislation (HB 1018) creating an exemption for biomass materials from the state’s sales and use taxes. To qualify for the exemption, biomass material must be utilized in the production of energy, including production of electricity, steam, and cogeneration. In 2007, Kentucky established the Incentives for Energy Independence Act to promote the development of renewable energy and alternative fuel facilities, as well as energy efficiency. Especially for renewable energy facilities, the bill provides incentives to firms that build or renovate facilities that utilize renewable energy. The maximum recovery for a single project may not exceed 50% of the capital investment. In Alabama, the Biomass Energy Program assists businesses in installing biomass energy systems. Program participants receive up to $75,000 in interest subsidy payments to help discharge the interest expense on loans to install approved biomass projects. Technical assistance is also available through the program. Bioenergy-supportive policies in southern states are summarized in Table 4.1.

**Table 4.1 Summary of Bioenergy-Supportive State Policies in the South**

| Type of Policy | State | Applicability and Amount | Requirements and Limits |
|---|---|---|---|
| Renewable Energy Production Tax Credit/ Production Incentive | FL, SC | -Amount: $0.01/kWh for electricity produced from 2007 through 2010 (FL)/ $0.01/kWh (SC) | |
| Clean/ Renewable Energy Tax Credit | GA, NC, KY | 35% of Corporate Tax Credit (GA, NC) | |
| Green Jobs Tax Credit | VA | - Amount: $500 per each job created<br>- Maximum incentive: $175,000 | Must create a new job in the alternative energy/renewable energy field |
| TVA-Generation Partners Program | GA, AL, MS, TN, NC, VA, KY | - Amount: $1,000 plus $0.03/kWh above the retail rate<br>- Performance-Based Incentive (PBI) payments continue for 10 yrs | |
| Biomass Sales Tax Incentive | GA, KY | 100% exemption (GA, and KY) | Must be utilized in production of energy (electricity, steam, and cogeneration) |
| Biomass Energy Tax Credit (Corporate) | SC | - Amount:25% of eligible costs<br>- Maximum incentive: $650,000 per year; credit may not exceed 50% of tax liability<br>- Carryover Provisions: Excess credit may be carried forward for 15yrs | |
| Green Power Production Incentive | NC | - Amount: Varies<br>- Terms: Payments contingent on program success | |
| Sales and Use Tax Credit for Qualified Facility Manufacturing Clean Energy Technology | TN | - Amount: 99.5% Credit<br>- Terms: Taxpayer must make $100 million investment (minimum) and create 50 full time jobs at 150% rate of TN's average occupational wage | |
| Renewable Energy Systems Property Tax Exemption | TX, KS | - Amount: 100% (TX)<br>- Applicable sectors: commercial, industrial, and residential | Eligible system size: None specified, but system must be used primarily for on-site energy needs (TX) |
| Sales Tax Exemption for Large-Scale Renewable Energy Projects | KY | 100% exemption from sales and use tax | - Maximum incentive: 50% of capital investment<br>- Equipment requirements:>1MW for biomass |
| Loan Program | KY, MS, NC, MO | - Amount: $15,000 ~ $300,000 (MS)/ $500,000 (NC)/ Maximum Incentives: $1 million (MO)<br>-Terms: 3% below prime rate; 7-yr repayment term (MS)/ 1% interest rate for renewable (NC) | |
| State Grant Program | AL | | Maximum Incentive: $75,000 (AL) |

*Data Source: Database of State Incentives for Renewables & Efficiency (DSIRE) Retrieved on July 15, 2010 from: http://www.dsireusa.org/

## 4.4 EXPANDED BIOPOWER

This chapter examines the potential to Expanded Biopower independent of changes to other renewables that might occur. Biopower will be discussed in the context of the full suite of renewable fuels in the integrated Chapter 10.

### 4.4.1 The Case for Expanded Biopower

In this study, we characterize the biopower generation that would occur in our Expanded Renewables scenario as the result of: 1) increased R&D and demonstration on biopower technologies; 2) extended production tax credits; and 3) improved feedstock supply.

These three assumptions underlying our Expanded Biopower scenario address the key barriers described above with supporting policies. The detailed explanations of the three policies are presented in Section 4.5 with results.

### 4.4.2 Modeling Scenario Assumptions

Based on capital and operating costs and capacity factors, as well as fuel costs, generation by the electricity sector is modeled in the Electricity Market Module (EMM) described in Chapter 2. The fuel costs are provided in sets of regional supply schedules and are passed to the EMM where biomass competes with other sources. Among the seven submodules of the EMM, the biomass electric power submodule (BEPS) treats biopower.

**Description of Biomass Supply Curves.** EIA’s biomass feedstock prices for electricity generation are estimated from regional supply curves which are inputs to the BEPS. The raw data for the supply schedules are collected at the state or county level. These resource availabilities are aggregated to form the regional supply schedule by North American Electric Reliability Council (NERC) region. Biomass resources are generally classified into five categories such as urban wood waste, mill residues, forestry residues, agricultural residues, and energy crops. Merging urban wood waste and mill residues in one category and agricultural residues and energy crops in another, the BEPS uses three different biomass resource supply curves. The annual supply curves of agricultural residues, energy crops, and forestry residues have recently been updated based on the biomass supply data from the POLYSIS model developed by the University of Tennessee. For estimating the supply curves, the USDA annual projection forecasts are used to determine the yield rates of energy crops and agricultural residues. The supply plans of urban wood wastes are provided by Oak Ridge National Laboratory (Perlack, et al., 2005).

Unlike other renewable resources, biomass is traded in the feedstock market. For that reason, the growth of biopower production highly depends on the feedstock price and supply. Figure 4.3, 4.4 and 4.5 show the variation in the resource availability as a function of price in 2020 and 2030. The supply curves of urban wood waste and mill residues are anticipated to remain the same until 2030. Figure 4.3 shows that ERCOT (TX) has the greatest potential supply among the four southern NERC regions.

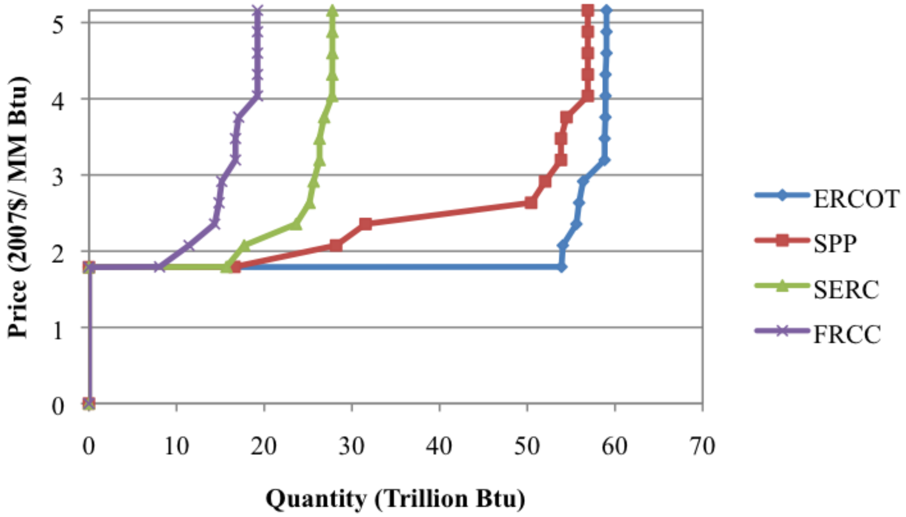

**Figure 4.3 Supply Curve of Urban Wood Waste and Mill Residues by NERC region**

The SERC region (MO, AR, MS, TN, AL, GA, FL, VA, NC, SC, and some parts of LA) has a far higher supply of agricultural residues and energy crops than other regions in the South. At the same price point, the supply from the agricultural sector is expected to increase by about 15 percent from 2020 to 2030. The supply in the SERC region at $20/MMBtu in 2030,is expected to reach 2,795 trillion Btu.

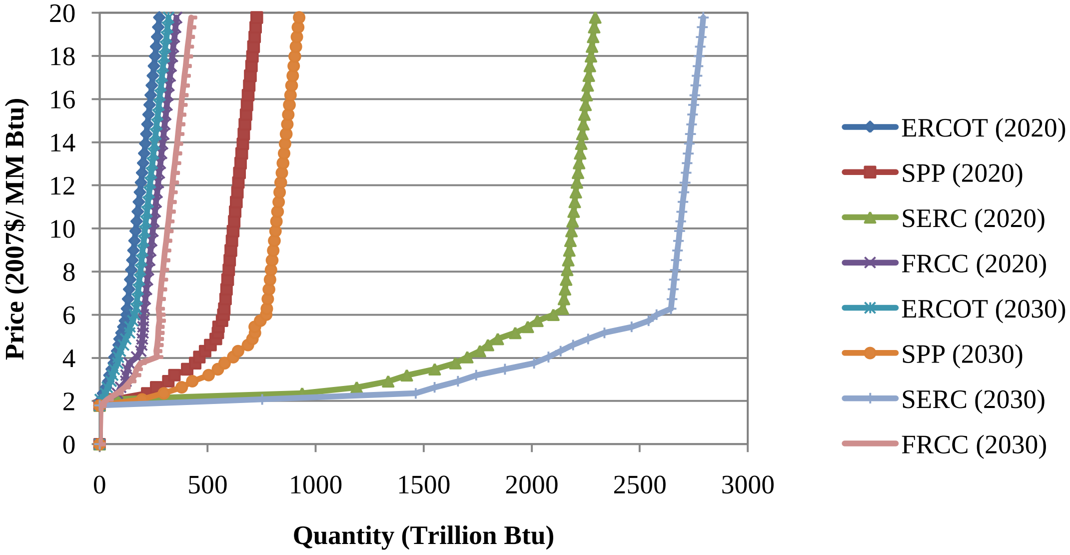

**Figure 4.4 Feedstock Supply from the Agricultural Sector in 2020 and 2030 by NERC region (Agricultural Residues and Energy Crops)**

EIa’s supply curves for forestry residues are the same from 2010 until2030. The SPP region (KS, OK, and a part of LA) and the FRCC (FL) region have larger potential for forestry residues than the SERC and ERCOT regions.

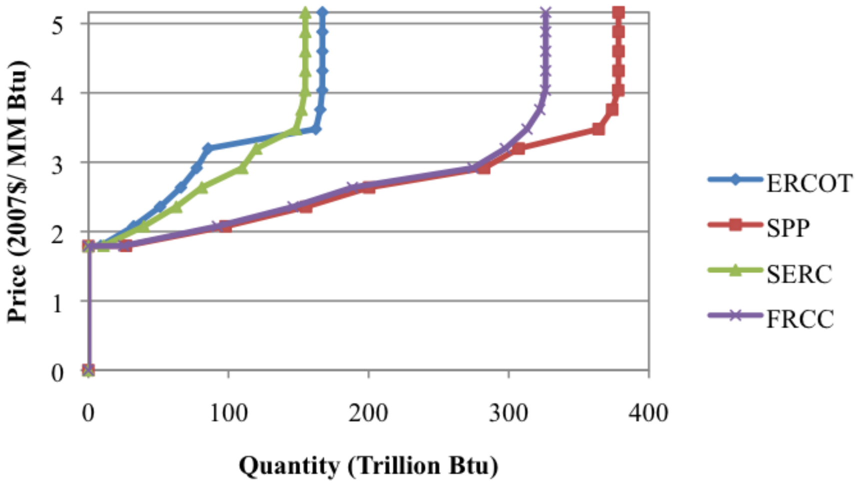

**Figure 4.5 Supply Curve of Forestry Residues by NERC region**

**Technological characteristics**. In addition to biomass supply, technology-specific inputs are used to predict the magnitude of biopower. SNUG-NEMS represents both dedicated biomass and biomass co-firing plants to estimate the capacity of biomass in electricity generation. NEMS assumes that biomass cofiring can account for up to a maximum of 15% of fuel used in coal-fired generating plants. The BEPS considers both dedicated biomass and biomass co-firing plants to forecast the capacity of biomass in electricity generation. The co-firing levels are assumed to vary by region as determined by the availability of biomass and coal-fired capacity of each region.

NEMS models the dedicated biomass plants in the same way as other generation options with a single kind of fuel such as coal, petroleum, and nuclear generation. The main inputs for the dedicated biomass generators are capital, operating, and maintenance costs, project life, production tax credit, and heat rate. Biomass co-firing plants are modeled in NEMS by assuming that plant owners can retrofit their coal-fired plants and transform them into biomass co-firing plants. In addition, NEMS assumes that no additional operating and maintenance costs would be required after the retrofitting in that the biomass would be co-mingled with coal, and the mixture would be fed into the boiler through the existing coal feed system. However, the co-firing system operated at higher levels would incur an additional capital cost to enhance the capacity and performance (EIA, 2003; Haq, 2002).

## 4.5 EXPANDED BIOPOWER SCENARIO RESULTS

### 4.5.1 Potential from Financial Incentive Policy

The federal renewable production tax credit (PTC) is a per-kWh tax credit for electricity generated by qualified renewable resources and sold by the taxpayer to an unrelated consumer during the taxable year. The PTC originally enacted in 1992 and has been renewed multiple times. While the tax credits a open-loop biomass[22] project are half of those for a wind project with the same production, closed-loop biomass[23] projects are eligible to receive the same level of PTC as wind. It is to motivate building closed-loop biopower generations which are relatively less adopted because of the poor cost-competitiveness.

This study modeled a scenario that the current PTC continues until 2030 and the rate stays at 0.9 cents per kWh[24]. The extended PTC is forecast to lead to a dramatic increase in electricity generation in 2030 in the South. It would result in an 8% increase in biopower in 2020 and around a threefold increase in 2030 in the South (Figure 4.6). The SPP region is anticipated to respond to the policy most actively.

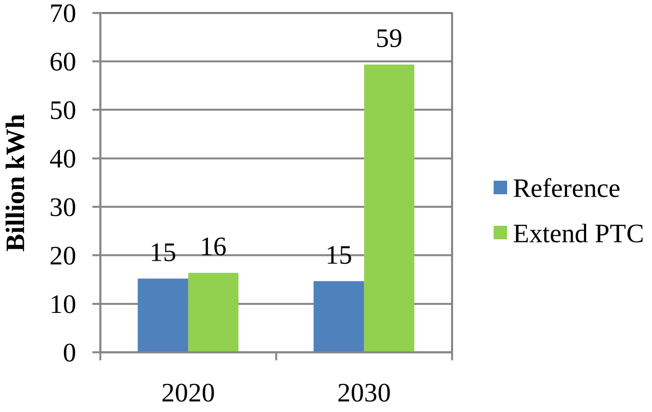

**Figure 4.6 Increase of Utility-Scale Biopower Generation by PTC in the South**[25]

### 4.5.2 Supportive R&D

Among the three technological options, cofiring, direct combustion, and BIGCC, the latter is the most advanced technology and has room for improvement in its performance. The heat rate of a reference scenario of the NEMS reference scenario is assumed to be 9,450 Btu/kWh in 2010, decrease by 1.76% annually, reach 7,766 Btu/kWh in 2021, and then stays at the same level through 2030.

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[22] Open-loop biomass includes urban wood wastes, landscaping wastes, agricultural residues, and forestry residues.

[23] Closed-loop biomass means crops grown specifically for energy production, as opposed to byproducts of agriculture, forestry, urban landscaping, and other activities.

[24] The PTC is specified in 2004$.

[25] The scenario of the Financial Incentive Policy was run with three modules of the electricity market module, the renewable fuels module, and the emission module of SNUG-NEMS.

Instead of a constant heat rate from 2022 to 2030, for this policy SNUG-NEMS models that the heat rate would continue to improve beyond 2021 through 2030 at the same rate (1.76%) and finally reaches 6,620 Btu/kWh.

This policy, active R&D of the BIGCC technology, when modeled by itself, increases the biopower generation in the South.The ERCOT region especially would respond to this scenario most sensitively ofthe four NERC regions and could produce three-times more electricity than a reference case due to the technological advancement. The improved BIGCC performance is anticipated to lead to a 9% rise in biopower generation in 2020 and a 22% increase in 2030.

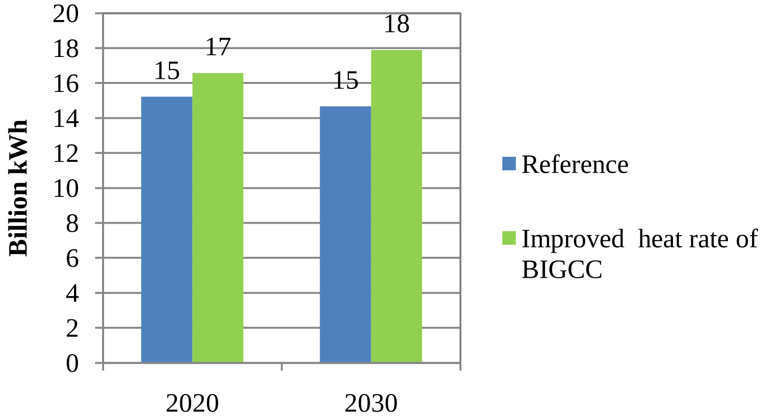

**Figure 4.7 Increase of Utility-Scale Biopower Generation in the Souththrough Supportive BIGCC R&D[26]**

### 4.5.3 Improved Feedstock Supply

Sales tax incentives typically provide an exemption from the state sales tax (or use tax) for the purchase of a renewable energy system. Several states have established tax incentives by allowing an exemption from the state sales tax. The range of sales tax of the states in the South is between 0% and 7%. Whereas Georgia and Kentucky enacted legislation creating an exemption for biomass materials from the states' sales and use taxes, many states in the South do not have such sales tax incentives for biomass purchased for electricity generation.

The third Expanded Biopower policy is a sales tax exemption program involving all states in the South with an improvement of loading and transportation systems. This study assumed that these measures would increase the biomass supply by10%. The South region would generate more biopower under a Improved Feedstock Supply only scenario; with a 32% rise in 2020 and a 45% increase in 2030 projected (see Figure 4.8). ERCOT is the NERC region that has the greatest potential for increasing biopower generation as a result of a sales tax exemption.

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[26] The scenario of the supportive R&D environment was run with three modules of the electricity market module, the renewable fuels module, and the emission module of SNUG-NEMS.

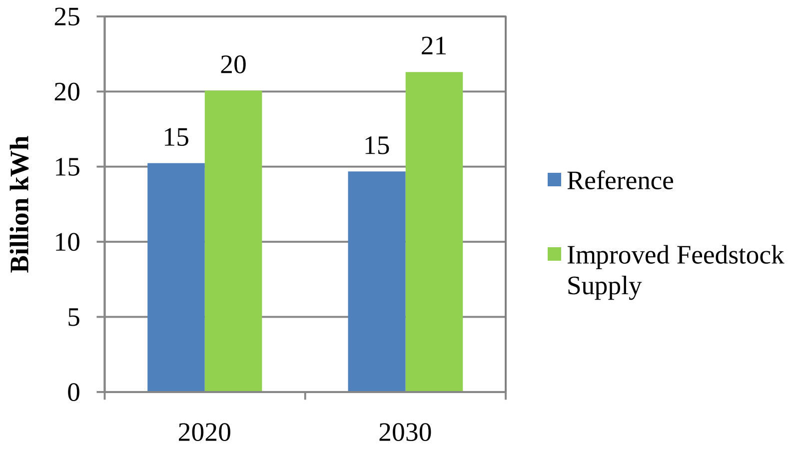

**Figure 4.8 Increase of Utility-Scale Biopower Generation in the South, through Improved Feedstock Supply** [27]

### 4.5.4 Expanded Biopower Scenario

The Expanded Biopower Scenario is defined as the combination of the three preceding policies. To reflect the second-order effect from the electricity demand side and other fuel markets, all of the modules in SNUG-NEMS including the macroeconomic activity module are involved to run this combined scenario. The utilities in the South could generate about four times more biopower under the supportive policy, market, and technological environment than the reference scenario.

In addition, the end-use sectors (especially the industrial sector) would generate a fair amount of biopower on site. For instance, the pulp and paper industry has its own electricity generation system using black liquor extracted from the mill residues. Especially the ERCOT region would be the greatest contributor to this trend since Texas has a large potential in urban wood waste and mill residues which are relatively low-cost feedstock among the three categories of biomass. Unlike other regions, the amount of biopower generated from the end-use sectors had been greater than that from the utilities in the SERC region in the past. However, if the combined policy suggested in this study is implemented, the utility-scale generation would outstrip the customer-owned generation in the future.

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[27] The scenario of the Improved Feedstock Supply was run with three modules of the electricity market module, the renewable fuels module, and the emission module of; SNUG-NEMS.

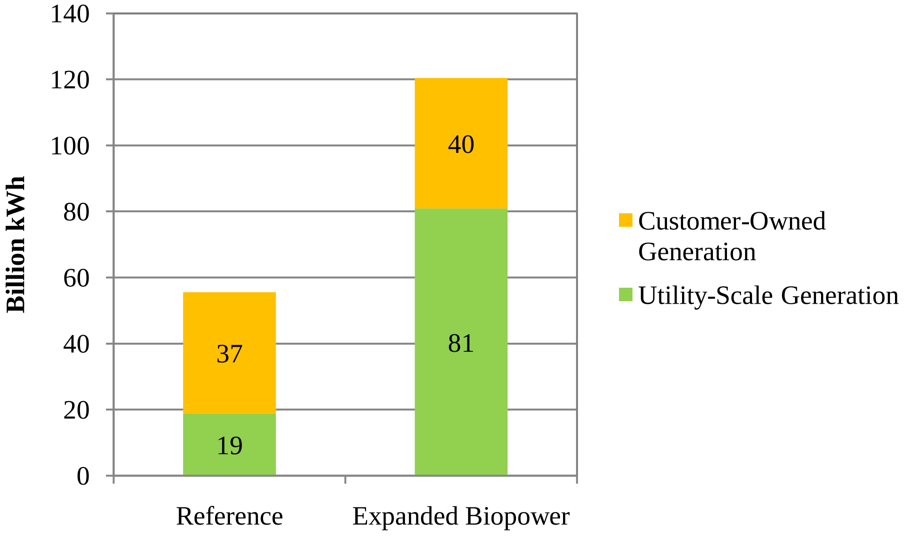

**Figure 4.9 Total Biopower Potential in the South in 2030**

Table 4.2 shows what percentage of total power generation could be met by biopower in 2030. With biomass, the electric power sector and the end-use sector could meet respectively 4% and 2% of the total power supply of the South in 2030. Utilities in the FRCC (FL) region could produce about 13% of electricity with biomass. While the ERCOT region is anticipated to grow the absolute amount of biopower generation motived by the three policies, the share of biopower to the total electricity generation would not increase significantly due to the dominance of fossil-fuel-based electricity in the region.

The majority of the increase in customer-owned biopower, on the other hand, occurs in the SERC region. Overall, this resource would only increase the share of customer-owned biopower generation from 1.8% to 1.9% by the Expanded Biopower scenario. The extended PTC underpinning the Expanded Biopower scenario does not motivate more customer-owned biopower, and the sales tax and R&D policies have only a minor stimulating effect.

**Table 4.2 Share of Biopower to the Total Electricity Generation by NERC region in 2030**

| **Utility-Scale Biopower** | | | | | |
|---|---|---|---|---|---|
| Region | ERCOT | SPP | SERC | FRCC | **South Total** |
| Reference | 0.1% | 0.5% | 0.7% | 3.3% | **0.9%** |
| Expanded Biopower | 0.0% | 2.6% | 3.3% | 12.8% | **4.0%** |
| **Customer-Owned Biopower** | | | | | |
| Region | ERCOT | SPP | SERC | FRCC | **South Total** |
| Reference | 0.0% | 1.8% | 2.8% | 0.7% | **1.8%** |
| Expanded Biopower | 0.0% | 1.9% | 3.0% | 0.7% | **1.9%** |

## 4.6 COST EFFECTIVENESS

The levelized cost of biopower reflects the cost to generate a particular amount of electricity with biomass through supportive policies and environments. The levelized cost of electricity (LCOE) calculated for biomass generation in the South ranges from 4.0 to 7.8 cents per kWh in 2020 and from 3.9 to 6.3 cents per kWh in 2030 (Table 4.3). The cofiring option indicates a low LCOE because its overnight cost is around 90% lower than that of the other two technology options.

**Table 4.3 LCOE by generating option in 2020 and 2030**
(2007 cents per kWh)

| | Direct Combustion | BIGCC | Cofiring |
|---|---|---|---|
| 2020 | 7.8 | 7.3 | 4.0 |
| 2030 | 6.3 | 5.7 | 3.9 |

## 4.7 CONCLUSIONS

The Expanded Biopower scenario modeled in this study suggests that the potential of biopower generation in 2030 could reach 120 billion kWh (excluding electricity from Municipal Solid Waste), which accounts for about 6% of the total electricity generation in the South. The potential is an economic potential which is estimated with a consideration of the competition among renewable resources in the electric power market. The combined scenario of the production tax credit, the supportive R&D environment, and the improved feedstock supply is expected to have a great impact on utility scale biopower and increase the market share of biopower to 4%. On the other hand, only the third scenario with a sale tax exemption would be influential to the customer-owned electricity generation.

The production tax credit is expected to be the most effective driver to enhance the potential. The ERCOT region is anticipated to increase the absolute amount of biopower generation significantly, but the portion of biopower to the total electricity generation would remain small, because fossil fuels are cost-competitive in the region. The FRCC (FL) region is expected to generate 40 billion kWh of biopower which covers about 14% of the electricity generated in the region in 2030. The SERC region would continue to be the greatest producer of the customer-owned biopwer in the future.

However, there are still several issues have to be solved for realizing the maximum economic biopower potential that we presented. Unless biopower incentives and mandates are carefully managed, they could negatively influence other manufacturing industries in terms of jobs and economic activities. There are some arguments that mill residues already have a beneficial use in other industries, and the economic impact of the use of the residues for producing secondary woody products is greater than power generation. In addition, the lack of incentives for closed loop crop production and use is pointed out as a problem. While energy crops (including short rotation woody crops) are often thought to be a part of the solution, there are few incentives for utilities or farmers (foresters) to start producing these crops.

On balance, the biopower potential is anticipated to depend on the supply of feedstock materials, policy environments, and technological advancements. For supporting compliance with renewable electricity standards (RESs), biomass could be regarded as a low-cost and low-risk option. The interaction between the renewable electricity market and a national RES is discussed in Chapter 10.

# 5. MUNICIPAL WASTE

## 5.1 INTRODUCTION

Municipal solid waste (MSW) is defined as total waste excluding industrial waste, agricultural waste, and sewage sludge. According to the U.S. Environmental Protection Agency, it includes durable goods, non-durable goods, containers and packaging, food wastes, yard wastes, and miscellaneous inorganic wastes from residential, commercial, institutional, and industrial sources. In general, appliances, newspapers, clothing, food scrapes, boxes, disposable tableware, office and classroom paper, wood pallets, rubber tires, and cafeteria wastes are included in the category. Waste-to-energy combustion and landfill gas are two major byproducts of municipal solid waste. The municipal solid waste industry has four components in the process of the waste treatment: recycling, composting, landfilling, and waste-to-energy via incineration. (EIA, 2008b).

When the raw wastes decompose in landfills, approximately 22% of the human-related methane of the United States is emitted. Landfill gas (LFG) generally consists of about 50% methane, 50% carbon dioxide, and a small portion of non-methane organic compounds. This air pollutant can be recycled and used as an energy source. LFG can be captured from landfills using a series of wells and a blower-flare (or vacuum) system. The collected gas can be flared or used to generate electricity, and to replace fossil fuels in industrial and manufacturing operations. In addition, LFG can be used for combined cycle gas turbines, which have a relatively higher efficiency because LFG is a higher quality fuel both in its higher heat content and lower emissions than other biomass resources.

The electricity generated from the MSW can be used on site or be sold to the grid. Especially, utilizing LFG as an energy source removes odors and other hazards, and at the same time, prevents methane from escaping to the air. The amount of methane from landfills is proportional to the amount of municipal wastes, which is highly correlated with the population. However, when the recycling rate of raw wastes increases, the quantity of wastes dumped in landfills decreases and the amount of methane produced from the landfills would be reduced accordingly.

## 5.2 LANDFILL GAS IN THE SOUTH

The landfills located in the South create 5,200 tons of methane annually which accounts for 35% of LFGs of the nation. In particular, Texas, North Carolina, and Florida are the greatest LFG producers, as shown in Figure 5.1.

### *Box 5.1 Palmetto Landfill Gas Project*

**Capacity:** **11 MW**
**Location:** **Wellford, SC**
**Operation Since:** **2003**

The Palmetto Landfill, originally opened in 1979, is located in Wellford, South Carolina. In 2003, it began supplying the BMW assembly plant in Greer, South Carolina, with landfill gas.

Overall, 70 percent of the plant's energy needs are satisfied by the use of landfill gas. About 25% of plant electrical needs are satisfied by generating electricity from the landfill gas using gas turbines (see picture to the left). Almost all of the plant's thermal needs are met through the recovery of 72 MMBtu/hr of hot water. Total savings at the plant from the use of landfill gas are at least $1 million per year.

Each year, the project also sequesters the same amount of carbon as 13,800 acres of pine or fir forest or that emitted by 12,300 passenger vehicles. BMW's efforts using landfill gas earned them the EIA's Landfill Methane Outreach Program 2006 Award for Energy Partner of the Year.

Picture from Dubose, 2007 Sources: Dubose, 2007; LMOP, 2010a; LMOP, 2010b

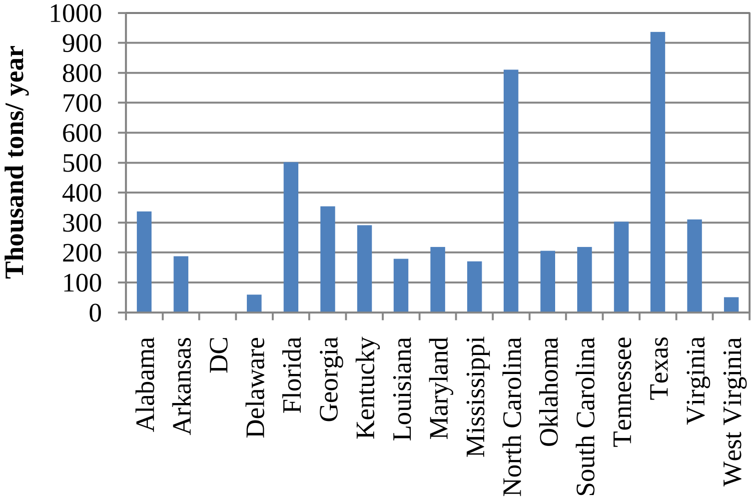

**Figure 5.1 LFG Availability in the South**
**(Data Source: Milbrandt, 2005)**

The U.S. EPA initiated the Landfill Methane Outreach Program (LMOP), which is a voluntary assistance program that helps to reduce methane emissions from landfills by encouraging the recovery and beneficial use of LFG. The LMOP provides a vast network of industrial experts and practitioners, as well as technical and marketing resources that assist with LFG energy project development. Due to LFG's high energy content and resource availability in the South, the region is expected to produce a fair amount of electricity from LFG. The next section summarizes barriers and policies surrounding LFG power.

## 5.3 BARRIERS, DRIVERS, AND POLICIES

Achieving the environmental and economic benefits associate with LFG requires advanced conversion technologies that neutralize environmental damage in landfill gases and sites. At the same time, the cost-competitiveness of the recycled energy from LFG is another key to the commercialization of LFG electricity (SCS Engineers, 1997). Table 5.1 summarizes the barriers to wider LFG use and some possible was to overcome those barriers.

**Table 5.1 Barriers and Policy Actions to Landfill Gas**

| Barriers | Solutions and Policy Actions |
|---|---|
| High Cost of Collecting and Recycling Technologies | R&D and Demonstration<br>Financial Incentives<br>• Investment Tax Credit (ITC) |
| Less Cost-Competitive than Fossil Fuels | Financial Incentives<br>• Sale and Use Tax Exemption<br>• Production Tax Credit (PTC) |

States in the South have promulgated policies for enhancing the installation and use of LFG-to-electricity facilities. For instance, Tennessee has enacted the Tennessee Clean Energy Future Act of 2009 and expanded its sales and use of tax credits for emerging industries with clean energy technologies. Landfill gas is included in the definition of clean energy technology in the act. Qualifying manufacturers must make a minimum $100 million investment, and create and maintain 50 full-time jobs for 10 years that pay 150% above the state's occupational average wage. In addition, the Tennessee Valley Authority (TVA) and participating power distributors of TVA power offer a production-based incentive program for the installation of LFG-to-electricity generation. TVA purchases 100% of the output from a qualifying system at a premium of $0.03 per kWh on top of the retail electricity rates for landfill gas. Georgia, Alabama, Mississippi, Tennessee, North Carolina, Virginia, and Kentucky are included in the TVA-Generation Partners Programs. Many southern states provide investment tax credits, and the range of the credits is 10% to 35% of the investment. Table 5.2 includes a more comprehensive listing of Southern LFG policies.

**Table 5.2 Summary of LFG-Supportive Policies in the South**

| Type of Policy | State | Applicability/ Amount | Requirements and Limits |
|---|---|---|---|
| Sales and Use Tax Credit | TN, KY | Amount: 99.5% Credit (TN), up to 100% (KY) | - Taxpayer must make $100 million investment (minimum) and create 50 full time jobs at 150% rate of the average occupational wage (TN). |
| Energy Investment Loan Program | MS | Amount: $15,000~$300,000<br>Terms: 3% below prime rate; 7-year repayment term | |
| Investment Tax Credits | NC, SC, KY, KS | -Amount: 35% (NC); 25% (SC); 50% (KY); 10% of the system's cost for the first $50 million invested and 5% of the cost that exceed $50 million (KS) | - System must be new and in compliance with all applicable performance and safety standards (NC).<br>- Carryover Provisions: Credits must be taken in five equal installments |

| | | | |
|---|---|---|---|
| | | | (NC); Excess credit may be carried forward for 15 yrs (SC); any unused credit may be carried forward in subsequent yrs as a deduction (KS). |
| Tax Credit for Renewable Energy Facilities | KY | Amount: Up to 100% of income tax or the limited liability entity tax (KY) | |
| Green Jobs Tax Credit | | Amount: 500% per each job created<br>Maximum Incentive: $ 175,000 | Must create a new job in the alternative/ renewable energy fields. |
| TVA-Generation Partners Program | GA, AL, MS, TN, NC, VA, KY | Amount: $1,000 plus $0.03/kWh above the retail rate | |

*Data Source: Database of State Incentives for Renewables & Efficiency (DSIRE)
Retrieved on July 15, 2010 from: http://www.dsireusa.org/

## 5.4 EXPANDED MSW POWER

### 5.4.1 The Case for Expanded MSW Power

The reference scenario of NEMS has an assumption consistent with EPA's recycling goal of the MSW. The recycling rate of the MSW is assumed to account for 35% of the total waste stream by 2005 and 50% by 2010, and stay the same until 2030.

This study characterizes a MSW recycling program that would occur in our Expanded Renewables Scenario. The program is assumed to increase the MSW recycling rate by 1% point annually beyond 2010 until 2030.

### 5.4.2 Modeling Assumptions

LFG-to-electricity capacity competes with other technologies in the Electricity Market Module of NEMS using supply curves that are classified by the amount of "high", "low", and "very low" methane producing landfills located in each NERC region. An average cost-of-electricity for each type of landfill is estimated using EPA's Energy Project Landfill Gas Utilization Software which contains information about characteristics and costs of gas collection system and electricity generator (EIA, 2010g).

Unlike other renewable resources, the supply of methane from the MSW of a region is highly correlated with macroeconomic indicators such as the Gross Regional Product (GRP) and the population. NEMS assumes that the annual growth rate of the GRP and that of the population grow by 0.8% and 3% respectively from 2010 to 2030 in the South. Emission parameters are the same as those used in estimating historical methane emissions in the EIA's Emissions of Greenhouse Gases in the United States 2003.The ratio of "high", low", and "very low" methane production sites to total methane production is estimated based on data collected for 156 operating landfills contained in the Government Advisory Associates. Cost-of-electricity for each site is estimated by assuming each site to be a 100-acre by 50-foot deep landfill and by using methane emissions factors for "high", "low", and "very low" methane emitting wastes (EIA, 2010g).

## 5.5 EXPANDED MSW SCENARIO RESULTS

The electricity generation from the MSW in the SERC region is anticipated to grow from 1.3 to 1.8 billion kWh in 2030 due to the improved recycling rate of the MSW. However, no significant change is expected in the rest of the three regions. It is because the portion of waste dumped in landfills with potential to degrade into methane decreases as the fraction of raw materials recycled for other purposes increases. For that reason, a tradeoff relationship exists between electricity generation from incinerating raw wastes and that from combusting methane produced in landfills.

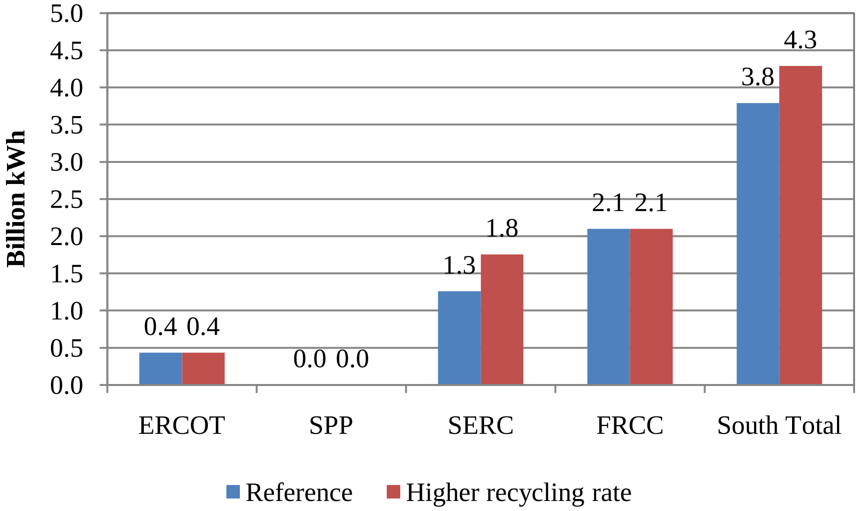

**Figure 5.2 Electricity Generation from Municipal Waste in 2030**[28]

## 5.6 COST EFFECTIVENESS

The levelized cost of MSW-electricity reflects the cost to generate a particular amount of electricity from the MSW through supportive policies and environments. This study found that the range of levelized costs of MSW-electricity is 5.4 cents per kWh in 2020 and 4.6 in 2030.

| **Table 5.3 LCOE for MSW-electricity in 2020 and 2030**<br>(2007 cents per kWh) | |
|---|---|
| 2020 | 5.4 |
| 2030 | 4.6 |

## 5.7 CONCLUSIONS

By incinerating raw wastes and landfill gases, the South is expected to generate 4.3 TWh which accounts for about 0.2% of total electricity generation of the region in 2030. The improved recycling rate of the MSW could increase the MSW-power generation by 12% in 2030. Since the

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[28] The reference scenario and the expanded MSW-power scenario in this chapter were run with three of the SNUG-NEMS's modules, the electricity market module, the renewable fuels module, and the emission module.

amount of MSW is highly correlated with population, the SERC region with the highest population in the South has the greatest potential among the four NERC regions.

# 6. HYDROPOWER

## 6.1 INTRODUCTION

Hydropower, as a form of energy derived from moving water, is one of the oldest energy resources harnessed by human kind. It accounts for approximately 83% of world renewable electric power capacity, with large hydro accounting for a majority (860 of the 1140 GW). Small hydropower (<30 MW) is growing rapidly, particularly in developing countries, and at 85 GW, it currently represents about 7% of all world renewable power capacity. Pico hydropower (<5 kW) is gaining popularity in developing countries such as Vietnam, China, Nepal and Kenya (Maher et al, 2003; Smith and Ranjitkar, 2000; Paish and Green, 2001).

The United States has approximately 77 GW of hydropower capacity (EIA, 2009, Table 16), but proportionately less of it is small hydropower – existing totaling 3% (3 GW) in 2008 (REN21, 2009, Table R4). As with wind and solar power, the major advantage of hydroelectricity is elimination of the cost of fuel. Unlike wind and solar, it is not an intermittent source but rather provides base load power with a capacity that varies with levels of rainfall.

Conventional hydroelectric plants require dams to produce electricity from the hydrostatic energy possessed by stored bodies of water. Low-impact hydropower, on the other hand, does not require dams. The following classification follows the U.S. Department of Energy terminology (Hall, et al., 2006; McConnell, et al, 2010).

- **Large conventional hydropower** facilities are generally defined as those with more than 30 MW of capacity. These account for the largest share of hydropower in the U.S. and in the South.
- **Small conventional hydropower** sites have the capacity to generate 1 to 30 MW, enough to serve a small community or industrial plant. Small hydro plants may be connected to conventional electrical distribution networks or they may be built in more remote areas to serve the needs of local consumers. Since small hydro projects can have minimal reservoirs and civil construction work, they are seen as imposing a relatively small environmental impact compared to large hydro. Small hydropower systems can also be installed in natural water bodies as “run-of-river” facilities with even more limited environmental effect. These systems use the natural flow and elevation drop of a river to generate electricity. Some or most of a river’s flow is diverted through a pipe and/or tunnel (called a “penstock”) leading to lower-elevation turbines; the water is then returned back to the river downstream. A small dam is required to ensure there is enough water to enter the penstock pipes.
- **Low-power hydro** facilities have capacities in the 100 KW to 1 MW range. They are often also called “low-impact” hydro because they typically do not require dams. Instead, electricity is generated by a turbine generator at the end of a penstock running parallel to the stream, using run-of-river concepts.
- At an even smaller scale, **micro hydro** is a term used for hydroelectric power generation of less than 100 KW. These types of low-impact hydro can be a major energy source in remote areas where other power sources are less viable.

Pumped hydro storage generates electricity by reversing the flow of water between two water sources, typically including an elevated reservoir or water tower. Such storage technologies can deliver more than 1 GW of capacity and can respond quickly with relatively low operating costs during periods of peak demand when purchasing power at spot market prices can be expensive. Pumped storage can serve as an important balance to the large-scale deployment of solar and wind power generating facilities. See Appendix B for a description of emerging hydrokinetic concepts. Worldwide more than 90 GW of pumped hydro storage facilities operated in 2007, and 22 GW are in the U.S. (EIA, 2009, Table A9).

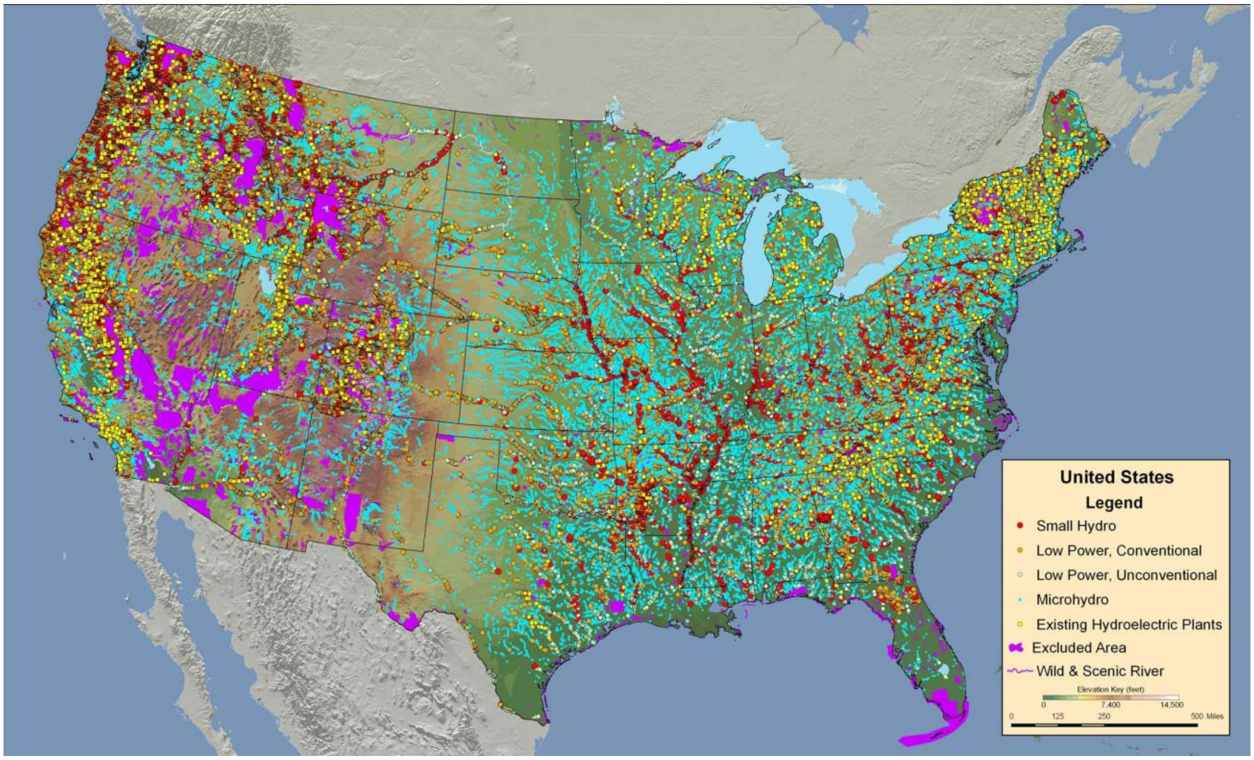

Figure 6.1 Existing hydroelectric plants and feasible potential hydropower projects in the U.S. (Source: Hall, et al, 2006)

## 6.2 HYDROPOWER IN THE SOUTH

In 2009, over 15 TWh of hydropower was generated in the South, comprising 38% of the total renewable energy generation, and 2.2% of the total electric power generation. With a generating capacity of over 4 GW, conventional hydropower is the largest renewable energy resource in the South (EIA, 2010; Hall, et al., 2006). Alabama leads the South in conventional hydropower generation, with a capacity of 1,036 MW; Tennessee is close behind with a hydro capacity of 848 MW. The hydro facilities in both of these states are managed almost entirely by the Tennessee Valley Authority.

Large hydropower is generally seen as fully developed in the South in that no new sites are likely to be developed in the future due to environmental concerns. Over the past decade, much progress has been made to expand the capacity of several existing large hydropower facilities. This is likely to continue, as additional modernization (i.e., turbines and generator update, operational improvement) is underway at existing large hydropower sites. Modernization of these readily-deployable projects would bring nearly 9,000 MW of new hydroelectric capacity nationwide (NHA, 2010). This is illustrated by the investment of approximately $20 million of stimulus funds in two conventional hydropower projects, updating turbines for hydroelectric plants in Alabama and North Carolina. Hydropower generation will increase by about 131,000 MWh annually after the updates in those two states (NASEO, 2010).

### *Box 6.1 Licensed Hydroelectric Project: Pine Creek Lake Dam*

**Nameplate Capacity:** **6.4 MW**
**Location:** **Little River, OK**
**Status:** **Licensed Project, On Hold**
**Estimated Operation:** **After 2011**

The Pine Creek Lake Dam is on the Little River, about eight miles north of Valliant, Oklahoma. The dam rises 124 feet above the stream bed and is 7,510 feet long. Work on the dam began in 1963 and was completed in 1969.

The dam was originally constructed for flood control, water issues, and recreational value. The lake formed by the dam provides an extensive shoreline for fishing, hiking, and other activities.

In April 2009, the city of Broken Bow licensed a project to modernize the dam and make it a hydroelectric facility. This is the only new hydroelectric facility licensed in the South. Construction on the project was to begin before April 2011, as required by the license.

In March 2010, the U.S. Corps of Engineers notified the city that a potentially serious issue with the dam was discovered, making it a high risk project. Later that month, the city requested a stay of the FERC license while the Corps conducted a detailed dam safety modification and risk assessment analysis. Originally, if construction did not begin by April 8, 2013, the license would be terminated. FERC granted a two year stay.

The different functions of the Corps and FERC make such dam conversion to hydroelectric facilities problematic, as seen above. The Corps focuses on the flood control and safety aspects of the dams, while FERC focuses on the power generation incorporation. In part due to these different interests, the Corps has a difficult time adhering to FERC timelines.

Picture from Valliant Chamber of Commerce, 2004

Sources: Brennan, 2010; Federal Business, 2010; FERC, 2010b; U.S. Army Corps, nd a & nd b

Where a dam already exists at a site suitable for hydro power development, a power house may be added with relatively low construction costs and limited ecological footprint, providing a useful revenue stream to offset the costs of dam operation. In fact, there are numerous hydroelectric sites where dams were built for other purposes such as water impoundment and flood control, without power generating facilities. According to Brennan Smith (2010), the U.S. has 82,000 dams and only 3% of them are generating electricity. Small-scale hydropower systems can be easily added to the non-powered dams. Hydropower developers nationwide are paying increased attention to existing non-powered dams because great potential exists when power generators are added. Many of the recent hydropower proposals are at existing federal dams (PennWell, 2010). If the hydrostatic energy at those existing dams is utilized by adding turbines, the country will benefit from a greater supply of cost-competitive and green hydroelectricity. As Hall, et al. (2006, pp vii) put it:

> "…there are a large number of opportunities for increasing U.S. hydroelectric generation throughout the country… These opportunities collectively represent a potential for approximately doubling U.S. hydroelectric generation (not including pumped storage), but more realistically offer the means to at least increase hydroelectric generation by more than 50%."

Currently, the Tennessee Valley Authority (TVA), which is the biggest hydropower supplier in the South, has four large pumped storage hydroelectric facilities (with generating capacity of over 4.3 GW) out of its 30 hydroelectric sites (see Appendix A.1 for more information about hydropower sites in the South). Large-scale deployment of intermittent renewable power can be assisted by pumped storage hydroelectric systems.

***Box 6.2 Potential Hydroelectric Project: Lake Livingston Dam***

**Potential Capacity:** **50 MW**
**Location:** **Livingston, Texas**

The Trinity River near Livingston, Texas, has several surface reservoirs, which supplies most of the drinking water in the Trinity River watershed. The largest of these is Lake Livingston, which was completed in 1969 and supplies the City of Houston with water.

According to the International Energy Agency, the existing dam at Lake Livingston can be updated to be a hydroelectric facility of 50 MW. This would allow electricity to be generated with the periodic releases of water from the dam, like the one shown below. Since the dam is already in place, the costs associated with retrofitting it to generate electricity will be much less than building an entirely new hydroelectric dam.

Picture from Trinity River Authority, 2010

Sources: IEA, nd; Trinity River Authority, 2010

## 6.3 BARRIERS, DRIVERS, AND POLICIES

Large-scale hydroelectric projects have difficulties getting public acceptance due to the environmental impacts of dams and reservoirs on natural water flows and ecosystems. The environmental impacts of hydro projects can be significant when dams or reservoirs must be created. These environmental impacts are much smaller for low-power and micro hydro facilities when either no dam or a small dam is required or when dams already exist for other purposes such as drinking water impoundment. As such, they have been characterized as one of the most sustainable energy sources (Varun, et al, 2009). But the prevailing public perception of adverse environmental impacts sometimes makes low-impact hydro projects hard to be accepted. Accordingly, some states do not recognize low-impact hydropower as a renewable energy resource, and they need to go through a complex environmental risk assessment and licensing procedure before construction. This unfavorable public image is one of the barriers that impedes the development of low-impact hydropower.

Site accessibility is another hurdle for constructing new hydroelectric projects. Some of the possible sites for small run-of-river hydro projects are located in rural and mountainous areas with small local populations. Though those sites have hydropower potentials, currently there is no need to expand new power plant because local demand for electricity is already satisfied. If hydroelectricity was to be exported from these remote sites, then transmission lines must be built for the hydroelectricity to reach consumers.

However, there are also regulations and policies supporting the development of new hydropower potential. The permitting regulatory agency for hydroelectric facilities, the Federal Energy Regulatory Commission (FERC), offers programs to support hydropower development. FERC is also updating its program to ease the licensing process for small hydroelectric projects. In addition, a pilot licensing policy is enhanced by FERC for hydrokinetic technologies (FERC, 2010; EPRI, 2010).

Low-power and small hydropower qualifies as a renewable energy resource at the federal and regional level. Updates of existing hydroelectric facilities, small hydroelectric projects at non-power dams, and hydrokinetic power qualify for the Renewable Electricity Production Tax Credit (PTC), which provides 1.1¢/kWh for eligible hydro facilities. Interestingly, this is only half of the 2.2¢/kWh subsidy offered for wind and biomass (DSIRE, 2010).

In the South, low-impact hydro facilities (smaller than 1 MW) are eligible for a performance-based incentive through TVA's Generation Partners Program. TVA will purchase 100% of the low-impact hydropower output from a qualifying system at $0.03/kWh above the retail rate (DSIRE, 2010). As with the Production Tax Credit, this is much lower than the $0.12/kWh offered by the same program for solar power.

Tax credits offered by individual states are also available for qualifying hydro (mostly small hydro and micro hydro) facilities in North Carolina, Kentucky and Oklahoma. State loan and other financing supports are available in North Carolina, South Carolina, Virginia and Mississippi. In contrast, hydroelectric is excluded from the state tax credit or loan programs for renewable energy in Georgia, Louisiana, Texas and Florida.

## 6.4 EXPANDED HYDROPOWER

### 6.4.1 The Case for Expanded Hydropower

The South has significant potential for adding small and low-impact hydro projects, as identified by Hall, et al. (2006). Numerous small hydro sites exist that already have dams but are not equipped with hydropower generators. Thus, the ecological footprints of these projects have already been felt, and power production is a relatively minor alteration. In addition, as low-impact hydro projects (i.e., low-power and micro hydroelectric facilities) do not require the building of dams, they are more likely to be accepted locally. With financial incentives, favorable regulatory treatment, or other means of encouragement, numerous small hydropower projects could be built to provide sustainable energy in the South.

For the Expanded Hydropower scenario, potential sites for new hydro projects are added to SNUG-NEMS based on a feasibility study of water energy resource by Idaho National Laboratory (INL) (Hall, et al., 2006). A brief description of how INL characterized feasible projects follows.

Feasible projects are defined by Hall, et al. (2006) as potential hydropower projects that could be permitted and constructed in suitable sites and could start generating electricity in the 2011 to 2030 time frame. Water energy resource sites are feasible if they satisfy the feasibility criteria of site accessibility, load or transmission proximity, and land use or environmental sensitivities that would make development likely.

Specifically, the feasibility criteria applied by Hall, et al. (2006) to each water energy resource site are as follows:

- Hydropower potential ≥10 kW
- Does not lie within a zone in which development is excluded by federal law or policy
- Does not lie within a zone that makes development highly unlikely because of land use designations
- Does not coincide with an existing hydroelectric plant
- Is within 1 mile of a road
- Is within 1 mile of part of the power infrastructure (power plant, power line, or substation) or is within a typical distance from a populated area for plants of the same power class in the region (Hall, et al., 2006, pp. 14-16).

After the selection of suitable sites based on these project feasibility criteria, the INL study estimates hydropower potential assuming that electricity is generated by a turbine generator at the end of a penstock running parallel to the stream (Hall, et al., 2006). Finally, “potential feasible projects” are low-power and small hydro (possibly located at existing non-powered dam sites) plants built on feasible sites. Low-power projects include low-head hydro (< 30 ft) with conventional turbines, low-head unconventional systems and micro-hydropower (≤100 kW).[29]

The hydropower potential estimated by the INL study emphasizes small conventional and low-power hydro, as well as hydrokinetic energy. Some streams have little power potential by virtue of a low hydraulic head, but they have adequate stream velocities. If a kinetic energy model consisting of one or a group of kinetic turbines had been applied to such streams, significant additional hydropower potential may well have been identified (Hall, et al., 2006, p. 13).

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[29] The “hydraulic head” of a stream is defined as the elevation change from the upstream to the downstream reach of the river.

Our Expanded Hydro scenario uses INL's estimation of feasible projects. Figure 6.2 shows how much additional low impact hydropower was added for Expanded Hydropower scenario. It shows that Tennessee possesses the largest share of new low-power and small hydropower potential – totaling 655 MW, followed by Arkansas, Alabama, and Virginia. Four additional states are estimated to have the potential to develop 300 MW of additional hydropower: North Carolina, Texas, Louisiana, and Mississippi (Hall, et al., 2006, Table B1).

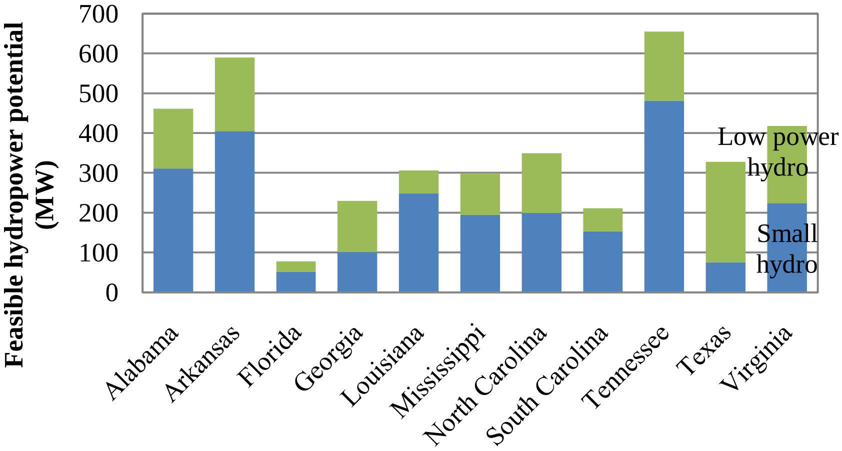


**Figure 6.2 SNUG-NEMS Additional Feasible Hydropower Potential for the South**

In the Expanded Hydro scenario, all of the feasible hydropower potential (Fig 6.2) was manually added to the ERCOT (TX), FRCC (FL) and SERC regions. NEMS's estimates of existing hydropower in the SPP region matches INL's record of existing hydropower capacity (Hall, et al., 2006). Thus, no new hydro potential was applied to the SPP region.

### 6.4.2 Modeling Scenario Assumptions

The Expanded Hydropower scenario models the hydropower potential based on the INL estimation of feasible low power and small hydro projects. The potential capacity by state shown in Figure 6.2 totals more than 3.9 GW; 62% of them are opportunities for small conventional hydroelectric plants with capacities of less than 30 MW and the remainder could be developed as low-power hydro projects. The feasible projects include about 600 small hydro sites, and 21,700 low-power hydro project sites. These are comprised of:

- 1,750 feasible projects for conventional turbines
- 1,560 feasible projects for unconventional systems
- 18,400 feasible projects for microhydro

A levelized cost of 10¢/kWh was assigned to all feasible projects to align our cost assumption with the estimations by other studies and the views of experts (Smith, 2010). Sites that already have dams and only need to have power generation infrastructure added (with appropriate licensing costs), are considered by experts to have much lower levelized costs, while other hydropower projects might be more expensive than 10¢/kWh. In the absence of a supply curve for hydropower in the South, a simple estimate of 10¢/kWh was used for all of the sites designated by Hall, et al. (2006) as a "potential feasible site." Hydropower with this assumed levelized cost is competitive in NEMS in the electricity market. This is consistent with the conclusion by Bakis (2007) that small-scale run-of-river hydropower is probably more cost-effective than other renewable energy such as wind, solar, and geothermal energy.

Environmental suitability factor, which is the probability of meeting environmental requirements (having the values of 0.1, 0.25, 0.5, 0.75, and 0.9), was set to be the highest value for the feasible projects since small and low-power hydro is considered to have much lower environmental impact than conventional hydropower. See Appendix F for more details about other modeling characteristics such as capacity factors, construction cost, capital cost, operation and maintenance cost, and licensing costs.

## 6.5 EXPANDED HYDROPOWER SCENARIO RESULTS

The Expanded Hydropower scenario projects the development of 3.7 GW more hydropower generating capacity by 2030 in the South, based on the addition of feasible low power and small hydro projects (Figure 6.3). The SERC region has a capacity increase of 3.29 GW, representing 89% of the hydropower potential in the South. Approximately 330 MW of additional hydropower is projected for ERCOT.

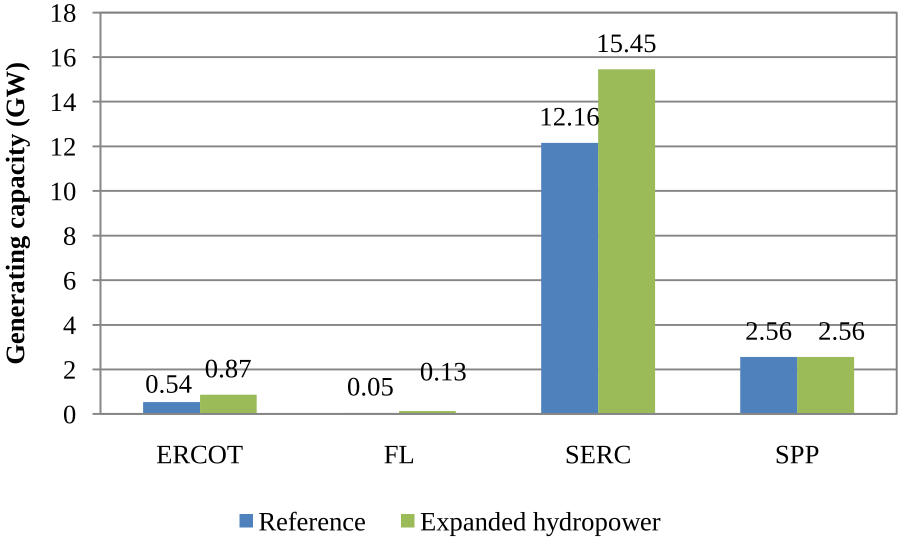


**Figure 6.3 Generating Capacity of Expanded Hydropower in 2030**

With these new generating capacities, hydropower expands to 4.0% of all electricity generation in 2020 (compared to 3.1% in the reference scenario's projection). In the year 2030, 70 TWh of hydroelectricity is generated (versus 52.9 TWh in the reference projection), which is 3.7% of total electricity generation (up from 2.8%) (Figure 6.4). These percentages decrease between

2020 and 2030 because the bulk of the new hydropower additions occur during the first decade. Cumulatively, the electricity generated from hydro increases by 345 TWh through 2030.

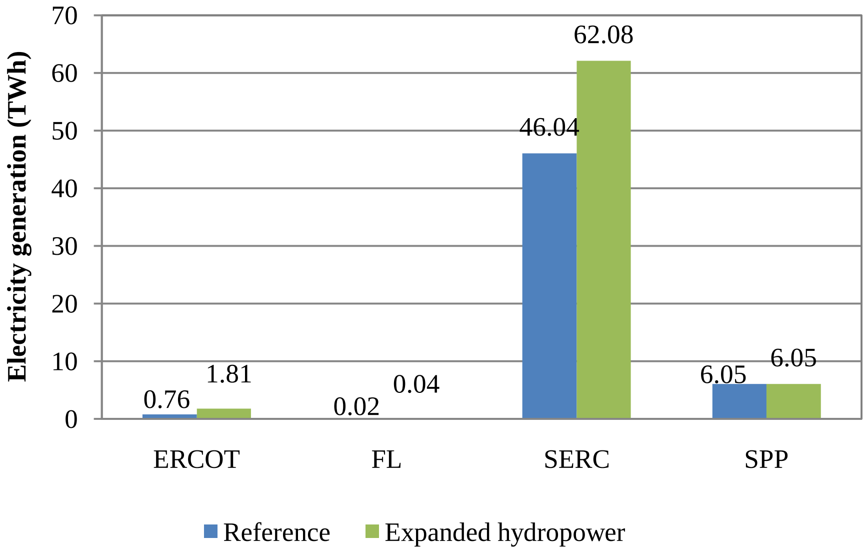


**Figure 6.4 Electricity Generation of Expanded Hydropower in 2030**

In the year 2030,, the SERC region generates 89% (versus 84% currently) of the hydroelectricity in the South. Comparing with 46 TWh of electricity generation in the year 2030 in the reference forecast, 62 TWh of hydroelectricity could be generated in the SERC region if the small and low-head hydro potential were developed.

## 6.6 CONCLUSIONS

The Expanded Hydropower scenario emphasizes the economic potential of low-power and small hydropower generated at feasible sites located throughout the South. By exploiting this water power resource, hydroelectricity could expand to 70 TWh of generation in 2030 (from 53 TWh in the reference forecast). These new hydropower resources could bring jobs to rural areas, while also providing affordable and sustainable energy. Public resistance based on environmental and ecological concerns should be minimized because many of the sites already have dams and reservoirs for other purposes, or are amenable to run-of-river designs that can be built with a small dam or without any dam. Financial incentives and favorable regulatory treatment would help hydropower to continue to be a leading source of renewable energy in the South, with a new emphasis on constructing and managing smaller projects. In addition, pumped storage could play an important role in enabling the South's large-scale use of intermittent renewable energy resources such as wind and solar.

The projected growth of hydropower by 3.7 GW provides a conservative estimation of hydropower potential in the South. The expanded hydropower scenario developed in this chapter only models the low-power and small hydropower potential. Many potential hydropower sites are deemed infeasible by INL through pre-established screening criteria. However, they might become acceptable and feasible as technologies develop and the nation’s population and infrastructure expands. In addition, we have not included the expanded hydropower generation that could occur with the accelerated modernization of existing large hydropower facilities.

Obviously, the hydropower potential examined in this chapter is a fraction of the potential that could be realized with advanced technology. Future generation technologies that make use of hydrokinetic energy in river, stream and constructed waterways (spillways and sluiceways) will bring enable further hydropower potential that is not modeled in this chapter. Moreover, the ocean wave energy of over 35,900 miles coastline in the South is another large future hydropower option (NOAA, 2010). See Appendix B for a brief overview of emerging hydropower technologies.

# 7. SOLAR POWER AND THERMAL ENERGY

## 7.1 INTRODUCTION

Solar technologies allow electricity to be generated from sunlight to power anything from houses to space stations. They also can use the sun's rays to heat water, indoor air, and much more. Solar technologies can be utility-scale, which allows large-scale electricity generation, or consumer-owned systems.

Utility-scale technologies are dominated by concentrating solar power (CSP) and photovoltaics (PV). Concentrating solar power, as one of the high-temperature solar thermal technologies, uses mirror arrays to focus sunlight on a collector tower or trough. The fluids within are heated and used to create steam. As in a conventional power plant, the steam turns a turbine and generates electricity.

Photovoltaic technologies generate electricity using semiconductor cell arrays. Semiconductors, usually crystal silicon or thin layers or films of photovoltaic materials applied to solar cells, convert solar radiation into direct current electricity. Inverters are needed to transform this direct current to alternating current. In some utility-scale PV deployments, tracking systems can be installed to increase electricity generation by following the sun. Since photovoltaics use diffuse light in addition to direct sunlight, PV technologies are able to utilize a greater portion of solar radiation than CSP technologies.

Electricity generation from solar power plants is intermittent since solar radiation varies by season, time of day, location, and weather. During the day, solar radiation tends to be coincident with electric power system peaks. Storage and reserve capacity assist with the provision of stable electricity output; such ancillary devices also allow PV and CSP systems to extend electricity generation into night-time hours.

There are a variety of demand-side solar technologies that consumers install on their properties. Examples are distributed solar PV and solar water heating. Distributed PV systems, usually smaller in size compared with utility-scale photovoltaics, include building integrated panels that can be placed on rooftops. Solar water heating is a low-temperature solar thermal technology used to heat water for building consumption. These usually include two components: a solar collector and water storage. The collector, oriented towards the sun, transfers solar energy to a working fluid that heats water in the storage tank.

There are two types of solar water heaters: active and passive systems. Active systems use electricity to pump and circulate the water. Figure 7.1 shows an active flat-plate solar collector installed on a Florida residence. Passive systems rely on gravity and the natural circulation of heated water. Due to their simplicity, passive systems are easier to maintain, operate, and have longer operating lives than active systems (DOE/EERE, 2010).

Solar water heaters are designed to meet a building's hot water needs, but back-up heating systems may be needed. These supplement solar water heating systems when solar insolation is inadequate, such as cloudy days. While solar water heaters have a higher initial cost than conventional natural gas or electric water heaters, they result in lower energy consumption and, therefore, lower utility bills. Flat plate collectors have been shown to save 59-61% of the energy consumed by a 50-gallon electric water heater in Florida (Colon and Parker, 2010).

**Figure 7.1 Active Residential Solar Thermal Collector (FlaSEIA, nd)**

Solar PV is one of the world’s fastest growing industries, and solar power is one of the most rapidly growing renewable electricity resources. Between 2004 and 2008, global solar photovoltaic capacity increased six-fold to 16 GW, and solar heating capacity doubled to 145 GW of thermal energy (REN21, 2009). In 2009, Germany led in solar PV installations. It was also the global leader in grid connected solar PV with 47% of existing global capacity. The U.S. and Spain lead in CSP opportunities (REN21, 2010).

Installations of solar water heaters are increasing in many countries, states, and localities as government mandates are implemented. For example, in 2008, Spain became the first country to mandate solar water heating nation-wide. China led in solar hot water installations in 2009 and in total installed capacity. By year’s end, it had more than 80% of the global hot water installations (REN21, 2009). In Jiangsu, one of the most populous provinces in China, all new residential buildings with 12 stories and below are required to use solar water heating (Xu, 2010).

The U.S. experienced rapid growth of grid-tied PV installations in the past two years. Annual PV installations in the utility sector almost tripled from 22 MW in 2008 to 66 MW in 2009 (SEIA, 2010). Cumulatively, solar PV grid-connected power in the U.S. grew to 0.7 GW in 2008, and CSP systems grew to 0.4 GW (REN21, 2009, Table R4).

In 2008, there were almost 17,000 solar thermal collectors shipped in the nation. From 1999-2008, U.S. manufactured systems were 66% of all solar thermal collectors shipped in the nation (EIA, 2010a; Table 2.1). Of the quantities installed, over 88% in 2008 went to residences, which largely use low to medium temperature collectors, while 8.8% of installations were commercial. The rest were for the industrial and electric power sectors. In 2008, solar thermal systems were mostly used for pool (81%) and water heating (13%) (EIA, 2010a; Table 2.13).

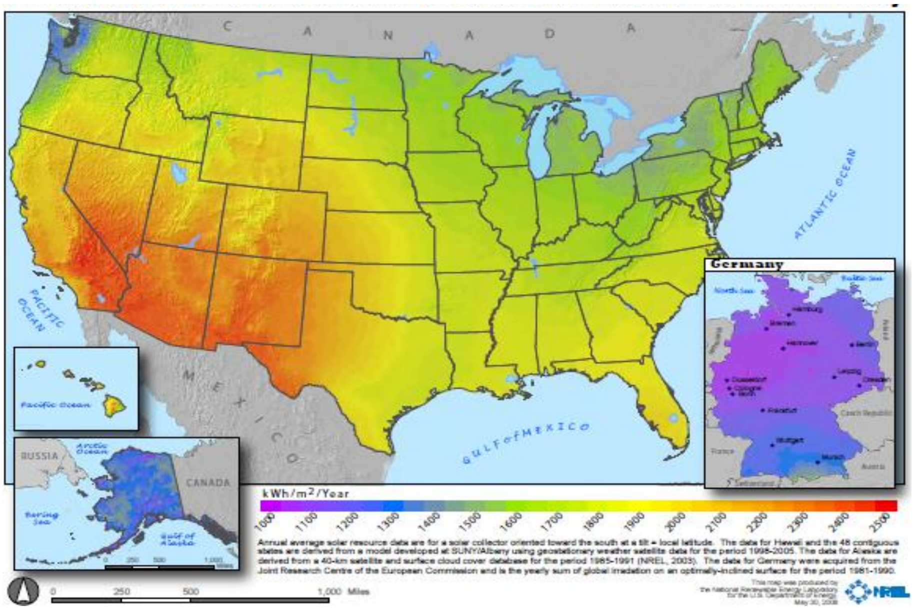
## 7.2 SOLAR POWER IN THE SOUTH

Solar renewable technologies have received less emphasis in the South, overall, than other regions. An often held view is that "[r]enewable energy sources like wind and solar are not really an option…in the Southeast." (Newkirk, 2010).

The monthly average solar radiation per day received by typical PV system installations is 5 kWh/m$^2$/day. Across the region, from West Virginia to Western Texas, average solar insolation ranges from 4 - 6 kWh/m$^2$/day (as shown in Figure 7.2). Ten southern states (i.e., Florida, Oklahoma, Kansas, Texas, Alabama, Louisiana, Mississippi, South Carolina, Georgia and Arkansas) have higher solar radiation levels (in kWh/m$^2$/day for comparable PV systems) than the national average (Denholm and Margolis, 2007).

Differences between the South and Southwest are revealed by comparing solar insolation for comparable PV systems in three cities: Phoenix, Atlanta, and Baltimore. Both Atlanta and Baltimore are considered part of the South by the Census Bureau. The 30-year average solar radiation for a flat-plate collector facing south with no tilt is 5.7 kWh/m$^2$/day in Phoenix, 4.6 kWh/m$^2$/day in Atlanta, and 4.0 kWh/m$^2$/day in Baltimore (NREL, 2010e). Atlanta is above the Southern average for solar resources, while Baltimore is at the lower range. Most of the states in the South have a CSP solar radiation level of 4 kWh/m$^2$/day or higher (NREL, 2010b).

Based on international deployment trends and rates of solar PV installations in California, one could argue that solar resource development seems to be less constrained by resource availability than by supporting policies. Germany, the world leader in grid connected solar PV with 9.8 GW in 2009 (REN21, 2010), has solar resources that most resemble Alaska's insolation, the lowest in the country. Figure 7.1 compares Germany's solar resource to the U.S.; despite its limited solar resources, Germany has still created a strong photovoltaic market through its renewable energy policies.



Annual average solar resource data are for a solar collector oriented toward the south at a tilt = local latitude. The data for Hawaii and the 48 contiguous states are derived from a model developed at SUNY/Albany using geostationary weather satellite data for the period 1998-2005. The data for Alaska are derived from a 40-km satellite and surface cloud cover database for the period 1985-1991 (NREL, 2003). The data for Germany were acquired from the Joint Research Centre of the European Commission and is the yearly sum of global irradiation on an optimally-inclined surface for the period 1981-1990.

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy May 30, 2008

**Figure 7.2 Photovoltaic Solar Resources: United States and Germany (NREL, 2008)**

### 7.2.1 Utility-Scale Solar Power

Solar PV power is one of the fastest growing renewable energy markets. While only one utility-scale PV power station is operating in the South today, others are under construction. The DeSoto Next Generation Solar Energy Center (NGSEC) in Florida is the largest PV farm in the nation, which started operating in October 2009. With a nameplate capacity of 25 MW, the PV farm is able to serve about 3,000 homes by generating about 42,000 MWh of electricity per year. The estimated levelized cost of NGSEC's generated electricity is about 19¢/kWh over the plant's 30 year lifetime (NREL, 2010a).

Among the large PV plants under construction in the South, the Blue Wing solar electric power plant in Texas, a 16 MW facility, should be completed by the end of 2010. The Davidson County Solar Farm in North Carolina, a 21.5 MW facility, is expected to be completed in 2011 (NREL, 2010a). Lastly, a 5 MW solar photovoltaic "Solar Farm" and Education and Welcome Center in Haywood County, Tennessee is also underway. Refer to Appendix A for additional solar projects in the South.

The national cumulative CSP capacity reached 2.38 GW with three new CSP plants in 2009 (SEIA, 2010). Seven commercial CSP plants are in operation in the U.S., three of which are in California, two in Arizona, one in Nevada, and one in Hawaii.

**_Box 7.1 Pippin Solar Photovoltaic Farm_**

**Capacity:** **200 kW**
**Location:** **near Arlington, GA**
**Operation Since:** **June 2010**

Trey Pippin installed a 200 kW capacity photovoltaic facility, which began operation in June 2010, on about one acre of his pecan farm. It is the largest solar array in Georgia and uses 836 panels manufactured by Suniva, an offshoot of the Georgia Institute of Technology.

A five year power purchase agreement has been signed with Georgia Power, where all generated electricity will be sold to the utility during that time. The produced power offsets about 223 tons of carbon per year.

Currently, Georgia Power purchases solar photovoltaic power for 17¢/kWh for residential systems up to 25kW and commercial systems up to 100 kW. The company also makes purchases agreements with individual photovoltaic energy providers at an agreed upon price. The Pippin Solar Photovoltaic Farm may be one of these providers since its capacity exceeds the 100 kW limit set for commercial providers.

Picture from AgFax, 2010

Sources: AgFax, 2010; Georgia Power, Suniva, nd

Although the South has no CSP plants currently in operation, one is under construction in Florida. The Martin Next Generation Solar Energy Center (MNGSEC) will use parabolic trough technology. The 75 MW solar facility will be combined with a 3.8 GW natural gas plant (FPL, 2010; Mouawad, 2010). Upon completion at the end of 2010, MNGSEC will be the first utility-scale solar facility in Florida and the first hybrid solar plant in the U.S. (NREL, 2010a).

### 7.2.2 Demand-Side Solar Technologies

Of the many demand-side solar technologies, this chapter focuses only on solar PV and solar water heating, which are seen as the principal near-term opportunities.

In the U.S., the cumulative installed capacity of grid-tied photovoltaics reached 1 GW in 2009 (less than 60 MW of which was in the South), with 150 MW of new installations in the residential sector (SEIA, 2010). The total capacity in the South is 11% of California's and 6.9%

of national installations (Appendix G.1 Table G.1). Though the South has higher solar insolation levels than the rest of the nation, the South has lower coverage of PV installation (Denholm and Margolis, 2007). No states in the region ranked in the top ten for cumulative installed distributed solar capacity in 2008 (Doris et. al., 2009).

### *Box 7.2 Camp Lejeune Solar Hot Water Installations*

**Installations: 900**
**Location: Camp Lejeune, NC**

Camp Lejeune in North Carolina is currently installing solar hot water heaters on 900 homes. Funding for the project is partially from ARRA subsidies.

The camp is obtaining solar panels from FLS Energy, which is selling them at a reduced cost. The military will repay the company over 12 years for the panels, which have an estimated life of 20 to 25 years.

Picture adapted from NPR, 2010

*Sources: Bhanoo, 2010

## 7.3 BARRIERS, DRIVERS, AND POLICIES

Though solar energy is seen as an ubiquitous and inexhaustible energy source, there are numerous market failures and barriers that impede solar technology implementation.

The intermittency of sunlight limits use of photovoltaic panels and solar thermal technologies to daylight hours. Solar power is attractive because its electricity production largely coincides with periods of high power demand, which is typically greater in the day than at night and higher during on-peak than off-peak hours. While California procurement rules set an on-peak and off-peak avoided cost (market price referent) that reflects these different values, few utilities in the South have such pricing schemes. Yet its application is limited because no solar system can run twenty-four hours a day, even with the help of thermal storage devices. In addition, because demand-side solar technologies are generally not dispatchable, they may be less appealing for utilities to incorporate as a generation resource.

Current solar technologies have low efficiencies in harnessing solar radiation to generate electricity. Photovoltaic panels have conversion rates of 12-18%. At high system temperatures, these conversion rates decrease. PV systems paired with concentrators have higher efficiencies ranging from 25-40%. The conversion rate for CSP is about 20% (EIA, 2010a). Low efficiencies can impede rooftop PV systems. Limited roof area may not allow some PV systems to generate enough electricity to fully power building needs. Even though solar energy is free and non-polluting (unlike fossil fuels), conversion efficiencies are important because they determine the electricity output of a PV system that has capital costs and may have limited square footage.

The production of solar photovoltaic modules may face material constraints. The use of rare earth minerals (e.g., indium) and compounds in the production of high efficiency solar photovoltaics may limit the quantity that can be manufactured – particularly “second generation” PV modules made from organic polymer materials (Barras, 2009). These compounds may also complicate production and disposal processes due to pollution concerns.

The lack of storage technologies limits the use of solar generated electricity during times with low or no solar insolation. In areas with ample solar resources, demand-side users of solar photovoltaics may generate more electricity than can be used onsite. This excess electricity may be sold to the grid, but in many areas, the lack of net metering and electrical grid access precludes this option.

The South has higher capital costs for installed PV systems than other regions in the nation. NREL's OpenPV program collects cost information for 45 states from local retailers' self-reports (Figure 7.3). Based on the voluntary cost reports, the average installed PV system cost in the South is $8.4/W in 2009, while the national average is $7.9/W (Figure 7.3, NREL, 2010c). This means, when considering solar panels, households in the South face higher cost hurdles than households elsewhere in the nation. There is a "catch-22" nature to this problem: costs in the South are high partly because there is only a limited market for PV, resulting in few distributors and dealers, and limited economies of scale.

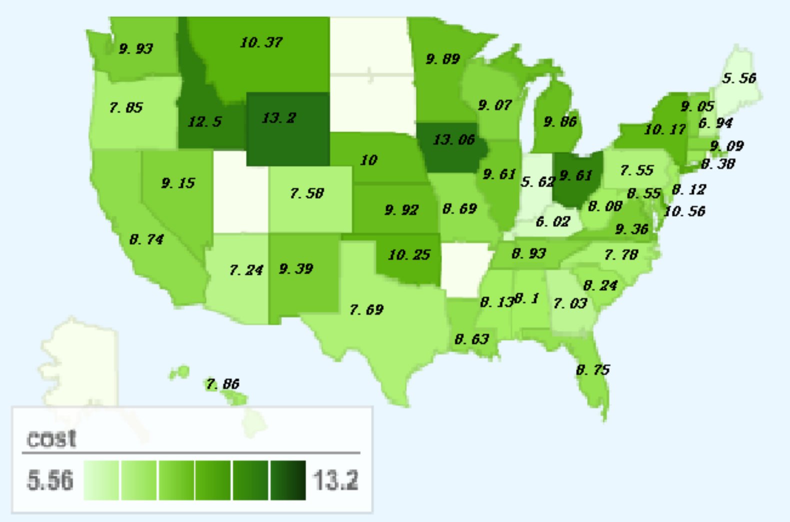


**Figure 7.3 OpenPV self reported Installed Cost ($2009/W) by State (NREL, 2010c)**

The South is lacking in innovative financing schemes, such as solar power purchase agreements (SPPA). SPPA allow a third-party to own, install, and maintain the photovoltaic panels, while the host, who has the panels installed on their building, can purchase lower-cost electricity (EPA, 2010d). In the South, Florida and North Carolina face legal barriers preventing such arrangements. Other Southern states are not currently using SPPAs, though they face no legal barriers (DSIRE, 2010a).

Currently, solar power is not as economically competitive as other renewable energy options such as biomass and wind energy. When considering these costs, most Southern states will likely prioritize development of other renewable energy sources before solar power. Still, some states in the South like Tennessee are subsidizing solar PV systems to develop a solar industrial base and generate jobs in the new energy economy.

For example, the State of Tennessee has devoted $61.5 million to solar investments through the State Energy Program (SEP) and Recovery Act funds. While this is the largest stimulus SEP solar investment, six other states in the region are using over $5 million from their allocations towards advancing solar (Gorman & Zidek-Vanega, 2010). This infusion of capital could help the South better use its solar resources.

The Business Energy Investment Tax Credit (ITC), a 30% federal subsidy in capital cost with no maximum, offers incentives to commercial, industrial, utility and agriculture sectors and buoys photovoltaic installations. For the residential sector, a 30% federal subsidy – Residential Renewable Energy Tax Credit (RRETC) – is also offered for solar photovoltaics and solar water heaters. Additionally, the Renewable Energy Production Incentive (REPI), established by the federal Energy Policy Act of 1992, provides performance-based incentive payments of 2.1¢/kWh for solar power generation to utility companies. REPI was reauthorized by the Energy Policy Act of 2005 through September 30, 2026.The Clean Renewable Energy Bonds (CREBs), one federal loan program, offers low interest loans to foster the development of solar power. CREBs are offered directly to municipal utilities and rural electric cooperatives with variable interests (DSIRE, 2010b).

Some Southern states have policies encouraging the development of green power markets. Texas and Virginia have adopted green power policies requiring electricity suppliers to offer renewable power options to consumers (e.g., the 100% renewable energy purchase option in Virginia). Texas, Arkansas, Florida, Maryland, DC, and Delaware have full environmental disclosure policies requiring electricity suppliers to provide information on fuel sources and emissions associated with electricity generation. Virginia has adopted a partial environmental disclosure policy and West Virginia has proposed such a policy (DOE, 2010a).

Four states in the South along with the District of Columbia have renewable electricity standards (RES): Delaware, Maryland, North Carolina, Texas, and West Virginia. Oklahoma and Virginia have also set voluntary renewable energy goals. Of the seven states and D.C. with a voluntary or mandated RES, Delaware, North Carolina, Texas, West Virginia and D.C. allow solar water heaters or solar thermal technologies to satisfy the RES requirements. A few states have minimum requirements for solar set. Solar electricity generation is required by D.C. (0.4% by 2020), Delaware (3.5% by 2026), and Maryland (2% by 2022). North Carolina requires 0.2% use of solar technologies by 2018, including not only solar PV and solar water heating, but also technologies such as solar absorption cooling and solar driven refrigeration (DSIRE, 2010d; DPSC, 2009).

At the utility level, a variety of utilities offer green pricing options to their consumers. Green pricing programs collect money from participants with a voluntary surcharge for renewable energy. For solar power, states with green pricing utilities are Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia (DOE, 2010a).

On the demand side, certain states and countries heavily promote the use of solar water heating. Starting in 2010, Hawaii began requiring solar hot water heaters for all newly constructed single-family homes.

The federal government also supports state and local programs to help the South utilize its solar resources. Through the Recovery Act funding or state appropriations, six states offer governmental rebates for photovoltaics, while eight states provide rebates for solar hot water heaters (five of the states offer both). Several of the states also provide tax credits for 30 to 50 percent of system costs up to a maximum level.

In addition to incentives, the Solar Alliance (2010) also advocates net metering, interconnection, and utility rates and revenue policies as the “Four Pillars” for solar policy. In its report, “Freeing the Grid 2009,” the Network for New Energy Choices (2009) rated the states on their net-metering and interconnection efforts. Highly rated states for net metering had high limits on allowable kilowatt-hours, broad applicability, and wide acceptance. While six states in the South either earned an F or do not have statewide net metering, seven states received an A or B for their implementation of this policy. The District of Columbia, Maryland, and Virginia earned high marks for interconnection procedures that are fair, transparent, simple, and broadly applicable, while five states in the region do not have statewide interconnection policy, and three other states received a failing grade.

At the local level, Austin, TX, Houston, TX, Knoxville, TN, and Orlando, FL, received designations from the U.S. DOE as Solar America Cities. Through partnerships, projects and technical assistance, these cities are developing solar resources within their communities (DOE, 2010b. Over the past two years, eight states in the region have also authorized Property Assessed Clean Energy (PACE) financing policies, which provides a funding mechanism for clean energy through municipalities (DSIRE, 2010b). With the Energy Efficiency and Conservation Block Grants and other efforts, localities are becoming key drivers of solar development.

Other broad policies, as outlined earlier in this paper, also impact solar deployment. The South does not have the solar resources of the Southwest, but the resource and potential is available for an expansion of this energy. Through lead-by-example efforts, public entities in the South are expanding their solar wattage, including the recent procurement of 900 solar hot water heaters at the Camp Lejeune military base in North Carolina (see Box 7.2 above). With stronger proposals and more effective implementation, policy-makers can also attract investment from citizens and companies to expand and install solar photovoltaics and solar hot water heating across cities and states.

## 7.4 THE CASE FOR EXPANDED SOLAR PHOTOVOLTAICS

The Expanded Solar scenario contains three components: the expansion of utility-scale photovoltaics, demand-side solar photovoltaics, and demand-side solar water heaters. Each of the three components of the scenario was run separately. The results of the separate runs are presented in this section for solar photovoltaics and in the following section for solar water heating. An efficiency improvement over time of existing PV and CSP systems is applied to utility-scale deployments. For demand-side solar, we implement updated cost estimations for photovoltaics and an extension of existing tax credits which provide 30% subsidy on capital cost for solar PV. In the residential sector, the subsidy is called the Residential Renewable Energy Tax Credit (RRETC), while it is called the Investment Tax Credit (ITC) in the commercial sector.

### 7.4.1 Modeling Scenario Assumptions

For the Expanded Solar PV scenario, all the modeling in the utility sector was based on NERC regions and the modeling in the residential and commercial sectors was based on census divisions. The efficiency improvements to reflect technology development for utility-scale solar photovoltaics were modified to increase by 2% every five years (no improvement is the default setting in NEMS). The updated assumptions match the efficiency assumptions for consumer owned photovoltaics in NEMS.

In addition to the efficiency improvement scenario, a cost reduction scenario was explored where the impact of an extended RRETC and ITC (e.g., 30% subsidy up to 2030) was applied to solar PV in the utility sector. The cost reduction did not produce any significant impact, unlike the efficiency improvement. Centralized photovoltaic power stations are modeled in the Electric Reliable Council of Texas (ERCOT) and Southwest Power Pool (SPP) regions. No concentrating solar power capacity is projected by SNUG-NEMS for the four NERC regions in the South.

In our modeling of demand-side photovoltaics, we reduced the NEMS cost assumptions to reflect literature that indicates lower PV system costs are warranted (SEIA, 2010; NREL, 2010c; Wiser, et al, 2009; SolarBuzz, 2010; ICF International, 2010; Chaudhari, et al, 2004). See Table 7.1 for a summary of installed PV system costs as reported in the published literature.

**Table 7.1 Installed PV System Cost as Reported in Literature**

| Reference | Cost ($2005) | Year | Bias |
|---|---|---|---|
| NREL: OpenPV project | Average: $7.21/W<br>Range: $5.06-$12.0/W | 2009 | Voluntary reported price; Varies across states |
| LBNL report: Tracking the Sun II | Average: $6.83/W | 2008 | Skewed to California and New Jersey |
| SEIA report: US Solar Energy Industry Year in review 2009 | Average: $5.92/W<br>0-5kW: $7.46/W<br>25-50kW: $7.10/W | 2009 | On-grid PV systems |
| ICF International report: PV cost and performance characteristics for residential and commercial applications | Average: $6.8/W<br>0-5kW: $7.8/W<br>10-100kW: $7.26/W | 2008 | References back to the LBNL study |
| Solarbuzz module survey report | Average $6.38-$7.64/W<br>Lowest cost: $2.28-$2.73/W | 2009 | Only for modules of 125W and larger |
| Navigant report: PV Grid Connected Market Potential under a Cost Breakthrough scenario | Residential sector: $5.30/W<br>Commercial sector: $4.25-4.65/W<br>Utility sector: $4.00/W | 2010* | *Cost projection (done in 2004) |

Table 7.2 shows the cost assumptions in our Expanded Solar PV scenario. Our cost trajectory begins with values comparable to the installed PV system costs reported by other studies (as shown in Figure 7.4). Our Expanded PV scenario diverges from the NEMS reference beginning in the year 2011 when we apply a low cost estimation.

| Table 7.2 SNUG-NEMS Assumptions on Capital Cost for PV systems ($2005/kW) | | | | | |
|---|---|---|---|---|---|
| | **2011** | **2015** | **2020** | **2025** | **2030** |
| Residential-scale PV | 6,386 | 5,059 | 3,400 | 3,189 | 2,977 |
| Commercial-scale PV | 5,768 | 4,538 | 3,000 | 2,741 | 2,481 |

In addition to the relatively low cost estimation, we examine the impact of an extended RRETC and ITC on solar photovoltaics on residential and commercial installations. The federal tax credits offer 30% subsidies for the installed cost of demand-side solar technologies such as solar PV systems and solar water heaters. In the commercial and residential sector, solar PV systems installed before December 31, 2016, are eligible for the ITC and RRETC with no maximum credits. To model the potential for solar PV systems in the South, we extended the expiration date of the tax credits from 2016 to 2030. By doing so, our Expanded Solar PV scenario further diverges from the NEMS reference beginning in the year 2017.

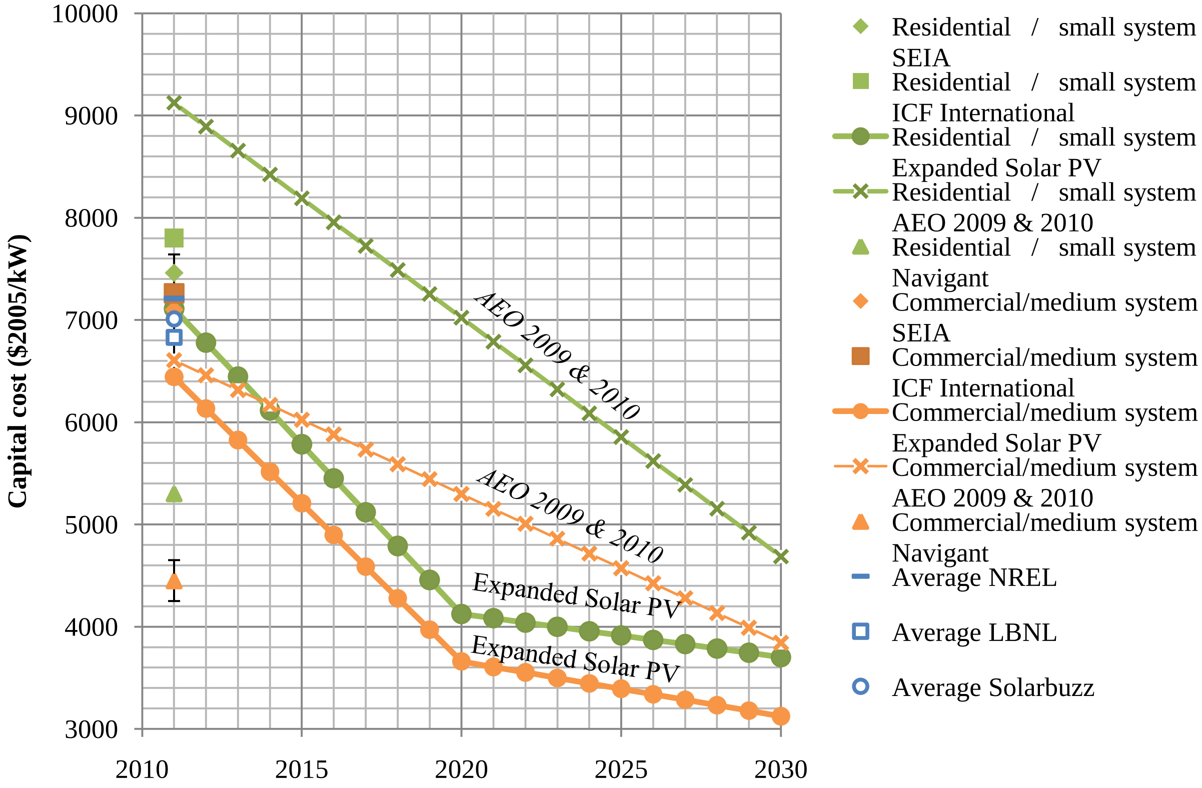


**Figure 7.4 SNUG-NEMS PV Cost Trajectory in Comparison to the Literature**

### 7.4.2 Stand-alone Modeling Results for Expanded Solar Photovoltaics

The Expanded Solar PV scenario projects a more rapid penetration rate for solar technologies in the residential, commercial and utility sectors than the reference scenario (Figure 7.5). In 2020, the combined cumulative generating capacity reaches 15.9 GW in the South Census region (versus 6.0 GW in the reference scenario), with 98% coming from distributed generation in the residential sector. In 2030, solar powered generating capacity increases to 41.8 GW (versus 8.5 GW in the reference scenario), with 94% installed in the residential sector.

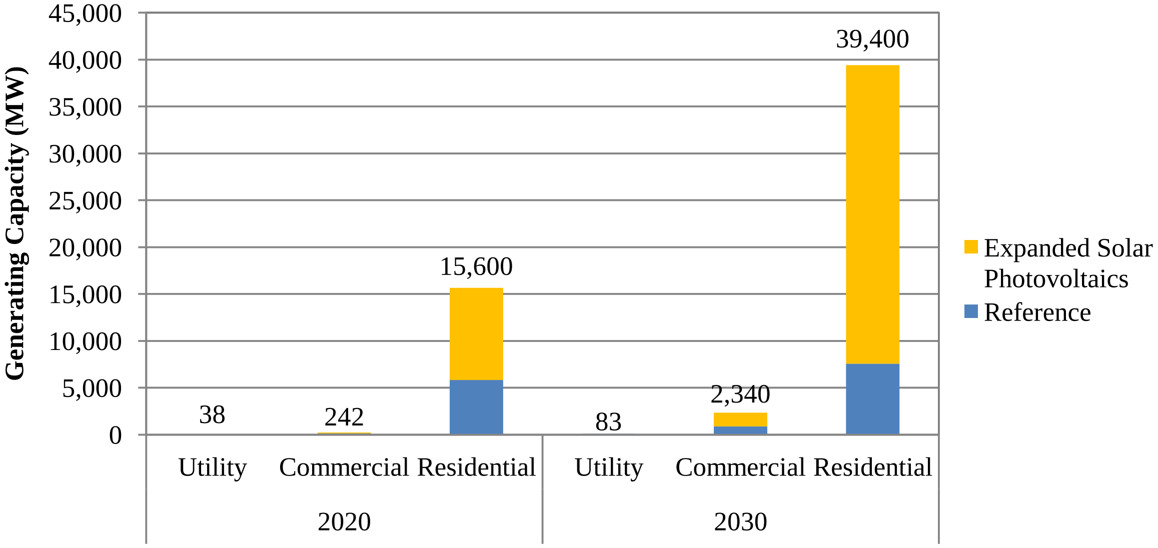


Figure 7.5 Generating Capacity of Solar Photovoltaics

This capacity projection is comparable to projections from other studies (Paidipati et al., 2008; Navigant, 2008). The rooftop PV capacity estimated in different scenarios by Paidipati et al., in the U.S. is between 1.97 – 11.12 GW by 2015, while our Expanded Solar PV scenario projects installed PV capacity of 9.62 GW for the nation's residential and commercial sectors in 2015. Our projection installs less PV than Paidipati's best scenario, which is more aggressive by assuming several focused policies such as electricity price escalation, cap and trade, nationwide net-metering and time-of-use rates, and a RPS. Navigant estimated Florida's PV potential in all sectors to be 3.2 GW by 2020. Florida processes one third of the PV potential in the South Atlantic (Chaudhari, Frantzis, and Hoff, 2004). Our projection of 8.8 GW for the South Atlantic in 2020 is close to Navigant's projection.

Electricity generated by solar photovoltaics reaches 26 TWh in 2020, which is 0.1% of total electricity generation in the Expanded Solar Photovoltaics scenario. Distributed generation in the residential sector is 98% of the total solar power generation in the South. Annual generation by solar power passes 69 TWh in 2030, which is 0.3% (tripling the reference scenario) of total electricity generation in the South (Figure 7.6).

In the utility sector, the results are presented by NERC regions while they are presented by census divisions in residential and commercial sectors. For the entire South, cumulative electricity generation from both consumer-owned and utility-scale solar photovoltaics will increase 371 million kWh by 2030 above the reference projection. The ERCOT and SPP regions will increase by 7.5 million kWh and 5.2 million kWh, respectively, in 2020.

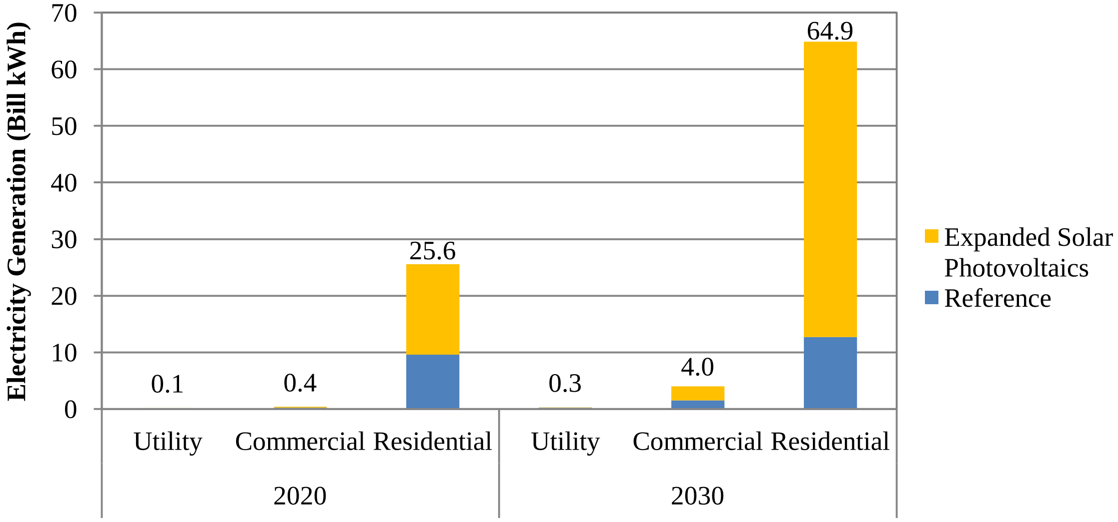


**Figure 7.6 Electricity Generation from Solar Photovaltics**[30]

The extended 30% subsidy has a significant effect on encouraging commercial and residential PV installations in the South. The cumulative electricity generation by photovoltaics is 42.1 TBtu in the commercial sector and 1,386 TBtu in the residential sector over the following two decades. More details about rooftop PV installation in the three census divisions can be found in Table G.3 and Table G.4 of Appendix G.

### 7.4.3 Cost Effectiveness

The Expanded PV scenario estimates the levelized cost of electricity (LCOE) for solar photovoltaics based on NEMS outputs of PV installations and power generation between 2010 and 2030. The scenario assumes all systems operating in 2030 continue generating electricity at a declining rate until 2050. The 2010 LCOE is estimated based on the cost and electricity generation from 2010 to 2050, while the 2020 LCOE estimation is calculated based on the cost and generation from 2020 to 2050. A discount rate of 7 percent was applied to the calculations. See Appendix G for additional details of the LCOE calculations.

**Table 7.3 LCOE for Utility-Scale Solar Photovoltaic**

| Energy Type | LCOE from 2010-2030 Excludes Tax Credits* | LCOE from 2020-2030 Excludes Tax Credits* |
|---|---|---|
| Electricity (¢/kWh) | 13.3 | 12.5 |
| Total Energy ($/MMBtu) | 39.0 | 36.6 |

* The LCOE calculation for utility-scale PV does not include the cost of existing tax credits (i.e., REPI and ITC). If the cost of tax credits were included in the LCOE calculation, the LCOE would be at least 2.1¢/kWh higher.

Note: These LCOE calculations assume efficiency improvements over time. If instead the efficiency and capacity factors were both fixed (as in the reference case), the LCOE would be 33.5¢/kWh for the utility-scale PV.

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[30] If a large PV farm existed in the South with a capacity factor around 15-20%, the capacity needed to generate 64.9 billion kWh of electricity per year would be 37 – 49 GW.

The LCOE for utility-scale PV was calculated based on a dynamic model, which assumes efficiency improvements over time. The estimated LCOE from 2010 to 2030 from utility-scale photovoltaics is 13.3¢/kWh. It drops to 12.5¢/kWh from 2020 to 2030.

The LCOE calculations in the Expanded PV scenario for distributed and utility-scale photovoltaic generation share the same assumptions. For solar panel installations on residences and businesses, the LCOE from 2010 to 2030 ranges from 9.2 – 10.1¢/kWh when the tax credit extensions are included.

**Table 7.4a LCOE of Solar Photovoltaics in the Residential Sector**

| | Levelized Cost from 2010-2030 | | Levelized Cost from 2020-2030 | |
|---|---|---|---|---|
| Energy Type | Tax Credit Extension* | Excludes Tax Credits** | Tax Credit Extension* | Excludes Tax Credits** |
| Electricity (¢/kWh) | 10.1 | 7.1 | 7.1 | 5.1 |
| Natural Gas (¢/therm) | -- | -- | -- | -- |
| Total Energy ($/MMBtu) | 29.6 | 20.8 | 20.8 | 14.9 |

**Table 7.4b LCOE of Solar Photovoltaics in the Commercial Sector**

| | Levelized Cost from 2010-2030 | | Levelized Cost from 2020-2030 | |
|---|---|---|---|---|
| Energy Type | Tax Credit Extension* | Excludes Tax Credits** | Tax Credit Extension* | Excludes Tax Credits** |
| Electricity (¢/kWh) | 9.2 | 6.5 | 8.7 | 6.1 |
| Natural Gas (¢/therm) | -- | -- | -- | -- |
| Total Energy ($/MMBtu) | 27.0 | 19.1 | 25.5 | 17.9 |

* Includes the cost of the RRETC and ITC and associated costs.

** Excludes the cost of RRETC and ITC and associated costs.

Note: The LCOE values presented above for demand-side PV are calculated by assuming capital cost reductions over time. If these capital costs did not decline over time, the LCOE would be as high as 28.4¢/kWh in 2010 and 15.3¢/kWh in 2020 with tax credit extension.

Solar panels are viable for households and business facilities who want to adopt distributed generation technologies. Consumers pay less for installing rooftop PV systems with tax credits which share 30% of the cost burden from the total investment. The federal tax credits incentivize private sector adoption for PV because the LCOE is lowered when one does not take tax credits as part of the cost. Furthermore, solar photovoltaics will likely experience continuous cost reductions in the future (SEIA, 2010; NREL, 2010c; Wiser, et al, 2009).

The calculated LCOE in 2010 and 2020 (Table 7.4) show a declining installed system cost trend for residential and commercial-scale photovoltaic systems. This underpins the accelerated addition of new distributed PV capacity during the second decade of our 20-year period of analysis.

## 7.5 THE CASE FOR EXPANDED SOLAR WATER HEATING

The potential for expanded solar water heating could occur either as the result of an extended subsidy that incentivizes the product. Because the residential sector has mores solar thermal installations (88%) when compared with the commercial and industry sectors, this section focuses only on solar water heating in residences (EIA, 2010a).

The South relies largely on electricity and natural gas for water heating. Still, liquefied petroleum gases (LPG) is also used, as well as a much smaller proportion of fuel oil. In 2005, the South Atlantic and East South Central census divisions used natural gas and electric water heating almost equally (46% and 45%, respectively), while the West South Central division used more natural gas water heating than electric (70% versus 22%). The South had the most expenditures associated with water heating, almost $11.5 billion or 36% of national water heating expenditures, in 2005 (EIA, 2009a). In 2005 and 2009, the South was the most populous region with about 37% of the nation’s population (EIA, 2009a; Census, 2010).

### 7.5.1 Modeling Scenario Assumptions

Reflecting current legislation, the NEMS reference case models a 30% subsidy under the Residential Renewable Energy Tax Credit (RRETC) from 2006 to 2016 for the capital cost of solar water heaters. Only one solar water heater model is available in NEMS for analysis. The SNUG-NEMS Expanded Solar Water Heating scenario extends this tax credit for capital cost in the residential sector to 2030. Table 7.5 shows the original NEMS costs and the SNUG-NEMS costs as altered for the Expanded Solar Water Heating scenario.

**Table 7.5 Original and New Costs for Solar Water Heater Modeling**

| Years | NEMS Cost | SNUG-NEMS Cost |
|---|---|---|
| 2006-2016 | $3,500* | $3,500 |
| 2017-2019 | $4,500 | $3,150 |
| 2020-2029 | $4,000 | $2,800 |
| 2030 | $3,500 | $2,450 |

*Once the 30% tax credit (RRETC) is removed, the original capital cost of the solar water heater is $5,000.

The cost of a solar water heater may vary from region to region. The average cost for a solar water heater in the nation ranged from $2,000 to $4,500 (DOE/EERE, 2003). In Florida, the cost ranged from $1,500 to $3,000 (DOE/EERE, 1996). These cost studies were conducted several years ago, suggesting that the actual cost of solar water heaters may be lower now.

NEMS solar water heater costs are at the high end of these ranges. New costs begin at $3,500 due to a 30% tax credit and lasts until 2016. Then they rise to $4,500 from 2017-2019 before decreasing back to $3,500 by 2030.

To bring the cost down to the approximate midpoints of the ranges above, a 30% tax credit is included from 2017 onwards in SNUG-NEMS. Even in 2030, the year with the lowest altered cost, the cost of $2,450 with the 30% tax credit extension does not exceed the lower range of $1,500 or $2,000 from the Department of Energy studies discussed in the above paragraph.

### 7.5.2 Stand-Alone Modeling Results for Expanded Water Heating

The residential sector realizes energy savings with greater solar water heating potential. Figure 7.7 displays the total primary energy savings for water heating in both sectors in 2020 and 2030. In 2030, the residential sector saves over 2.7 TBtu of total primary energy from fossil fuels, with about 66% from electricity and the remainder from natural gas. During this year, over 22 TBtu of additional solar energy is used for water heating when compared to the reference scenario. This solar energy displaces fossil fuels that would otherwise be required for residential water heating.

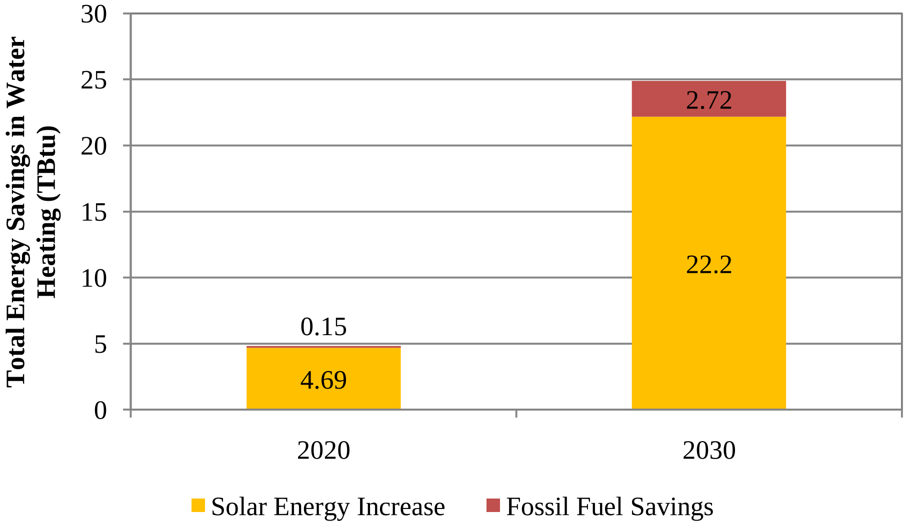

**Figure 7.7 Total Water Heating Savings with Expanded Solar Water Heating Scenario**

Regardless of the solar water heating system type, the majority of solar hot water users have a supplementary water heating system. These supplementary systems, usually electric or natural gas, help heat the water to desired temperatures when sunlight is low, such as during winter months or cloudy days. In NEMS, it is assumed that 50% of the hot water heating demanded is supplied by the solar water heater while the remainder is supplied by a supplementary electric water heating system.

In the South, the fraction of water heated by the sun may be higher than 50%. Graystone Electric conducted a one-year study of solar water heating systems in Georgia. They discovered 84.2% of the hot water was heated by the sun, while the remainder was heated by a supplementary system (Personal Correspondence with Gerry Kilgore, June 15, 2010). The average solar fraction, or the amount of water heated by the sun, ranges from 40-80% within the U.S. (Denholm, 2007). Water pipe insulation can also increase the solar fraction by 5-10% with little added cost (Colon and Parker, 2010). This suggests that the solar fraction in the South may be in the upper range of that available in the nation, far surpassing the 50% assumed by NEMS.

When the supplementary electric heating assumption of 50% was removed as a sensitivity in SNUG-NEMS, the total benefits increased. Since solar water heating in the South will likely have more than 50% of the water heated by the sun, the total water heating savings will be higher than those presented in Figure 7.6.

The assumption that 50% of the energy needed for solar water heating is electrically supplied also influences the fossil fuel savings realized by the scenario. Though 22.2 TBtu of additional solar energy is used in 2030 from this scenario, the assumption requires the same amount of electricity to be supplied for solar water heating. Because of this, electricity usage actually increases over the baseline for most of the scenario. Only after 2022 are electricity savings realized, rising to about 66% of the total fossil fuel savings in 2030. Due to the greater electricity demand to match the increased solar energy demand, the total fossil fuel savings from the Expanded Solar Water Heating scenario are small.

## 7.6 CONCLUSIONS

The Expanded Solar scenario, which includes the Expanded Solar PV and Expanded Solar Water Heating scenarios, examines the potential of solar technologies to generate electricity and energy savings in the South. Most notably, electricity generated by distributed solar photovoltaics grows modestly to 26 TWh in 2020 and then rises to over 69 TWh in 2030, accounting for 0.3% of total electricity generation in the South, which is three times more than in the reference scenario. Electric demand is also tempered in the Expanded Solar scenario through the increased penetration of solar water heaters. These results suggest that, when it comes to utilizing solar power, consumers are moving far ahead of utilities. The demand-side solar technologies not only provide the South with a significant amount of green electricity through PV panels, but also help reduce the amount of electricity demanded for water heating through solar water heaters.

Solar technologies can help Southern states meet Renewable Electricity Standards, increase energy security and independence, improve air quality, and reduce electric peak requirements. This chapter examined only a limited number of technologies. Available solar technologies continue to increase in variety and performance as science and technology advances. Because of this, the potential examined in this chapter is likely only a portion of the full solar power potential, which will expand further with future technology innovation.

# 8. HEAT PUMP WATER HEATERS

## 8.1 INTRODUCTION

Heat pumps are a class of energy-saving devices that move heat from a higher temperature "source" such as the air, water, or ground, to a lower temperature "sink" with the help of electricity. With a reversing valve, heat pumps can provide either heating or cooling. Air-source heat pumps (the most common type of heat pump) can decrease electricity consumption for space conditioning by 30-40% (DOE/EERE, 2009b). Ground source (geothermal) heat pumps offer the potential for even greater electricity savings—cutting electricity consumption for heating and cooling by 25-70%, depending on the location and efficiency (Goetzler, Zogg, Lisle, and Burgos, 2009). There are also heat pump water heaters, an over 40-year-old technology that has benefited from recent technical advances and a resurgence of interest. These devices use air-source heat pumps to heat water.

The energy efficiency of a heat pump is indicated by its Coefficient of Performance (COP), the ratio of the heat delivered by the heat pump and the electricity supplied. The higher the temperature differences between the heat source and output temperature, the lower the COP. Because of this, heat pump performance declines with high temperatures differences, such as cold weather (Zogou & Stamatelos, 1998).

## 8.2 HEAT PUMPS IN THE SOUTH

The South has the highest regional temperature in the nation, making it a fitting geographical candidate for use of air source heat pumps. Figure 8.1 shows the average temperature of the South in comparison to other census regions and the nation.

Ideally, the heat source for a heat pump should have high temperatures during times when heating water or air is desired (Zogou & Stamatelos, 1998). Because of this, the South may be better suited to use heat pumps for water heating, which is required year round, since the temperature difference between the heat source (ambient air) and final water temperature is smaller.

Retrofitting existing buildings with energy efficient technologies or implementing such technologies into new construction provide an opportunity to realize energy savings. For instance, residential retrofitting alone may reduce energy consumption by up to 40% per home (Recovery through Retrofit, 2009). Heat pumps reduce the electricity used for space conditioning and water heating by taking advantage of the solar-derived energy within the surrounding environment. For this reason, heat pumps have been labeled a "renewable" technology by some policymakers (Tokyo Electric Company, 2010).

Resource and time constraints combined with the complexities of modeling heat pumps for space conditioning resulted in a focus on heat pump water heaters in this chapter. Also, by evaluating the potential for heat pump water heating, we are able to conduct a fuller assessment of renewable options for water heating – complementing our previous examination of solar water heating.

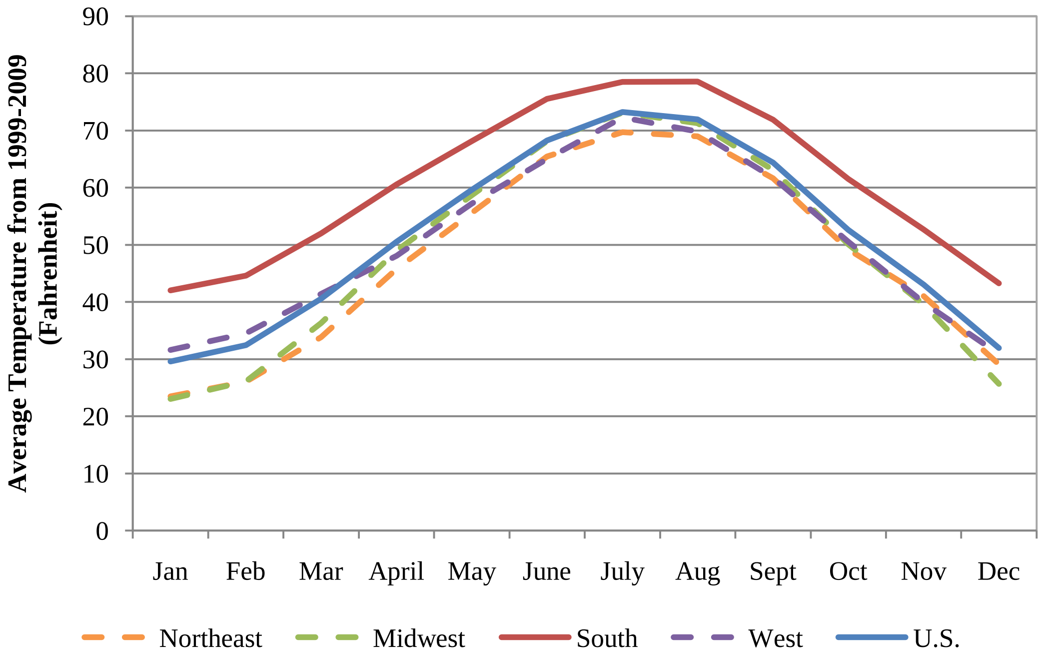

**Figure 8.1 Average Temperatures for Census Regions and U.S., 1999-2009 (NOAA, 2010)***
*The South Region does not include D.C. and the West Region does not include Alaska and Hawaii statistics for the averages included on this graph.

## 8.3 BARRIERS, DRIVERS, AND POLICIES

Though heat pump water heaters use ambient air temperatures as a renewable resource to heat water, barriers still exist that impede greater use of the technology.

The seasonal variation in ambient air temperatures causes fluctuations in the ability of heat pump water heaters to use ambient heat to heat water. This limitation of the technology may be partially overcome by proper location of the heat pump water heater during installation.

Heat pump water heaters have a high initial cost that may deter consumers. The use of subsidies and tax credits may help lessen this impact.

Information barriers regarding heat pump water heaters have prevented widespread acceptance of the technology in the past. Heat pump water heaters have been in existence for over forty years but have not gained much of a market foothold. Home owners may not be aware of this technology due to the widespread acceptance of electric and natural gas water heaters. They may also not be aware of subsidies or tax credits that may lower the initial purchase and installation costs for these technologies. To increase information about heat pump water heaters, manufacturers and retail outlets have advertised the savings and benefits to the general public (General Electric, 2010c).

A variety of public incentives exist today to encourage consumers to purchase heat pump water heaters. The Federal government offers a tax credit of 30% of the installation and cost of heat pump water heaters with a maximum of $1,500. These water heaters must have energy factors greater than 2.0 and be installed in existing primary residences (Energy Star, 2010). In addition, States across the South offer rebates on heat pump water heaters through the Recovery Act's appliance rebate program. For instance, during the first half of 2010, when revenues were still available, Georgia residents could receive $199 cash back for such a purchase (DOE, 2010).

Utilities also offer discounts and rebates to consumers to encourage the deployment of energy efficient water heaters. The Tennessee Valley Authority's (TVA) Energy Right Water Heater Program for provides $50 incentives to partner utilities for each installation of an energy efficient water heater. This incentive may be passed on to the customer where rebates ranging from $25 to the full cost of the water heater may be provided to customers (DSIRE, 2010c).

## 8.4 EXPANDED HEAT PUMP WATER HEATING SCENARIO

As with our solar water heating analysis, we limit our assessment of air-source heat pump water heaters to the residential sector in the South.

### 8.4.1 The Case for Expanded Heat Pump Water Heating

The Expanded Heat Pump Water Heating scenario is consistent with either an R&D effort reducing technology cost or an extended tax credit incentivizing the product. The Expanded Heat Pump Water Heating scenario does not include any technological performance improvements.

The inclusion of such energy-efficient products in buildings helps realize energy savings without sacrificing performance. The heat pump water heater can cut annual energy costs for water heating by over 50% (Energy Star, 2009). These water heaters use heat from the surrounding air to heat water for household use. They can be standalone units, like the one shown in Figure 8.2, or they can be added to existing conventional storage water heaters as a retrofit measure (DOE/EERE, 2009a). The higher upfront costs for a standalone unit are estimated to be paid back by energy savings in about three years (Energy Star, 2009).

**Figure 8.2 Heat Pump Water Heater (Lapsa, 2009)**

Due to the warm temperatures in the South, there are resources available for the use of heat pump water heaters. Since these water heaters remove heat from the air to supplement electrical water heating, areas with warmer ambient temperatures, like the South, are better suited for their implementation. The placement of heat pump water heaters within the house may also influence their performance since a large volume of indoor air is needed. In humid climates (typical of much of the Southeast), the dehumidified air produced by heat pump water heaters provides a valuable secondary benefit, especially during the summer. Similarly, the cooler exhaust air is a benefit during summer months, but it can require a small boost in home heating during winter months.

### 8.4.1 Modeling Scenario Assumptions

NEMS currently includes two types of heat pump water heaters in the commercial and residential sectors for the 2010 through 2030 time period. The first has an energy factor of 2.3, while the second has an energy factor of 2.4. The technologies and costs within NEMS are reflective of current technologies and costs. For example, the GE Geospring™ Hybrid Water Heater, a commercially available heat pump water heater, has an energy factor of 2.35 and a manufacturer suggested retail price of $1,699 (GE, 2010b). Rheem also has offers a heat pump water heater with comparable performance and cost, called the Rheem Hybrid Electric water heater (Rheem, 2010).

The current NEMS baseline includes a 30% subsidy in the form of a tax credit that expires in 2010 in the residential sector. As a result of the tax credit, the residential heat pump water heater with a 2.3 energy factor, as modeled in NEMS, has step-wise cost changes, rising from a capital cost of $980 in 2009-2010, to $1,400 in 2011-2019 and then decreasing to $1,200 in 2020-2030. The version with a 2.4 energy factor had a consistent capital cost of $1,700 from 2011-2030, while 2010 capital cost was $1,190 due to the tax credit.

In SNUG-NEMS, the 30% tax credit seen from 2009-2010 was extended in the residential sector scenario from 2011-2030 for both types of heat pump water heaters. The cost for the lower energy factor heat pump water heater was also altered from a stepwise decrease in cost over time to a linear one. This change was to better reflect real price changes, which are more likely to decrease slowly over time instead of having large price drops about every decade. The costs in 2010 and 2030, before the tax credit, remained at the original NEMS values. All other costs in-between 2010 and 2030 linearly decrease from the previous year's value. For additional information on the SNUG-NEMS modeling for this scenario, see Appendix H.[31]

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[31] For the Extended Heat Pump Water Heater scenario, we also extended the 30% tax credit for the two heat pump water heaters options in the commercial sector. However, as there was little adoption of those technologies, the commercial sector will not be discussed in this chapter.

## 8.5 STAND-ALONE MODELING RESULTS

### 8.5.1 Energy Savings and Cost Effectiveness

SNUG-NEMS was altered to provide census division level results for water heating consumption. Additional code was written to create a residential output file with census division results and fuel type (See Appendix H for details). This allowed calculation of the energy savings in water heating from an expanded heat pump water heating scenario.

Relative to the NEMS reference projection, the SNUG-NEMS modeling projections indicate that the residential sector realizes significant energy savings with expanded heat pump water heating. It is assumed that heat pump water heaters have a 20 year life. The savings projected in the last year, 2030, could be assumed to extend until 2050 (decreasing linearly over time as the performance of the units degrades or superior technologies are purchased). Figure 8.3 displays the total energy savings for water heating in the residential sector in 2020 and 2030. The energy savings increase over time, to 277 TBtu in 2030.

The total energy saved by this scenario rises to 19% of the projected baseline energy consumption for residential water heating in 2030. Over the duration of the projections, the energy savings are about 11% of the projected baseline water heating consumption. In this scenario, over 99% of the total energy savings from water heating are attributed to electricity savings. Most of the remainder (0.3%) is due to natural gas savings. LPG and fuel oil savings are negligible.

Most of the savings seen in the South are realized in the South Atlantic Census division with, on average, about 61% of the savings. The West South Central Census division has 26% of the savings, while the East South Central Census division realizes only 13% of the savings seen in the South. For comparison, the South Atlantic Census division was estimated to have about 52% of the population in the South in 2009. The West South Central Census and East South Central divisions were estimated to have 31% and 16%, respectively (US Census, 2010).

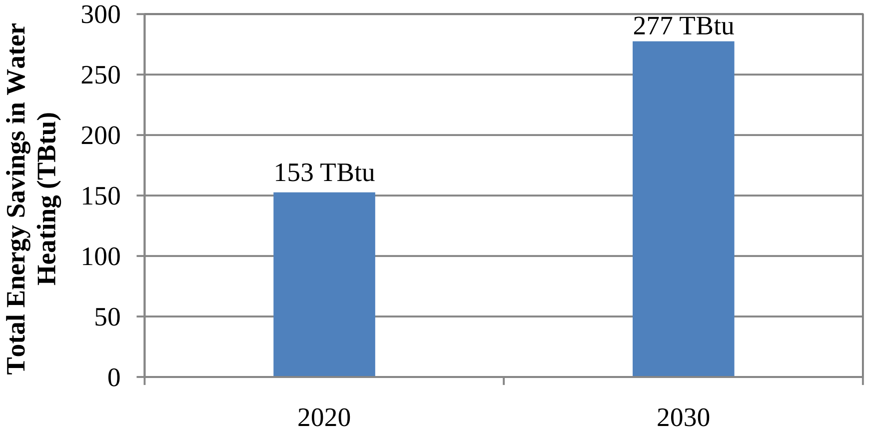

**Figure 8.3 Total Residential Energy Savings for Water Heating***
(*Total savings refers to the magnitude of energy saved in a given year from all of the heat pump water heaters operating in that year. It does not include forecasted savings.)

The heat pump water heating savings are largely electric, with little natural gas savings. The levelized cost for electricity, natural gas, and total energy are shown in Table 8.2 for the residential sector.

**Table 8.2 Levelized Cost for Heat Pump Water Heaters**

| Energy Type | Levelized Cost |
|---|---|
| Electricity (¢/kWh) | 3.2 |
| Natural Gas (¢/therm) | 21.0 |
| Total Energy ($/MMBtu) | 9.4 |

Due to its high benefit-cost ratio in the residential sector, the expanded heat pump water heating scenario produces a low levelized cost for electricity savings (3.2¢/kWh). This levelized cost is much lower than the average residential electricity price in the South which, for example, was 10.4¢/kWh in 2008 (US EIA, 2010e). The levelized cost of natural gas of 21¢/therm is about 15% of the average residential natural gas price in the U.S. from 2005 through 2009 (US EIA, 2010c). The cost of each unit of energy saved is competitive with current retail prices for energy consumption. Refer to Appendix H for details on the levelized cost calculations.

## 8.6 CONCLUSIONS

The Expanded Heat Pump Water Heating scenario estimates that heat pump water heaters have the potential to reduce energy consumption for residential water heating by an average of 11% over the projected period and up to 19% in 2030. These savings can be cost efficient in the residential sector, with a levelized cost of electricity savings of less than 4¢/kWh. The majority of the energy savings from this expanded scenario are from electricity, but there are also small natural gas savings.

The South has ample high ambient temperatures that may encourage the region to broaden its use of technologies like heat pump water heaters. This chapter only modeled two residential heat pump water heater technologies in this expanded scenario. When this scenario is combined with other water heating scenarios, such as an Expanded Solar Water Heating scenario, competitive effects between the different water heater types may occur. Due to the variety of heat pump water heater technologies available and future technology development, the potential of an expanded heat pump water heating scenario in the South may be greater than that presented here.

# 9. COMBINED HEAT AND POWER

## 9.1 INTRODUCTION

CHP (sometimes referred to as "cogeneration") is a form of distributed generation that requires much less fuel to achieve the same energy output as separate heat and power systems. As illustrated in Figure 9.1, traditional systems of separately producing heat and power operate at 45% efficiency, whereas CHP systems can bring that efficiency up to 80% or higher (Shipley, et al., 2008). Any industrial facility that consumes heat and electricity in sufficient quantities can benefit from installing CHP.

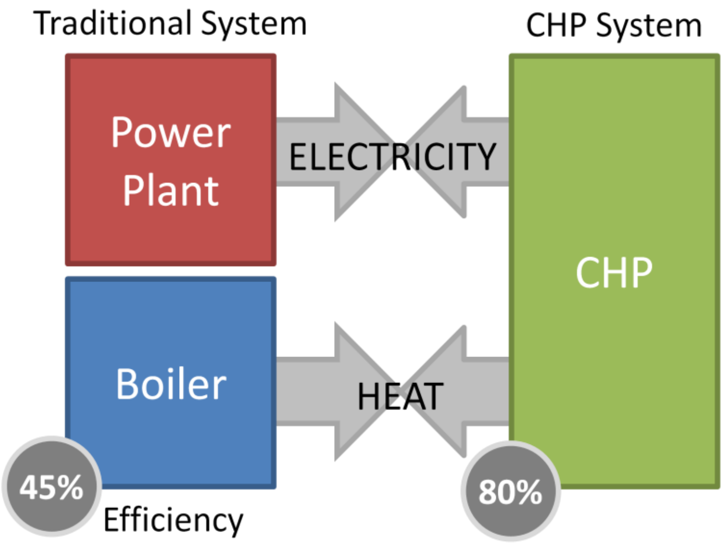

**Figure 9.1 CHP Process Flow Diagram**

(Source: http://www1.eere.energy.gov/industry/distributedenergy/chp_basics.html)

Several state renewable electricity standards (RESs) include CHP as an eligible resource, as do many state energy-efficiency resources standards (EERSs). This "crossover" status of CHP reflects the fact that CHP recycles energy that would otherwise be wasted (similar to renewable energy resources), while it also converts fuels into electricity at a high rate of efficiency (qualifying it as an energy-efficiency resource). A few state RESs require that CHP systems meet a minimum efficiency percentage, such as the 50% total efficiency required in Connecticut. While most states and NEMS define CHP narrowly to include the use of waste heat to generate electricity, other states broadly define CHP in their state regulations, including industrial waste energy recovery from hot exhaust, flared gas, and pressure drops.

## 9.2 CHP IN THE SOUTH

CHP could be a driver for employment, manufacturing, and environmental quality in the South. Consumers would benefit from reduced costs if electricity could be supplied cheaper by CHP systems compared with other sources and if the savings were passed through to them. Many of the benefits, such as energy security, pollution reduction, and climate change mitigation would accrue to society as a whole.

Currently, the total CHP capacity in the South is approximately 15,200 MW, and CHP generates about 85,000 GWh of electricity, based on the reference case forecast for the year 2010 from EIA's *Annual Energy Outlook 2009*. According to the Southeast Clean Energy Application Center (CEAC), CHP facilities and cogeneration sites are dispersed throughout the region (Figure 9.2).

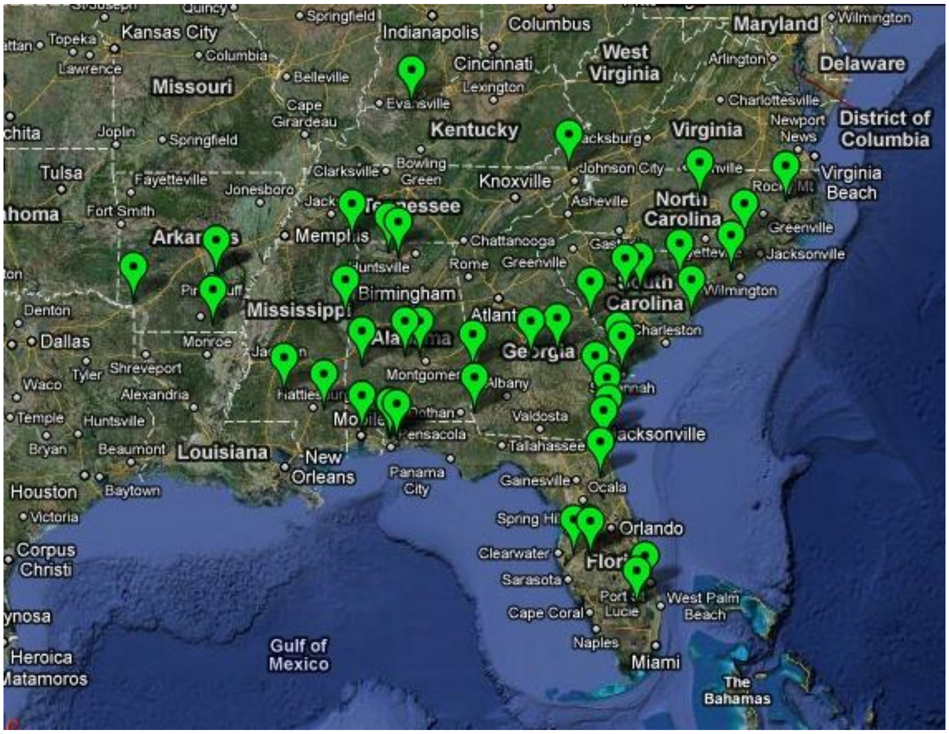

**Figure 9.2 Cogeneration and CHP Sites in the Southeast**
**Source: http://www.chpcenterse.org/maps.html**

## 9.3 BARRIERS, DRIVERS, AND POLICIES

Numerous barriers inhibit the timely and efficient installation and operation of CHP facilities. Most notable among these barriers are air quality regulations, interconnection issues, the prohibition of third party sales of electricity, utility rates, and access to capital. These barriers are not specific to CHP, but apply to most distributed generation projects.

Fourteen states include CHP in their energy portfolio standards as a way of overcoming these barriers. Only one of these 14 states (North Carolina) is in the South.

North Carolina established a Renewable Energy and Energy Efficiency Portfolio Standard (REEEPS) in 2007, requiring that 12.5% of 2020 retail electricity sales by investor-owned utilities (IOUs) come from eligible resources by 2021. Municipal utilities and rural electric co-ops must meet a target of 10% by 2018. Up to 25% of these requirements may be met through energy-efficiency measures including CHP. After 2018, 40% may be met by CHP and other energy efficiency improvements. To qualify, a CHP system must perform the same function or provide the same level of service at the customer's facility using less energy. Thermal energy as well as electricity earns renewable energy credits (RECs): thermal energy typically earns RECS based on the end-use energy value of electricity, measured as 3.413 MMBtu of heat output per MWh of electricity, while electricity earns the credit base on the heat rate of its generation.[32]

The current multiplicity of state renewable electricity standards increases transaction costs, causes confusion in the marketplace, and prevents economies of scale. A federal portfolio standard could reduce the regulatory confusion and administrative burdens that have resulted from the patchwork of state regulatory efforts. A federally mandated quota would produce a standardized regulatory environment that would provide manufacturers and industry with consistent and predictable business rules, which are important when attempting to create national markets for green technologies such as combined heat and power. Promulgating standardized measurement and verification (M&V) guidelines would also likely be less costly to operate than having a variety of state-defined M&V approaches. In addition, a nationwide policy could provide greater economic efficiency by allowing utilities to trade energy savings credits across the country.

On the other hand, advocates of the state-by-state approach argue that it allows individual states and regions to consider their particular differences and design a program that works best for them. Federal programs are a "one size fits all" solution that is not tailored to the specific resources available in a region. The pursuit of standardization through a federal program could be harmful if the program imposes significant mandates and costs on a region that cannot easily absorb such costs (Sovacool and Brown, 2009). In either event, the inclusion of CHP as a qualifying resource in these programs would encourage CHP investments.

The U.S. has a long history of using regulatory oversight and investment tax credits (ITCs) to encourage the growth of CHP. Enactment of PURPA in 1978 required utilities to buy power produced in qualifying facilities at avoided cost. Developers were able to take those long-term purchase power agreements to the bank and get their projects financed. Shortly after PURPA, Congress passed a limited term ITC of 10% and a shortened depreciation schedule for CHP systems. PURPA and the tax incentives spurred the growth of CHP from an installed capacity of 12 GW in 1980 to 66 GW in 2000 (across the industrial, commercial and institutional sectors) (Shipley, et al., 2008). Investment tax credits for CHP projects were authorized again in the Energy Improvement and Extension Act of 2008. Congress passed this law on October 3, 2008, establishing a new 10% ITC for CHP systems. The credits began in 2008 and are currently scheduled to continue through 2016.

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[32] http://ncuc.commerce.state.nc.us/cgi-bin/webview/senddoc.pgm?dispfmt=&itype=Q&authorization=&parm2=SAAAAA06080B&parm3=000127195

The American Recovery and Reinvestment Act provided an option of a 30% grant or ITC for biomass-based CHP projects; however, this funding mechanism expires at the end of 2010, at which time the ITC will be reduced to 10%, which is the ITC level provided for non-biomass CHP.

The DOE and EPA have singled out CHP for support, committing to a target of increasing CHP capacity to 92 GW nationwide by 2010. According to Shipley et al. (2008), this goal was nearly met in 2008. In 2001, the DOE established the first of eight regional CHP application centers to provide local technical and educational assistance for CHP development. These centers are now called Clean Energy Application Centers (CEACs); one of them is located in the Southeast and is a partnership between the North Carolina Solar Center and Mississippi State University. Its website offers a CHP online screening tool to determine how suitable a CHP technology might be for a given industrial facility.

Other examples of federal involvement in reducing energy use, mitigating emissions, and improving energy efficiency are embodied in the Energy Independence and Security Act (EISA) of 2007. Signed into law on December 19, 2007, this act created or enhanced a number of other programs related to industrial waste heat (EIA, 2008b, p. 16). For example, Sections 451, 452, and 453 direct the EPA to survey all major industrial combustion sources and create a registry of the quantity and quality of waste energy at each site. DOE may provide up to 50% of the funding for a feasibility study to determine whether the waste heat can be captured with a 5-year payback. In addition, EISA authorizes DOE to spend nearly $200 million on industrial energy efficiency R&D partnerships.

### *Box 9.1 West Virginia Alloys - Recycled Energy Project*

**Capacity:** **60 MW**

**Location:** **Alloy, WV**

West Virginia Alloys produces silicon using electric arc furnaces. It is the largest silicon production facility in the world, churning out 72,000 tons of silicon a year. The plant’s electricity bills are a third of its operating cost.

Recycled Energy Development (RED) will install waste heat recovery boilers to extract heat from the furnace exhaust at a cost of over $100 million. This heat will turn turbines to generate 60 MW of electricity. The generated electricity will supply one third of the furnace electricity needs and allow the plant will significantly reduce its energy bills.

RED provides all of the upfront costs and energy expertise. In return, it will receive a modest return on the capital and halve remaining financial benefits with West Virginia Alloys.

RED is currently negotiating a power purchase agreement with a utility. If an agreement is consummated, the utility would purchase all of the energy produced from the waste heat for 20 years. Over half a million tons of CO2 would be avoided annually by the project.

Picture from RED, nd b Sources: Steiner, 2008; RED, nd a

Despite all of these subsidies and assistance, CHP industry representatives argue that stronger interventions are needed to reinvigorate the independent power community to invest in CHP projects. The industry faces too many major barriers including interconnection issues, permitting problems, and the inability for projects to get financing without meaningful long-term purchase power agreements (PPAs). Two of these stronger policies are feed-in tariffs and a program to promote PPAs with utilities such as the Clean Energy Standard Offer Program (CESOP).[33]

## 9.4 CHP POTENTIAL IN THE SOUTH UNDER EXPANDED RENEWABLES SCENARIO

### 9.4.1 The Case for Expanded CHP Resources

A program of accelerated R&D combined with greater financial assistance to reduce the capital costs of installing CHP systems could cause a rapid boost in the deployment of this renewable resource. Our expanded renewables scenarios provide CHP with the types of research and financial assistance that wind, biopower, and solar technologies have received over the years.

### 9.4.2 Modeling Assumptions

The modeling assumes that the federal government promulgates an energy portfolio standard that qualifies CHP and includes a 30% ITC. The public cost of administering this ITC is estimated to be 2% of the level of tax subsidy or grant provided by the federal government each year.

We also assume that the expanded production of CHP systems engenders greater experience with the technology that pushes the industry further along the “learning curve.” Together with an expanded R&D effort ($4 million additional R&D funding annually for ten years beginning in 2011), this is expected to improve the performance of CHP systems. Specifically we assume that the overall efficiency of CHP systems would be improved by 0.7% annually for ten year under the federal EPS policy, where the production of CHP systems doubles.

CHP systems are typically identified by the type of prime mover deployed: reciprocating engines, combustion or gas turbines, steam turbines, microturbines, or fuel cells (Shipley, et al., 2008). To illustrate the influence of a 0.7% annual improvement, consider the performance of a new 25 MW “gas turbine CHP system” – that is, a gas turbine run in a combined cycle mode. In the SNUG-NEMS, such a CHP system is assumed to have operated at a 71% efficiency level in 2008.

- In the reference case its efficiency improves to 73% by 2020 and to 74% by 2030.
- In the Expanded CHP scenario, the same system is assumed to improve to 77% efficiency in 2020 and 82% in 2030.

With the 30% ITC, the installation cost of a 25 MW gas turbine run in a combined cycle mode is assumed to decline from $622 per kW (in $2005) in 2011to $569 in 2030. The reference forecast assumes the same costs, but without the ITC.

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[33] http://www.recycled-energy.com/main/cesop

## 9.5 EXPANDED CHP SCENARIO RESULTS

Figure 9.3 illustrates the potential for CHP expansion in the South. The total electricity generation from CHP facilities is estimated to be 87,000 GWh in 2010, and is projected to grow just 17% to approximately 102,000 in 2030. In contrast, the South has the potential to generate 113,300 GWh of industrial CHP electricity in 2020, rising to 151,100 in 2030—an increase of 74% over today's level.

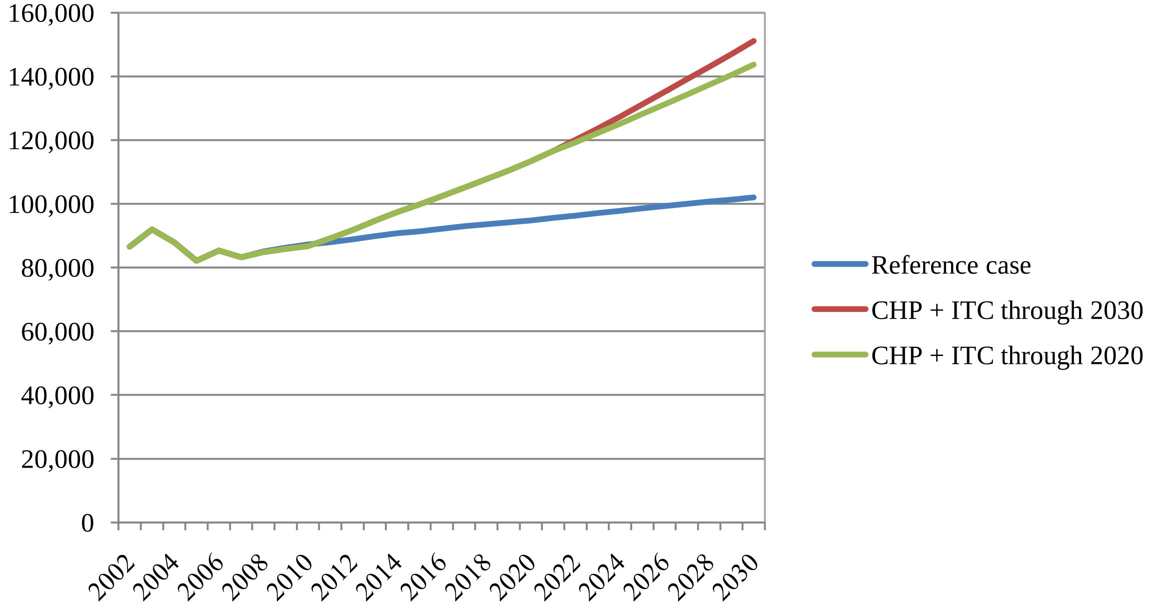

**Figure 9.3 The Potential for Industrial CHP Electricity in the South (in GWh)**

In the reference case, the total CHP capacity in the South increases from 15,200 MW in 2010 to approximately 17,300 MW in 2030. In contrast, our expanded resource scenario, which includes accelerated R&D and an investment tax credit, forecasts an increase to 18,800 MW in 2020 and 23,000 MW in 2030—a 53% increase over today.

As shown in Figure 9.4, the vast majority of the electricity produced by industrial CHP systems is used by manufacturers to meet their own needs. However, over time the electricity sold back to the grid could grow rapidly; it has the potential to more than double between 2010 and 2030.

The accelerated market penetration of CHP technology results in highly variable increases in CHP-produced electricity generation across different industries. The chemicals industry and the pulp and paper industry are the largest CHP electricity generators in the South, yet they are seen as having significant remaining potential for growth. This is especially true for chemicals production, which could generate almost 90,000 GWh of electricity by 2030. The pulp and paper industry could grow more modestly, to about 35,000 GWh in 2030.The food industry, on the other hand, starts at only about 1,000 GWh today, but could grow to more than 8,000 GWh in 2030. (All of these projections are based on the Enhanced CHP scenario using SNUG-NEMS).

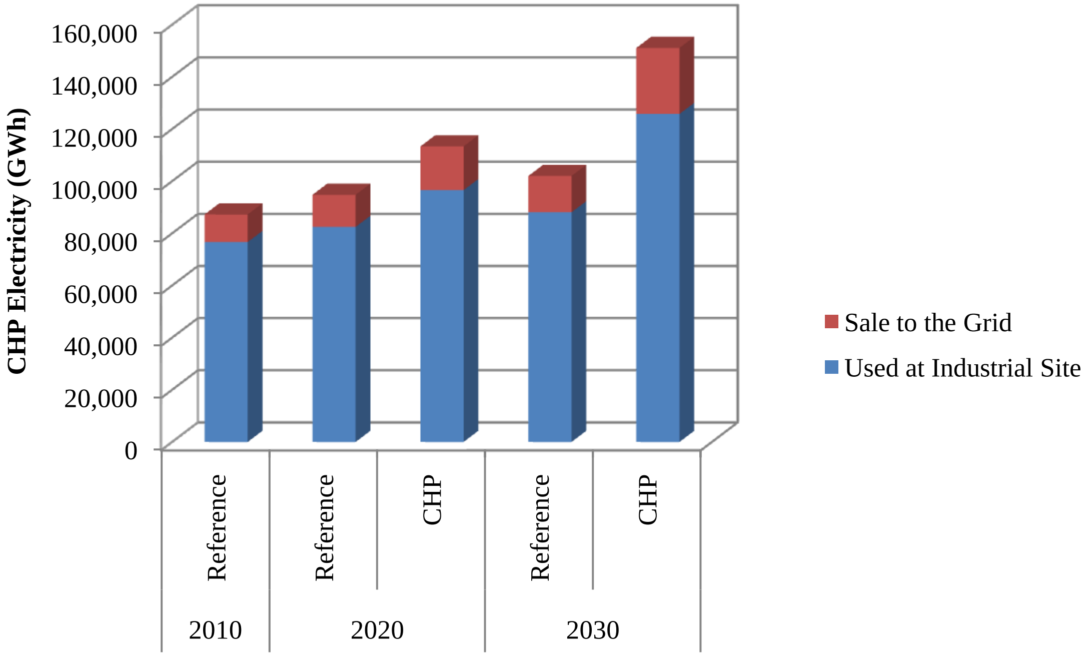

**Figure 9.4 The Potential for CHP-Generated Electricity to be Used at Industrial Sites or Sold to the Grid in the South**

The SNUG-NEMS analysis underscores the potential for net present value (NPV)-positive investments in CHP in the South. A 30% ITC for CHP would generate an annual investment of $109 million by industry and other private investors in the year 2020, supplemented by $62 million in public subsidies (mostly investment costs from the ITC, but also including $3.4 million in program administration costs and R&D expenditures). These costs are considerably smaller in 2030 because they are presented in present value terms, using an annual 7% discount rate.

Cumulative private plus public discounted investment costs $3,540 million in 2030. In contrast, the total discounted cumulative savings start at $9,840 million in 2020 and rise to $30,000 million in 2030 and $53,900 million by the time the last of the CHP systems installed in the 2011-2030 period is assumed to be retired. The result is an overall benefit/cost ratio of 11.8.

The public costs include R&D funding, administrative costs, and investment tax credits for CHP projects motivated by the federal ITC policy, including credits for “free riders” that were going to make CHP investments anyway. The magnitude of these free riders can be estimated by the incremental CHP growth that is forecast in the EIA reference case.

This policy is estimated to reduce the industrial consumption of energy by 264 TBtu (Figure 9.5) while at the same time generating a surplus of relatively clean and affordable electricity, with a levelized cost of 1.28 ¢/kWh (Table 9.1). If we assume that the ITC ends in 2020, the levelized costs drop to 0.94 ¢/kWh.

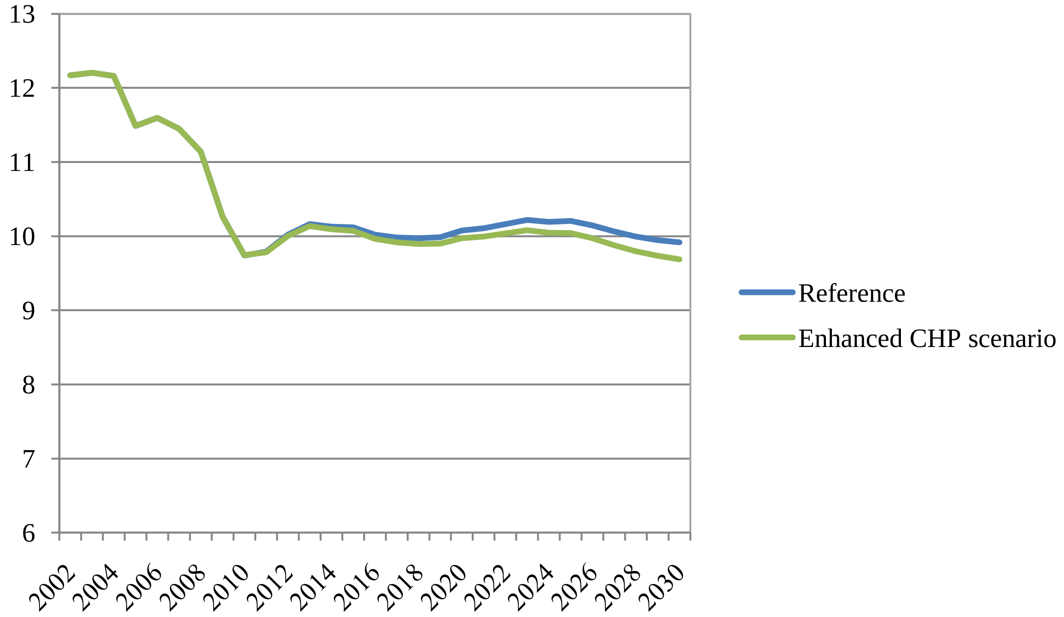

**Figure 9.5 Total Industrial Energy Consumption (Quads): Reference Case vs. the Policy Scenario and Sensitivity**

| Table 9.1 Levelized Cost of Electricity from CHP | |
|---|---|
| Year | Levelized Cost of Electricity |
| CHP ITC 2030 Electricity (¢/kWh) in 2020 | 1.28 |
| CHP ITC 2020 Electricity (¢/kWh) in 2020 | 0.94 |

Most CHP systems are installed in facilities that are already relying on natural gas for their industrial processing. With the installation of CHP systems, their natural gas consumption increases, but they are also producing electricity and displacing grid power that is typically carbon-intensive.

The environmental benefits are even greater when CHP systems displace carbon-intensive fossil fuels in conventional boilers—principally fuel oil and coal. SNUG-NEMS estimates that CHP systems could cut coal consumption in the South by 4.4 TBtu and 15 TBtu in the years 2020 and

2030, respectively, while the consumption of fuel oil and other petroleum products could be reduced by 7.6 TBtu and 25 TBtu in 2020 and 2030, respectively.[34]

The expansion of CHP systems saves energy by reducing the need for purchased electricity, which is generated less efficiently than co-generated electricity. CHP systems also allow an increase in total electric sales to the grid, which displaces the energy that would otherwise have been required to generate this electricity, mostly from inefficient coal plants.

Our analysis has shown the potential for CHP systems to generate 197 TBtu of electricity in 2020 (with 47 TBtu that are sold back to the grid) and 512 TBtu of electricity in 2030 (with 119 TBtu sold back to the grid). While the expansion of CHP would reduce energy consumption altogether, natural gas consumption would increase because of its greater use in CHP systems. In the Enhanced CHP scenario, natural gas consumption increases by 108 in 2020 and 287 TBtu in 2030.

## 9.6 CONCLUSIONS

The CHP industry has been growing rapidly in many other countries of the world. In contrast, growth in U.S. markets has been sluggish. By qualifying CHP systems to receive investment tax credits and improving its performance with an accelerated R&D program, a strong market for CHP could emerge across the nation, and particularly in the South where energy-intensive manufacturing is dominant.

It may be that stronger policies are needed to reinvigorate the independent power community to invest in CHP projects; options such as feed-in tariffs and programs to promote PPAs have been suggested. A long-term ITC may not be sufficient to overcome the industry’s array of challenges and obstacles. What is clear is that policy interventions are needed to realize the significant potential to expand the use of CHP systems in industry. If successful, significant improvements in industrial energy efficiency would result, and the cogeneration of low-cost, low-carbon electricity would help the country meet its growing appetite for electricity while reducing its environmental emissions.

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[34] Two reviewers questioned the ability of CHP to displace significant quantities of fuel oil and coal. One of these reviewers suggested that fuel oil and especially coal boilers in industry are already a part of CHP systems so there are few applications where CHP would displace conventional boilers. The NEMS model does not reflect this.

# 10. EXPANDED RENEWABLES: AN INTEGRATED PERSPECTIVE

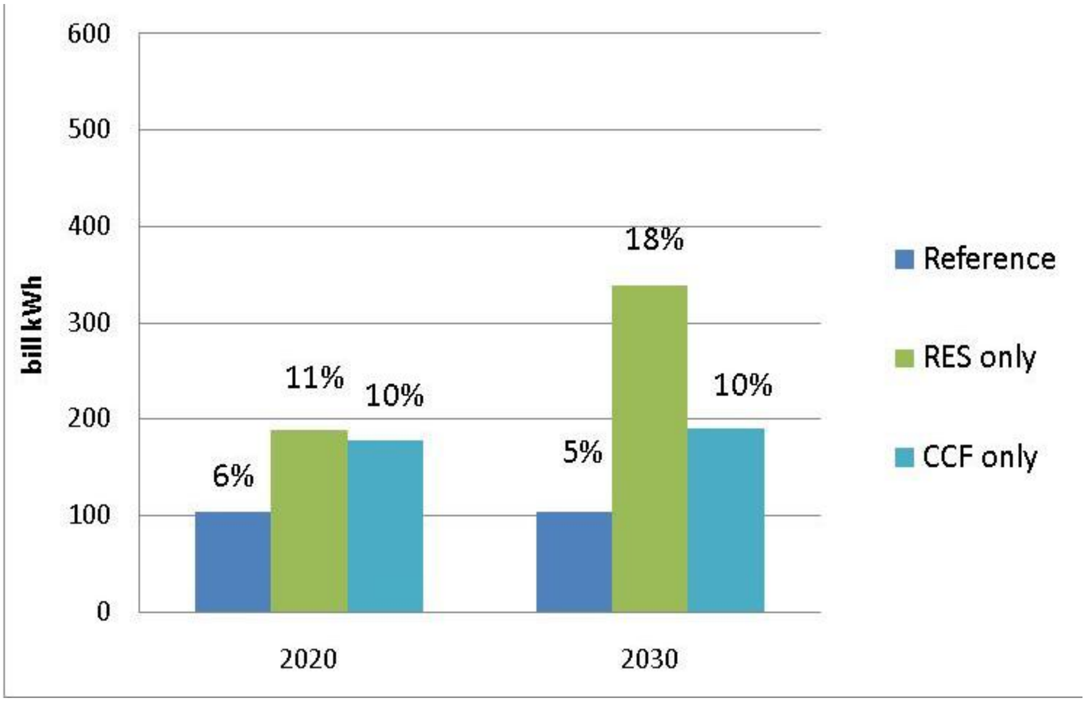
This chapter combines the analyses described in the previous seven chapters into a single Expanded Renewable scenario. The main comparison of note is between the Reference scenario's projection and this Expanded Renewable scenario, which shows how the future generation of renewable electricity may differ from the projected status quo in the South.

This analysis allows trade-offs between different renewable resources and between utility-scale and customer-owned resources to be examined. In addition, we examine the impact of adding a renewable electricity standard and a carbon-constrained future scenario to the assumptions about expanded renewables. Many policy analysts believe that an energy bill (with an RES) or a climate bill (with some type of CCF) will be passed sometime over the next several years. If they are promulgated, how much difference will they make above and beyond the impacts of the specific technology-specific resource, cost, and policy assumptions that comprise the Expanded Renewables case?

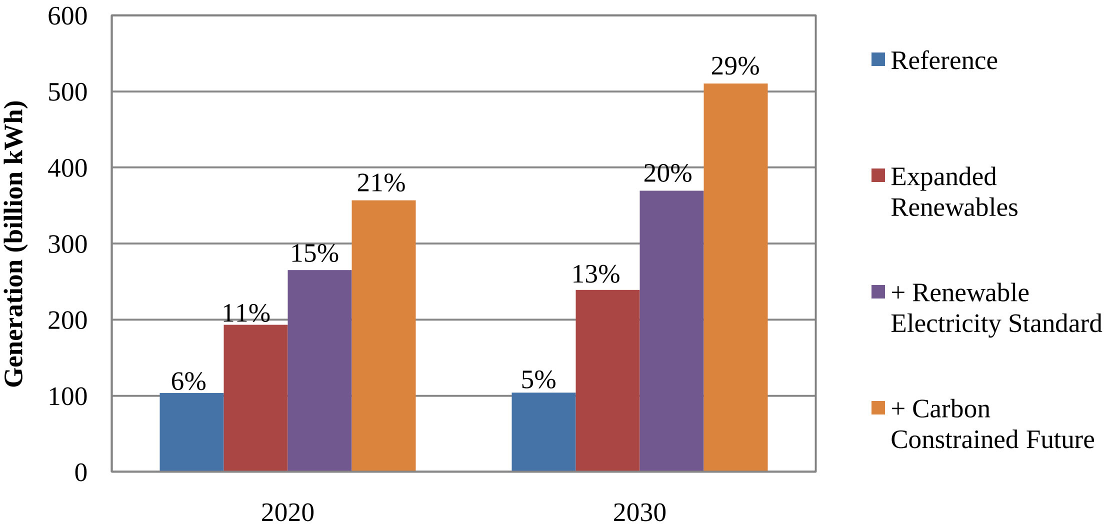
## 10.1 RENEWABLES UNDER MULTIPLE SCENARIOS

Current utility-scale renewable generation in the South is approximately 75 billion kWh. The baseline SNUG-NEMS forecast for the South reaches over 100 billion kWh by 2020. Figure 10.1a shows how utility-scale renewable generation grows under three futures without Expanded Renewables. In contrast, Figure 10.1b compares utility-scale renewable generation with Expanded Renewables under the scenarios as described in Chapter 2. Also displayed is the proportion of total electricity generation in the South that could come from renewable resources over the next twenty years. In the Expanded Renewables Scenario, renewable electricity generation doubles the output of the Reference forecast for the South. If a federal RES is imposed or the policies represented by our Expanded Renewables +CCF scenario are implemented, we estimate that 15% to 20% of the South's electricity could be generated from utililty-scale renewable sources by 2020 and 20% to 30% by 2030 (Figure 10.1).

Table 10.1 shows the amounts of electricity (in billion kWh) that would be generated under the three renewable-enhancing scenarios, as well as the electricity displaced by heat pump water heaters. Most of the growth in renewable power comes from wind, CHP and distributed PV as well as biomass. The modeled scenarios reflect an environment in which renewable sources are increasingly economically competitive or mandated, as in the case of an RES. Of the utility-scale renewable sources, wind and biomass not only provide the most generation potential, but are also the least expensive. Wind out-competes biomass as the integration of renewable sources expands through the modeled time horizon.



**Figures 10.1a Utility-Scale Generation in the South from RES and CCF Policies Along (with % of total generation)**



**Figures 10.1b Utility-Scale Generation in the South from the Scenarios with Expanded Renewables (with % of total generation)**

By definition, an RES must meet an increased renewable target by 2025. Placing a price on carbon, represented by our Expanded Renewables +CCF Scenario, unsurprisingly also leads to marked increases in renewable uptake. Interestingly, the Expanded Renewables +CCF Scenario has about 150% more utility-scale renewable generation than a stand-alone CCF Scenario. These results suggest there is large, economically viable utility-scale renewable potential that is close in costs to the other major GHG emission-free technology, nuclear. Table 10.1 also points out that customer-owned renewable sources are significant. This is particularly true in the case of CHP. Our study suggests that in 2030 CHP may displace as much as 288 TWh of electricity generation in the South.

**Table 10.1 Renewable Generation and Customer-Owned Renewables in the South in 2030 (billion kWh)**

| | **Utility-Scale Renewables** | | | | | | |
|---|---|---|---|---|---|---|---|
| | Wind | Biopower | Municipal Waste | Hydro | Solar PV | **Total** | **% above Reference** |
| Reference Forecast | 39 | 19 | 4.3 | 42 | 0.2 | 104 | - |
| Expanded Renewables | 151 | 24 | 3.8 | 60 | 0.3 | 239 | 129% |
| Renewable Electricity Standard | 54 | 238 | 4.3 | 42 | 0.2 | 339 | 224% |
| + Renewable Electricity Standard | 224 | 82 | 3.8 | 60 | 0.3 | 370 | 254% |
| Carbon Constrained Future | 59 | 83 | 4.3 | 43 | 0.2 | 190 | 81% |
| + Carbon Constrained Future | 362 | 83 | 4.3 | 61 | 0.3 | 511 | 389% |
| | **Customer-Owned Renewables** | | | | | | |
| | CHP | Distributed Biopower | Heat Pump Water Heaters* | Solar Water Heaters* | Distributed Solar PV | **Total** | **% above Reference** |
| Reference Forecast | 102 | 37 | - | - | 10 | 149 | - |
| Expanded Renewables | 151 | 34 | 34 | 21 | 68 | 308 | 107% |
| Renewable Electricity Standard | 85 | 32 | -1.8 | 0 | 13 | 128 | -14% |
| + Renewable Electricity Standard | 145 | 32 | 33 | 21 | 69 | 300 | 101% |
| Carbon Constrained Future | 210 | 39 | 12 | 0.3 | 9 | 270 | 81% |
| + Carbon Constrained Future | 288 | 42 | 42 | 23 | 69 | 464 | 211% |

+ RES and + CCF include the Expanded Renewables scenario assumptions in addition to the RES and CCF scenarios.

*The heat pump and solar water heater numbers are the incremental difference between the reference forecast and each scenario. These numbers, though presented in billion kWh, differ from the other values presented in the table. Since the water heater technologies do not generate electricity, these numbers are the energy savings these technologies avoid. They can be interpreted as the avoided fossil-fuel generation attributed to heat pump and solar water heaters.

One unique characteristic of this analysis is that it evaluates demand-side renewables that are not generally appreciated in RES analyses or many other renewable assessments. Figure 10.2 shows for each scenario how much total renewable potential could be realized by 2030, considering both utility-scale and customer-owned renewables. Combined heat and power systems as well as solar and heat pump water heaters are classified as customer-owned resources that avoid fossil fuel generation. (The category "Demand-Side Solar" in Figure 10.2 includes distributed solar PV and solar water heating.) Adding customer-owned renewables to utility-scale renewables nearly doubles the potential of renewable generation in the South. Wind dominates the utility-scale resources, and CHP dominates the customer-owned resources.

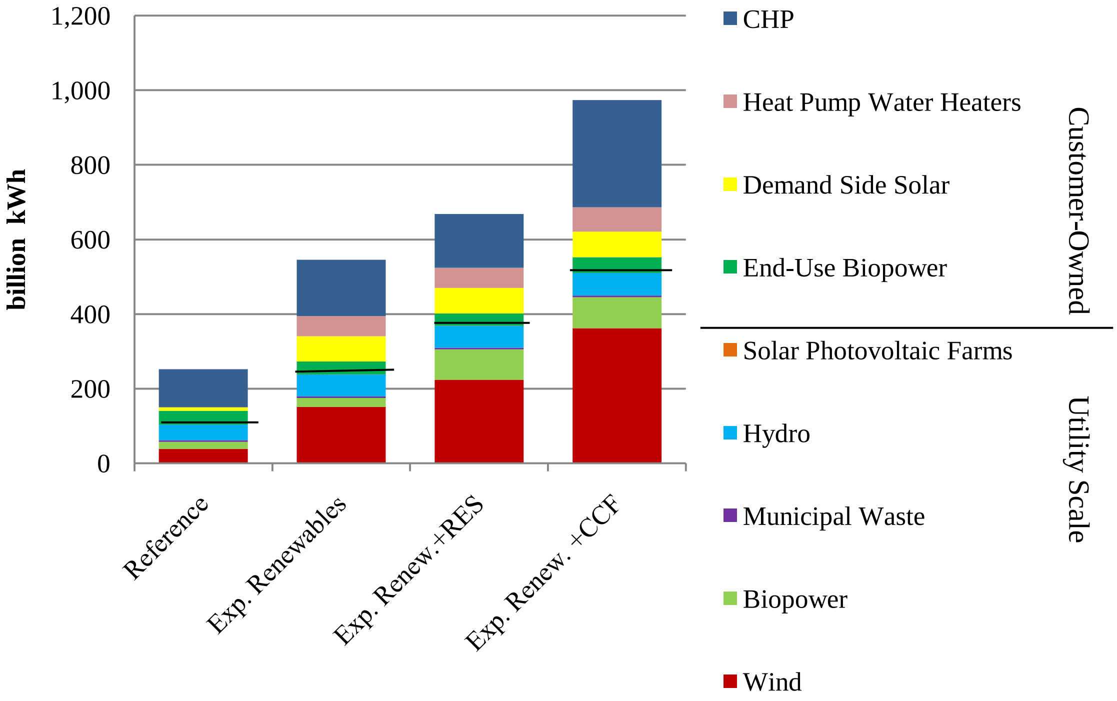


**Figure 10.2 Economic Potential for Utility-Scale and Customer-Owned Renewable Generation in 2030**

**Figure 10.2 Renewable Potential in the South in 2030**

Figure 10.3 illustrates how much total renewable potential is likely to be realized by 2030 under each of our scenarios, considering both utility-scale and customer-owned renewables. The chart shows that customer-owned generation can account for as much or more electricity than can utility-scale renewable sources.

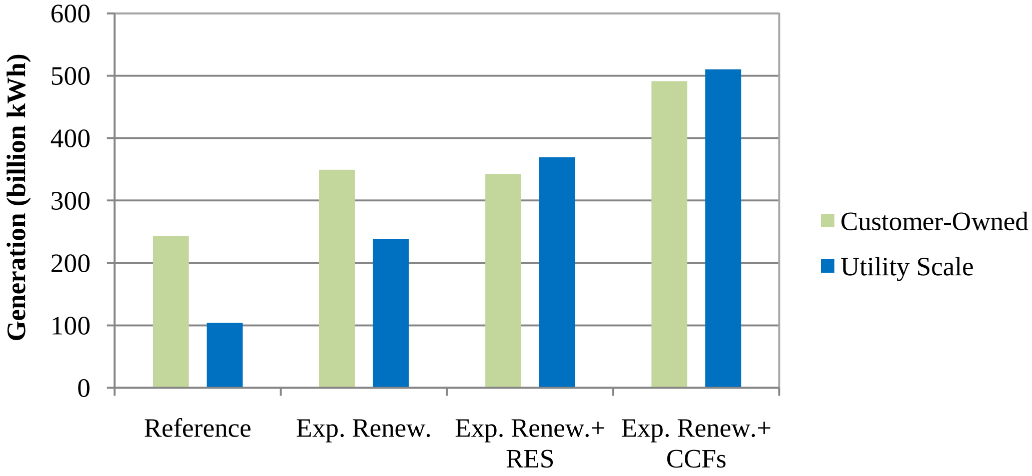


**Figure 10.3 Economic Potential for Renewable Generation and Avoided Generation, 2030**

The distribution of renewable generation within the South is not uniform. The western part of the region is dominated by wind. The southeast contains most of the hydropower, currently generating about 40 billion kWh per year. Notably, in these scenarios wind generation becomes cost competitive in Florida but not compared to the rest of the Southeast, so Florida purchases imported wind. It is less expensive for Florida to import electricity generated from wind than it is to generate its own electricity from natural gas or coal. Wind in SERC cannot compete with cheap coal, so it is cost-effective to export it to Florida. The contribution of biomass, while not insignificant, is attenuated by its higher cost when compared to wind. See Figure 10.4 below for the distribution of a few of the main sources of renewable electricity generation.

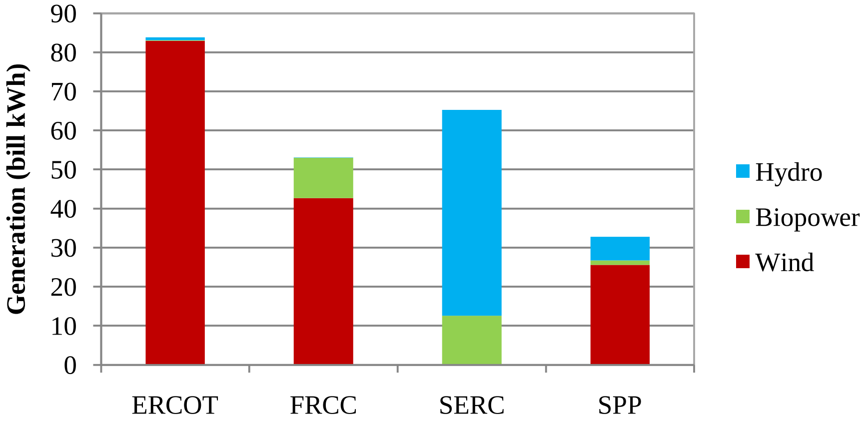


**Figure 10.4 Renewable Distribution in Expanded Renewables Scenario, 2030**

## 10.2 WIND AND BIOPOWER TRADE-OFFS

The Expanded Renewables Scenario predicted that given aggressive investment in R&D and installation of advanced technologies, and its attractive price-competitiveness in renewable electricity generation, wind would substitute for a sizable portion of the market share of biomass in the South. To clarify the trade-off relationship between wind and biomass in the renewable electricity market in the future, we ran a set of additional scenarios excluding the new capacity additions in wind. If wind resources are limited to EIA's currently estimated level, the predicted potential of biopower grows by almost 50% (Figure 10.5).

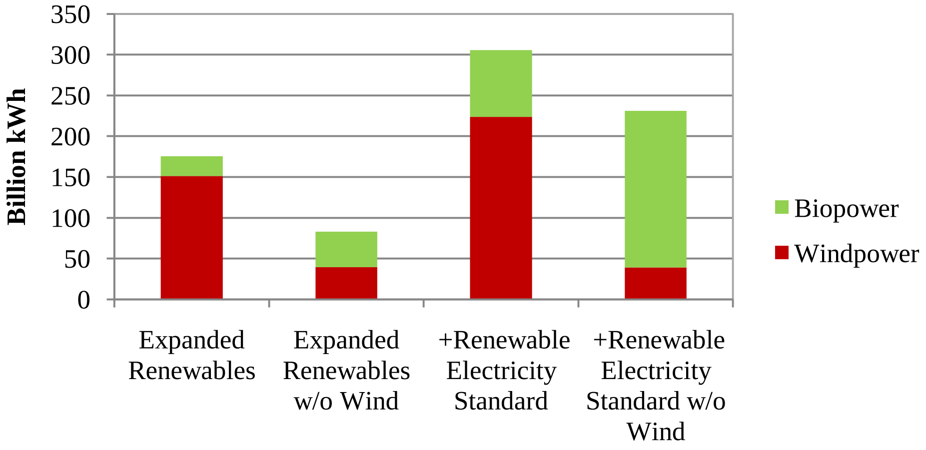


**Figure 10.5 Comparison of Wind Power and Biopower Generation in the South in 2030**

The marginal resource of substitution depends on the policy, technology, and regional characteristics of the change that causes the displacement. The trade-off relationship between wind and biomass is most obvious under the RES scenarios (Table 10.2). However, biopower could not be considered as a perfect substitute for wind power in that there still exists a portion of wind generation that could not be substituted with biopower. If an RES is implemented, the share of biopower would be even larger since biomass cofiring in existing coal plants is a low-cost and low-risk option for supporting compliance with the RES.

**Table 10.2 Comparison of Windpower and Biopower Generation in the South in 2030**

| | Windpower (Billion kWh) | % of Total Electricity Generation | Biopower (Billion kWh) | % of Total Electricity Generation |
|---|---|---|---|---|
| Expanded Renewables (ER) | 151 | 8% | 24 | 1% |
| ER w/o Wind | 40 | 2% | 44 | 2% |
| ER + RES | 224 | 12% | 82 | 4% |
| ER w/o Wind + RES | 39 | 2% | 192 | 11% |

## 10.3 GREENHOUSE GAS EMISSIONS REDUCTIONS

One of the goals of increasing the share of renewable energy is to reduce greenhouse gas (GHG) emissions. Future GHG emissions are reduced through the policy scenarios as illustrated below in Figure 10.6. Note that under a CCF scenario, a price on carbon will lead to emissions reductions unrelated to increasing renewables. Notably, renewable sources could be expected to help reduce emissions from electricity generation in the South in 2030 between 7% (in the Expanded Renewables scenario) and 55% (in the Expanded Renewables +CCF scenario).

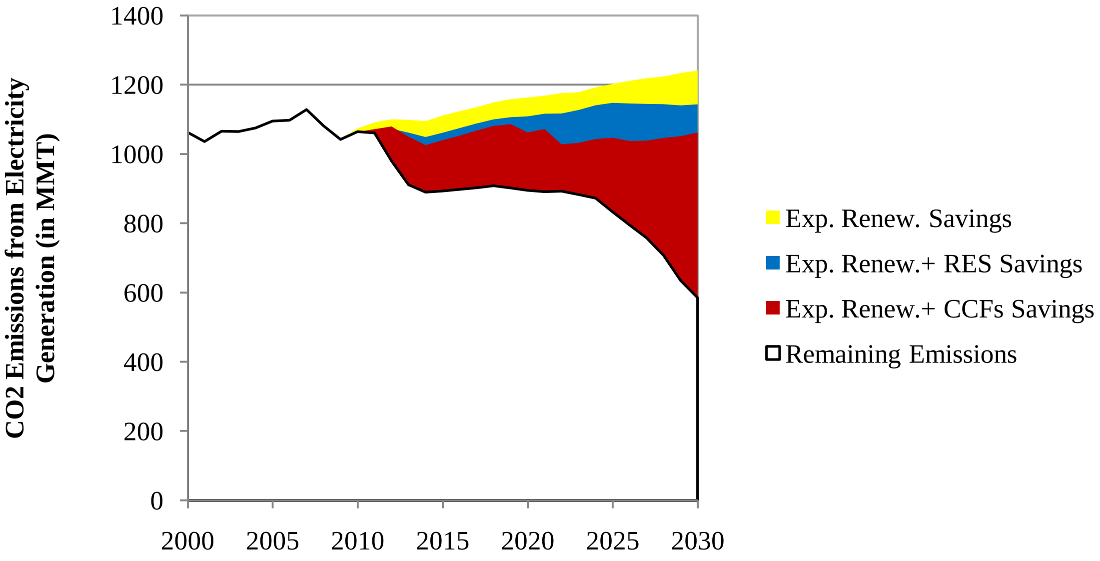


**Figure 10.6 Southern Electricity Carbon Dioxide Emissions Reductions, by Scenario**

Most of the emission reductions in the South come from the electricity sector, either due to cleaner utility-scale generation or to customer-owned renewables displacing electricity generation. Table 10.3 provides the absolute emissions reductions for each scenario. The relative size of each reduction is similar to the avoided emissions from electricity shown in Figure 10.6.

**Table 10.3 Emission Reductions from Reference (million tonnes $CO_{2e}$)**

| | Expanded Renewables | Renewable Electricity Standard | Expanded Renewables + RES | Carbon Constrained Future | Expanded Renewables. + CCF |
|---|---|---|---|---|---|
| 2020 Avoided | 54 | 69 | 100 | 169 | 300 |
| 2030 Avoided | 84 | 160 | 160 | 553 | 710 |

## 10.4 ECONOMICS OF RENEWABLE ENERGY IN THE SOUTH

Beyond the potential impact of Expanded Renewables on the future electricity generation mix and carbon emissions, another key consideration is the cost of electricity and electric rates under different scenarios.

Our assessment shows that the electricity rate changes resulting from the Expanded Renewables scenarios are modest, but favorable relative to the electricity rates forecast in the Reference case. As shown in Figure 10.7 and Table 10.4, average electricity rates in the South are forecast to rise by 23% in the EIA Reference case (from 7.9¢/kWh in 2010 to 9.7¢/kWh in 2030). In contrast, the average electricity rate for all users in the region in the Expanded Renewables scenario would rise by only 16% over the two decades, to 9.0¢/kWh rather than the 9.7¢/kWh rate forecast of the Reference Case.

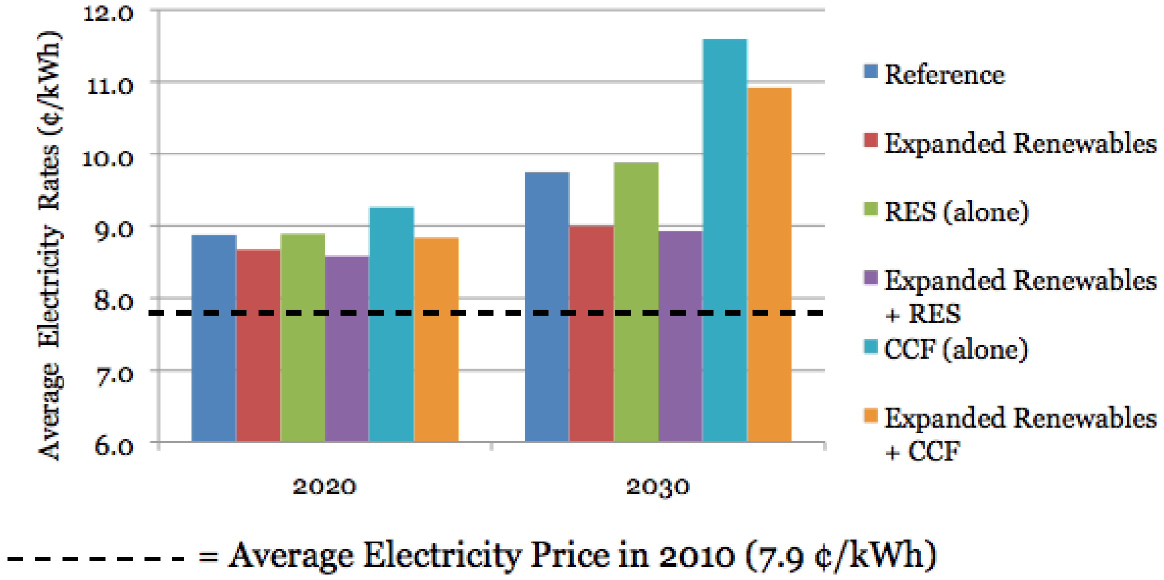


**Figure 10.7 Average Electricity Rates in the South Under Alternative Scenarios**

While the CCF alone scenario shows rates rising to 11.6¢/kWh in 2030, adding the Expanded Renewables scenario to the CCF scenario (that is, Expanded Renewables +CCF) could limit the increase to 11.6¢/kWh. A large expansion of cost-competitive renewable resources helps to explain why rates are reduced when the Expanded Renewable scenario is invoked.[35] The expanded cost-competitive renewable resource is related to several effects, recognition of a larger renewable resource base for wind and hydropower, overcoming regulatory hurdles, advances in technology, and subsidies for renewable power generation.

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[35] These rate impacts do not reflect the costs of public programs designed to expand renewable resources.

**Table 10.4 Average Electricity Rates in 2030 (¢/kWh)**

| | South Atlantic | East South Central | West South Central | Weighted Average |
|---|---|---|---|---|
| Reference | 10.1 | 8.2 | 10.6 | 9.7 |
| Expanded Renewables | 9.5 | 7.8 | 9.2 | 9.0 |
| RES (alone) | 10.4 | 8.5 | 10.4 | 9.9 |
| Exp. Renew. +RES | 9.5 | 7.8 | 9.0 | 8.9 |
| CCF (alone) | 11.9 | 10.2 | 11.9 | 11.6 |
| Exp. Renew. +CCF | 11.4 | 9.9 | 10.9 | 10.9 |

The Expanded Renewable scenario has a similarly favorable impact on energy bills. In the Reference Case, the South's energy bill (across all fuels) would total $306 billion in 2020, and would rise to $341 billion in 2030 (in $2007). In the Expanded Renewables scenario, electricity bills would increase less—reaching an estimated $292 billion in 2020 and $318 billion in 2030 (7% less).

Part of this reduced increase in energy bills is due to lower electricity rates (discussed above), but it is also a result of lower energy consumption in the South in the Expanded Renewable case. In the Reference case, the South's energy consumption is forecast to rise from 30 to 35 quadrillion Btu as the South continues to expand its economy. In the Expanded Renewables case, energy consumption increases at half the rate (to 32.3 quadrillion Btu in 2030). The significant energy savings delivered by the Expanded Renewable scenarios is largely the result of the inclusion of significant customer-owned renewables – especially CHP and solar and heat pump water heaters – that displace energy consumption in the industrial and residential sectors, in particular.

In the future energy mix, the consumption of electricity increases in the Reference case by 385 billion kWh in 2030, but it increases even more in the Expanded Renewables case (increasing by 406 Billion kWh in 2030). This additional growth in renewables is counter-balanced by a small decrease in the consumption of natural gas for power generation, an offsetting effect that has been discussed in recent energy dialogues, including MIT's *Future of Natural Gas* initiative (Kinderdine, 2010).

To demonstrate one measure of the costs associated with renewable generation in the South, the levelized cost of generation was calculated for each fuel discussed in chapters 3 through 9. Below, in Figures 10.8a and b, we show the range of levelized costs calculated. Where possible, the Borin, et al. (2010) calculator was used to estimate levelized costs, while in other cases the levelized cost was assumed based on the literature (hydro), or calculated by the authors (heat pump water heaters, and CHP). The ranges are based on alternative policy designs, technology performance assumptions, and time frames.

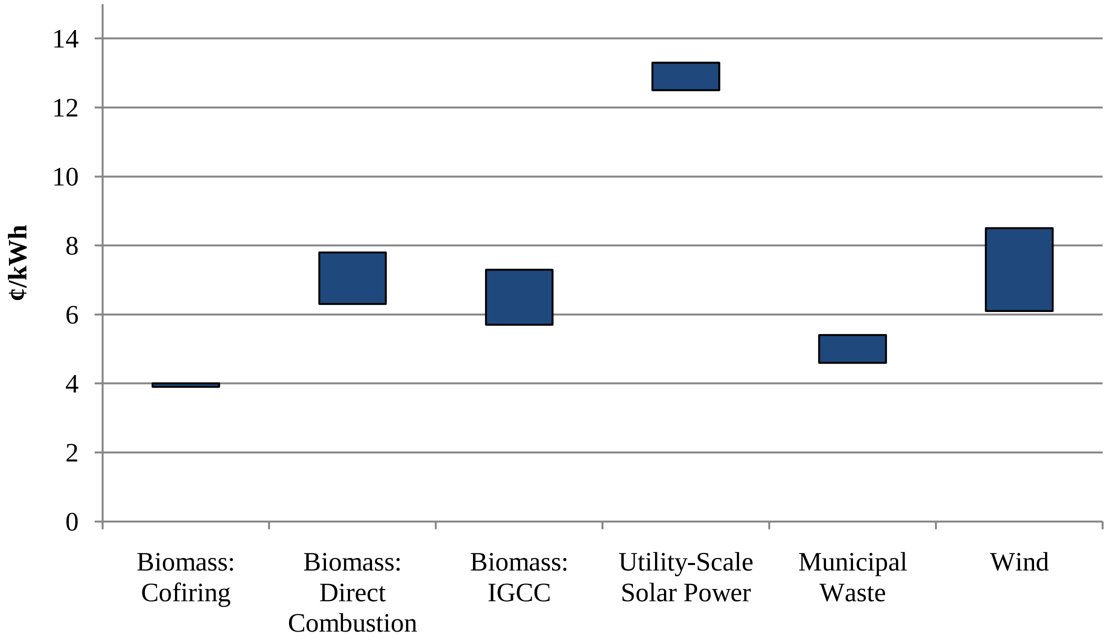


**Figure 10.8a Utility-Scale Levelized Cost Comparison**

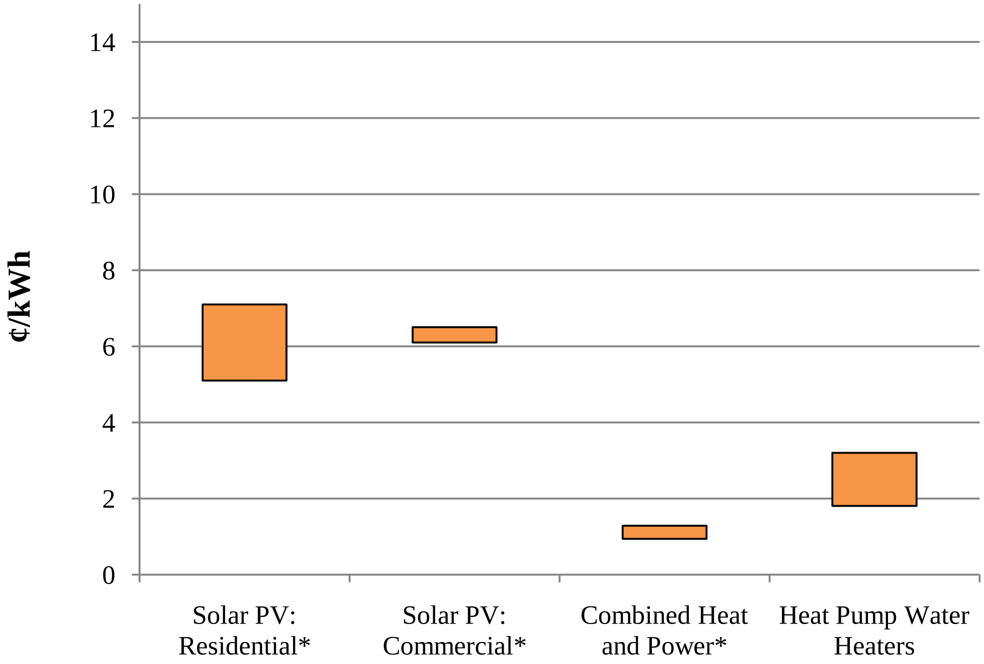


**Figure 10.8b Customer-Owned Levelized Cost Comparison**

## 10.5 COMPARISON WITH OTHER STUDIES

When comparing the results of "Renewable Energy in the South" with the findings of other recent assessments of the potential for renewable energy in this region, we see an array of similarities and differences. Findings differ, as expected, because of the variety of assumptions used in each study, the scope of renewable resources included in the analyses, the definition of the term "potential," alternative modeling methodologies, smaller or larger geographic coverage, and shorter or longer time frames. Table 10.5 depicts the results of five recent studies addressing renewable electricity generation in the South, including their target years and regional coverage.

**Table 10.5 Potential for Renewable Electricity Generation in the South**

| | Renewable Energy in the South ("Expanded Renewables") | SACE (2009) | EIA (2009b) | Beck, et al. (2002) | Creech, et al. (2009) |
|---|---|---|---|---|---|
| Renewable Generation (in TWh) | 239-547* | 492 | 252 | 84 | 1,300 |
| Target Year | 2030 | 2030 | 2030 | 2020 | 2025 |
| Regional Coverage | 4 NERC regions & 3 Census Divisions | 11 States | 4 NERC Regions | 6 States | 8 States |

Note: Census South includes 16 states, and NERC South includes most of 12 of the states and parts of a few others. See Chapter 1 Figures 1.1 and 1.2 for overlaps.
*The lower estimate includes only "utility-scale" generation while the higher estimate includes "customer-owned" renewable energy.

The low-end estimate of 239 TWh reported for our study represents the "utility-scale" generation in our "Expanded Renewables" scenario, while the higher estimate includes 308 TWh of "customer-owned" renewable energy. Many of these demand-side resources are not represented in the other studies referenced in Table 10.5.

Two of the studies (including ours and the study by EIA) cover four NERC regions: ERCOT, SPP, SERC, and FRCC. The SACE (2009), Beck et al. (2002), and Creech et al. (2009) studies, on the other hand, cover much smaller regions. "Renewable Energy in the South" as well as the SACE (2009) and EIA (2009b) studies provide estimates for 2030, while Beck, et al. (2002) projects only to 2020 and Creech, et al ends at 2025. These distinctions help explain the lower estimates of renewable energy potential by Beck, et al. (2002). The high estimate provided by Creech, et al. (2009) appears to be largely a function of its focus on "feasible" renewable resources – those that could be developed with available technologies at reasonable costs.

The SACE (2009) and EIA (2009b) reports were intended to describe how the South could meet a federal renewable electricity standard, and was not intended to simply model the market-based adoption of renewable resources under a continuation of today's policies. As a result, it is useful to compare them to our “Expanded Renewables + RES” scenario in “Renewable Energy in the South.” This cross-walk is provided by category of renewable resource for the SACE (2009) report in Table 10.6.

The SACE estimate of 492 TWh is close to the “Expanded Renewables + RES” estimate of 471 TWh when the “other” categories of renewables are excluded. In terms of the composition of renewables estimated for 2030, our report has lower estimates for solar and biopower potential and a higher estimate for on-shore wind potential. As was shown in an earlier section of this chapter, wind and biopower are close tradeoffs in our study.

**Table 10.6 Cross-walk of the “Renewable Energy in the South” and SACE (2009) Estimates of Renewable Potential in 2030 in TWh**

| | Expanded Renewables | Expanded Renewables + RES | SACE (2009) |
|---|---|---|---|
| On-Shore Wind | 151 | 224 | 33 |
| Biopower (2 types) + MSW* | 62 | 118 | 214 |
| Hydro* | 60 | 60 | 78 |
| Solar (3 types) | 89 | 90 | 167 |
| Subtotal | 362 | 471 | 492 |
| Other** | 185 | 178 | 0 |
| Total | 547 | 670 | 492 |

*An estimate of “current” renewable generation is included in these rows (biomass=9 TWh, hydro=42 TWh)

** “Other” includes CHP and heat pump water heaters.

The EIA (2009b) analysis of the Waxman-Markey Bill covered the same territory as “Renewable Energy in the South,” but its inclusion of renewable resources was limited to the power generation options eligible in the proposed legislation. Biopower dominated the estimates for renewable power in the SPP and SERC regions, while biopower became the largest resource in FLCC as wind also became a significant contributor, Wind dominated in ERCOT region but biopower was also significant. Solar contributed small but discernible amounts in all four regions, and landfill gas contributed small amounts in the SPP and SERC regions.

*Powering the South* (Beck, et al., 2002) characterizes the potential for efficiency and renewable resources in a six-state region of the Southeast (including the Carolina’s, Georgia, Tennessee, Alabama, and Florida) in 2020. After accounting for a 23% reduction in electricity demand from investments in energy efficiency, it estimates that 84 billion kWh of renewable electricity generation could meet 10% of the region’s electricity demand in 2020. Biomass co-firing accounts for 4 of the 10%; all six states have biomass co-firing opportunities because of the distribution of coal plants. Biomass CHP accounts for 2.1%, with slightly more variation across states due to the distribution of pulp and paper mills. Wind power is forecast to grow to 3.5% of the total—mostly from on-shore wind turbines, but one-fourth is seen as coming from off-shore wind turbines by 2020. Solar photovoltaics represent a small portion of the total renewable generation, explained by its relatively high costs.

The short report by Creech, et al. (2009, p. 3) is based on a review of recent studies of renewable energy potential in the Southeast. It focused on identifying "feasible" renewable resources that could be developed with available technologies and at reasonable costs—"that is, no more than the most expensive conventional electric power options." Their definition of the Southeast included eight states stretching from Virginia down the Atlantic seaboard to Florida, and including Alabama, Tennessee and Mississippi. This review concludes that approximately 30% of this region's electricity could be met by renewable resources, totaling 1,300 billion kWh in the year 2025. As is the case with most of these studies, this percentage would be much higher if significant improvements in energy efficiency occurred simultaneously. In the near-term (2010-2015), biopower plays a dominant role; in the mid-term (2020-2025), biopower accounts for less than half of the potential while solar power has grown to 35% (Creech, et al., 2009, Figure 2).

Unlike the SACE (2009) and Creech, et al. (2009) studies, *Renewable Energy in the South* uses a fully integrated macro-economic model, similar to the EIA (2009b) and Beck (2002) analyses. The common modeling approach of these three studies does not result in common results due to variable policy assumptions and the small region and short time-frame of Beck, et al. (2002). We attempted to characterize an energy future that is economically viable based upon current assumptions of fuel prices, cost of capital, and technology improvement rates, but assuming vigorous levels of policy intervention extending beyond the promulgation of a national renewable electricity standard. This broader portfolio of policies, impacting both utility-scale and customer-owned renewables, would appear to be important to achieve an aggressive expansion of renewables in the future U.S. power system.

## 10.6 CONCLUSIONS

There are myriad opportunities for development of wind in western parts of the South, such as Texas and Oklahoma. Other states and localities have their own resource strengths – hydropower potential is a strength in many states, for example. Utility-scale solar projects continue to receive attention and funding, but account for only a small fraction of renewables. Ongoing solar projects are more about building skill and experience than creating very large outputs. Potential for demand-side renewables exists across the region. The use of renewables is beneficial no matter how far down-stream it occurs, demand or supply side.

### 10.6.1 Utility-Scale Renewables

With the inclusion of up-to-date data on wind resource availability (using 80-meter data), wind's lower levelized cost favors it in a regional analysis of utility power generation. As a result, our analysis suggests that over the next two decades, wind will overwhelm biopower as a preferred renewable resource for the electric utility sector in the South. Onshore wind in the western part of the South is a low-cost resource that will motivate the resolution of transmission issues associated with wheeling wind power to markets in the Southeast.

Previous EIA analysis using NEMS and lower altitude wind potential measurements found biopower to be the preferred renewable resource over wind (EIA, 2009). The real-world adjustments to these assumptions in our modeling resulted in the shift of emphasis between the two sources.

Hydropower resources in the South are also shown to be significant. Opportunities to expand small-scale and low-power hydro exist in every southern state except Mississippi and the District of Columbia.

While utility-scale solar resources are forecast to remain a small contributor to the South's electricity requirements over the next 20 years, solar projects have received more than $60 million of funding from the ARRA. These resources will be used to build an additional 120 MW of new solar capacity, which will expand its current capacity by more than 200%. These projects will also bring solar workforce skills and supply chain infrastructure to the region. Future growth should be spawned from these investments, exceeding the NEMS modeling estimates.

### 10.6.2 Customer-Owned Renewables

The potential for demand-side renewables rivals that of supply-side renewables for electricity generation. Whether to meet clean or local energy goals, customer-owned renewables achieve similar results, even though customer-owned renewable energy does not get the attention that utility-scale renewables do.

Of the technologies we examined, CHP, solar PV, and heat pump water heaters show the largest potential for expanding customer-owned renewables in the South. These are an important part of any future growth strategy for local and clean energy technologies. However, these technologies will only flourish once they overcome financing, regulatory, and information barriers.

### 10.6.3 Summary

By including a full suite of renewable electricity sources, this report identifies a broad and diversified portfolio of renewable resources available for electric power generation in the South. Under realistic renewable expansion and policy scenarios, the region could economically supply a large proportion of its future electricity needs from both utility-scale and customer-owned renewable energy sources. Additional renewable potential is likely to materialize over the next several decades, when solar becomes more cost-competitive, problems associated with intermittency and transmission infrastructures are overcome, and emerging technologies mature.

This study dispels the notion that there is little potential for the development of renewables in the South. By exploiting the renewable sources available in each subdivision of the region – wind in the west, biomass in the southeast, hydro wherever it is available – and utilizing demand-side renewable sources throughout, the South could meet the requirements of a national RES.

This study demonstrates that increased reliance on renewables should not be expected to lead to a drastic increase in electricity expenses. Indeed, if utilized as in our Expanded Renewables scenario, renewable resources could moderate the increase in electricity rates that is forecast to occur over the next 20 years. When added to the RES and CEF policies, the Expanded Renewables scenario moderates the price escalation that might otherwise occur.

Given the magnitude of climate change and energy security challenges facing the nation and the world, each of the renewable technologies described in this report needs to be considered as a possible contributor to a cleaner and more secure energy future. In addition, every state and region of the country needs to exploit its renewable resources. Success will involve transforming and modernizing energy systems in fundamental ways. These transformations in many cases will require more than just the next generation of technology. They will require acceptance of entirely new concepts such as complex integrated systems that optimize suites of technologies, optimizing utility-scale and customer-owned renewable resources. Federal, state, and local public policies can accelerate this transition. The South has an abundance of renewable energy resource potential to help transition the nation away from increasingly scarce, carbon-intensive and polluting fossil fuels. With the commitment of policymakers, utilities, regulators, entrepreneurs, capital markets, and other stakeholders, this potential could be realized.

## REFERENCES

ADAGE. (2009). *ADAGE Hamilton Biopower*. Retrieved on October 12, 2010 from: http://www.adagebiopower.com/florida/hamilton/index.php

AgFax.com. (2010, June 3). *Georgia farmer launches state's largest solar electric generation site*. Retrieved from: http://agfax.com/Content/georgia-pecan-farmer-solar-06032010.aspx.

American Wind Energy Association. (2000). *Fair transmission access for wind: A brief discussion of priority issues*. Retrieved from: http://www.awea.org/policy/documents/transmission.PDF

American Wind Energy Association (AWEA). (2010). *Wind energy basics*. Retrieved on August 16, 2010 from: http://www.awea.org/faq/wwt_basics.html.

AREVA. (2009, May 27). *ADAGE announces proposed site of first U.S. biopower facility*. Retrieved on October 12, 2010 from: http://us.arevablog.com/2009/05/27/ adage-announces-proposed-site-of-first-us-biopower-facility/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+ArevaNorthAmericaBlog+%28AREVA+North+America+Blog%29.

Arkansas Energy Office. (2010). State energy program. Retrieved on August 2, 2010 from: http://arkansasenergy.org/energy-in-arkansas/energy-policy-and-legislation/recovery-2009/state-energy-program.aspx.

Bakis, R. (2007). The current status and future opportunities of hydroelectricity: Energy sources part B. *Economics, Planning & Policy* 2(3): 259-266.

Barras, C. (2009, February). Why sustainable power is unsustainable. Retrieved on September 27, 2010 from the *New Scientist* website at: http://www.newscientist.com/article/dn16550-why-sustainable-power-is-unsustainable.html.

Beck, F. and E. Martinot. (2004). Renewable energy policies and barriers. *Encyclopedia of Energy*. Cutler Cleveland, editor. San Diego: Academic Press/Elsevier Science, pp. 365-383. Retrieved from: http://www.martinot.info/Beck_Martinot_AP.pdf.

Beck, Fredric, Damian Kostiuk, Tim Woolf, and Virinder Singh (2002). Powering the South: A Clean Affordable Energy Plan for the Southern United States. Renewable Energy Policy Project. http://www.repp.org/articles/static/1/binaries/pts_repp_book.pdf

Bhanoo, S. (2010, May 24). Green: Solar panels advance on Camp Lejeune. Retrieved from the *New York Times* Website's Green: A Blog about Energy and Environment at: http://green.blogs.nytimes.com/2010/05/24/solar-panels-advance-on-camp-lejeune/.

Bolinger, M. and R. Wiser. (2010). *2009 Wind technologies market report*. Retrieved from the U.S. Department of Energy, Energy Efficiency & Renewable Energy website at: http://www1.eere.energy.gov/windandhydro/pdfs/2009_wind_technologies_market_report.pdf.

Borin, S., T. Levin, and V.M. Thomas. (2010). Estimates of the cost of new electricity generation in the South. School of Public Policy Working Paper 54. Atlanta, GA: Georgia Institute of Technology.

British Petroleum (BP). (2010). *Alternative energy: Wind power projects and operations*. Retrieved on July 30, 2010, from: http://www.bp.com/sectiongenericarticle.do?categoryId= 9025014&contentId= 7046507.

Brown, M.A. and Y. Baek. (2010). The forest products industry at an energy/climate crossroads. *Energy Policy* 38 (2010) 7665-7675.

Carley, S. (2009). State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy* 27, no. 8 (August): 3071-3081.

Chaudhari, M., L. Frantzis, and T.E. Hoff. (2004). *PV grid connected market potential under a cost breakthrough scenario*. Navigant Consulting, Inc. Retrieved on September 16, 2010 from: http://www.ef.org/documents/EF-Final-Final2.pdf.

Colon, C. and D. Parker. (2010). Side-by-side testing of water heating systems: Results from the 2009-2010 evaluation. FSEC-CR-1856-10. Retrieved on August 16, 2010 from the *Florida Solar Energy Center* website from: http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1856-10.pdf.

Committee on Climate Change Science and Technology Integration (CCCSTI). 2009. *Strategies for the Commercialization and Deployment of Greenhouse Gas Intensity-Reducing Technologies and Practices"*(Washington, DC: U.S. Department of Energy) Report DOE/PI-20007, http://www.climatetechnology.gov/Strategy-Intensity-Reducing-Technologies.pdf.

Creech, D., E. Metzger, S. P. Del Pino, and J. D. Wilson (2009). Local Clean Power (World Resources Institute Issue Brief), April. http://www.renewableenergyworks.org/files/WRI2009_CleanEnergySE.pdf

Database of State Incentives for Renewables and Efficiency (DSIRE). (2010a). *Summary maps: 3rd-party solar PPA policies*. Retrieved from: http://www.dsireusa.org/summarymaps/index.cfm?ee=0&RE=1

Database of State Incentives for Renewables and Efficiency (DSIRE). (2010b). *Solar policy guide*. Retrieved from: http://www.dsireusa.org/solar/solarpolicyguide/.

Database of State Incentives for Renewables and Efficiency (DSIRE). (2010c). *Heat pumps*. Retrieved from: http://www.dsireusa.org/incentives/index.cfm?EE=1&RE=1&SPV=0&ST=0&technology=heat_pumps&sh=1.

Database of State Incentives for Renewables and Efficiency (DSIRE). (2010d). *Rules, regulations & policies for renewable energy***.** Retrieved December 3, 2010, from: http://www.dsireusa.org/summarymaps/ index.cfm?ee=0&RE=1.

Delaware Offshore Wind Project. (2008). Retrieved on September 29, 2010 from the University of Delaware College of Earth, Ocean, and Environment website at http://www.ceoe.udel.edu/windpower/deproject.html.

Delaware Public Service Commission (DPSC). (2009). *Rules and procedures to implement the renewable energy portfolio standard*. Retrieved on December 3, 2010, from: http://depsc.delaware.gov/electric/rpsrules_fin021009.pdf

Denholm, P. (2007). *The technical potential of solar water heating to reduce fossil fuel use and greenhouse gas emissions in the United States*. National Renewable Energy Laboratory. NREL/TP-640-41157. Retrieved on August 12, 2010 from: http://www.nrel.gov/docs/fy07osti/41157.pdf.

Denholm, P. and R. Margolis. (2007, December). *The regional per-capita solar electric footprint for the United States.* NREL/TP-670-42463. Retrieved from the National Renewable Energy Laboratory (NREL) website on September 16, 2010 at: http://www.nrel.gov/docs/fy08osti/42463.pdf.

Doris, E., J. McLaren, V. Healey, & S. Hockett. (2009). *State of the states 2009: Renewable energy development and the role of policy*. NREL/TP-6A2-46667. Retrieved from: http://www.nrel.gov/docs/fy10osti/46667.pdf.

Dubose, S. (2007). *An overview of landfill gas energy in South Carolina and the US*. Retrieved on September 29, 2010 from: http://www.regulatorystaff.sc.gov/electricandgas/LMOP%20Powerpoint%20-4-07.pdf.

Duke Energy. (2010). *Power up with wind*. Retrieved on August 3, 2010 from: http://www.duke-energy.com/pdfs/Wind-Power-Projects-Fact-Sheet.pdf.

Electric Power Research Institute (EPRI). (2010). *Driving forward, state of the technology I 2010*. p. 24.

Energy Star. (2010). *Federal tax credits for energy efficiency*. Washington, D.C.: Energy Star. Retrieved from: http://www.energystar.gov/index.cfm?c=tax_credits.tx_index.

Energy Star. (2009). *Save money and more with ENERGY STAR qualified heat pump water heaters*. Retrieved from: http://www.energystar.gov/index.cfm?c=heat_pump.pr_savings_ benefits.

Federal Business Opportunities. (2010). Z--Pine Creek Dam, McCurtain Coutny, OK. Retrieved on September 30, 2010 from: https://www.fbo.gov/index?s=opportunity&mode=form&id=db2b77665f98b6c7b26e8997412ca63b&tab=core&_cview=0.

Federal Energy Regulatory Commission (FERC). (2010a). *FERC looks to ease development of small hydropower projects*. Retrieved on August 14, 2010 from: http://www.ferc.gov/default.asp.

Federal Energy Regulatory Commission (FERC). (2010b). Order granting stay in part. Retrieved on September 30, 2010 from: http://www.ferc.gov/whats-new/comm-meet/2010/091610/H-3.pdf.

Florida Power and Light (FPL). (2010). *Martin Next Generation Solar Energy Center*. Retrieved on July 27, 2010 from: http://www.fpl.com/environment/solar/martin.shtml.

Florida Solar Energy Industries Association (FlaSEIA). (nd). *Photo library: "Active" solar water heater (example two)*. Retrieved on June 23, 2010 from: http://www.flaseia.org/Technologies/photos/wat_htr/act_2.htm.

General Electric. (2010a). *GeoSpring™ hybrid water heater*. Retrieved from: http://www.geappliances.com/heat-pump-hot-water-heater/water-heater-rebate.htm.

General Electric (GE). (2010b). *GeoSpring™ hybrid water heater*. Retrieved on May 20, 2010 from: http://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SpecPage&Sku=GEH50DNSRSA**.**

Georgia Power. (2010). *Electric service tariff: Renewable and nonrenewable resources schedule: "RNR-6"*. Retrieved on October 1, 2010 from: http://www.georgiapower.com/pricing/pdf/11.10_RNR-6.pdf.

Georgia Power. (2009). *Facts & Figures*. Retrieved on August 3, 2010 from: http://www.georgiapower.com/about/facts.asp.

Goetzler, W., R. Zogg, H. Lisel, and J. Burgos. (2009). *Ground- source heat pumps: Overview of market status, barriers to adoption, and options for overcoming barriers*. Navigant Consulting, Inc. Submitted to the U.S. Department of Energy, Energy Efficiency and Renewable Energy, Geothermal Technologies Program. Retrieved on October 10, 2010 from: http://www1.eere.energy.gov/geothermal/pdfs/gshp_overview.pdf.

Gorman, T. and A. Zidek-Vanega. (2010). *Solar in the stimulus: An analysis of state energy program spending*. Retrieved from: http://www.dsireusa.org/documents/PolicyPublications/DSIRE_ASES_2010.pdf.

Hall, D.G., K.S. Reeves, J. Brizzee, R.D. Lee, G.R. Carroll, and G.L. Sommers. (2006, January). *Feasibility assessment of the water energy resources of the United States for new low power and small hydro classes of hydroelectric plants.* INL,DOE-ID-11263, Table B-1. Retrieved from: http://www1.eere.energy.gov/windandhydro/ pdfs/doewater-11263.pdf.

Hanes, S. (2010, September 29). *Southeast wind energy: Is the answer blowing in the wind?.* Georgia Institute of Technology Clean Energy Speaker Series. Retrieved on October 11, 2010 from: http://www.secleanenergy.org/files/Hanes.pdf.

Haq, Z. (2002) *Biomass for electricity generation*. Energy Information Administration (EIA).Retrieved from: http://www.eia.doe.gov/oiaf/analysispaper/biomass/.

Hoffmann, W. (2006). *PV solar electricity industry: Market growth and perspective - Solar energy materials & solar cells*. Retrieved from: http://www.epa.gov/greenpower/buygp/ solarpower.htm.

Huang, B. J., Lin, T. H., Hung, W. C., & Sun, F. S. (2001). *Performance evaluation of solar photovoltaic/thermal systems*. *Solar Energy,* 70(5), 443-448.

International Energy Agency (IEA). (nd). *United States: Small hydro site database*. Retrieved on September 24, 2010 from the International Small-Hydro Atlas website at: http://www.small-hydro.com/index.cfm?fuseaction=countries.sites&country_ID=82.

ICF International. (2010). Photovoltaic (PV) cost and performance characteristics for residential and commercial applications. Prepared for EIA

Kenderdine, Melanie. 2010. “Natural Gas: Opportunities, Challenges, and Implications” Presentation at a panel discussion hosted by “Our Energy Policy,” Washington, DC, December 2

Keoleian, G. A., & Lewis, G. M. (2003). Modeling the life cycle energy and environmental performance of amorphous silicon BIPV roofing in the US. *Renewable Energy*, 28(2), 271-293.

Kilgore, G. (2010, June 15). President, Suncatcher of Atlanta. Telephone Correspondence.

Kim, S.S., Na, S.I., Kang, S.J., & Kim, D.Y. (2010). Annealing-free fabrication of P3HT:PCBM solar cells via simple brush painting. *Solar Energy Materials and Solar Cells*, 94(2), 171-175.

Landfill Methane Outreach Program (LMOP). (2010a). *BMW manufacturing landfill gas energy project*. Retrieved on September 29, 2010 from the EPA website at: http://www.epa.gov/lmop/projects-candidates/profiles/bmwmanufacturinglandfillg.html.

Landfill Methane Outreach Program (LMOP). (2010b). *Energy projects and candidate landfills*. Retrieved on September 29, 2010 from the EPA website at: http://www.epa.gov/lmop/ projects-candidates/index.html#map-area.

Lapsa, M. (2009). *Buildings summary: Considerable room for improvement*. Powerpoint presentation. Oak Ridge, TN: Oak Ridge National Laboratory.

Lazard. (2010). Levelized cost of energy analysis – Version 4.0.

Maher, P., N. P.A. Smith, and A.A. Williams. (2003). Assessment of pico hydro as an option for off-grid electrification in Kenya. *Renewable Energy,* 28(9), 1357-1369.

McConnell, B.W., S.W. Hadley, and Y. Xu. (2010, July). *A review of barriers and opportunities for the integration of renewable energy,* Final Draft. Oak Ridge, TN: Oak Ridge National Laboratory.

Milbrandt, A. (2005). *A geographic perspective on the current biomass resource availability in the United States,* NREL, TP-560-39181. Retrieved from: http://www.nrel.gov/docs/ fy06osti/39181.pdf.

Mouawad, J. (2010, March 4).The newest hybrid model. Retrieved on July 27, 2010 from the *New York Times* website at: http://www.nytimes.com/2010/03/05/business/05solar.html?ref=energy-environment.

Musial, W. and S. Butterfield. (2004). *Future for offshore wind energy in the United States.* NREL/CP-500-36313. Golden, CO: National Renewable Energy Laboratory. Retrieved from: http://www.nrel.gov/docs/fy04osti/36313.pdf.

Musial, W., S. Butterfield, and B. Ram. (2006). *Energy from offshore wind.* NREL/CP-500-39450. Golden, CO: National Renewable Energy Laboratory. Retrieved from: http://www.nrel.gov/docs/fy06osti/39450.pdf.

National Association of State Energy Officers (NASEO). (2010). *State Energy Program ARRA update*. Retrieved from: http://www.naseo.org/programs/sep/recovery/State_Energy_Program_ARRA_Update-2010-03.pdf.

National Hydropower Association (NHA). (2010). *Hydropower modernization*. Retrieved from: http://www.hydro.org/hydrofacts/Modernization4.pdf.

National Renewable Energy Laboratory (NREL). (2010a) *Solar research*. Retrieved on July 29, 2010 from: http://www.nrel.gov/solar/.

National Renewable Energy Laboratory (NREL). (2010b). *U.S. solar maps. PV resource map for flat-plate collectors.* Retrieved on July 18, 2010 from: http://www.nrel.gov/gis/solar.html.

National Renewable Energy Laboratory (NREL). (2010c). *Open PV Project*. Retrieved June 29, 2010 from: http://openpv.nrel.gov/.

National Renewable Energy Laboratory (NREL). (2010d). *Wind powering America: Wind resource potential*. Retrieved on July 18, 2010 from: http://www.windpoweringamerica.gov/wind_maps.asp.

National Renewable Energy Laboratory (NREL). (2010e). *30-Year average of monthly solar radiation, 1961-1990*. Retrieved on September 23, 2010 from: http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/sum2/state.html. Retrieved on November 3, 2010 from http://www.renewableenergyworks.org/files/48258.pdf

National Renewable Energy Laboratory (NREL). (2010f). Evaluating Renewable Portfolio Standards and Carbon Cap Scenarios in the U.S. Electric Sector

National Renewable Energy Laboratory (NREL). (2008). Photovoltaic Solar Resource: U.S. and Germany. Available at: http://www.seia.org/galleries/default-file/PVMap_USandGermany.pdf

National Research Council. (2009). *Hidden costs of energy: Unpriced consequences of energy production and use.* Washington, DC: The National Academies Press.

Navigant Consulting. (2008). *Florida renewable energy potential assessment*. Navigant Consulting, Inc. Retrieved on September 16, 2010 from: http://www.psc.state.fl.us/utilities/electricgas/RenewableEnergy/FL_Final_Report_2008_12_29.pdf.

Navigant Consulting. (2007). *EIA-Technology Forecast Updates- Residential and Commercial Building Technologies – Advanced Case, 2nd Edition (Revised).* Power Point. Washington, D.C.

Nelson, Gabriel (2010). "It's red states vs. blue in legal war over EPA rules." ClimateWire. E&E Publishing, LLC. October, 12, 2010b. www.eenews.net/greenwire/climate_courts/2010/10/12/1

Network for New Energy Choices. (2009). *Freeing the grid: Best and worst practices in State net metering policies and interconnection procedures*. Retrieved from: http://www.solaralliance.org/editor/upload/files/FreeingTheGrid2009.pdf.

Newkirk, M. (2010, June 13). Solar industry challenges Georgia Power. Retrieved from the *Atlanta Journal Constitution* website at: http://www.ajc.com/business/solar-industry-challenges-georgia-548016.html.

Nogee, A., S. Clemmer, B. Paulos, and B. Haddad. (1999). *Powerful solutions: Seven ways to switch America to renewable electricity*. Retrieved from the Union of Concerned Scientists website at: http://www.ucsusa.org/assets/documents/clean_energy/ps-all.pdf.

OPEN ENERGY INFO (OpenEI). (2010). *Sales tax exemption incentives*. Retrieved from: http://en.openei.org/wiki/Sales_Tax_Exemption.

Pacala, S.W. and R.H. Socolow. (2004). Stabilization wedges: Solving the climate problem for the next 50 years with current technologies. *Science,* 305, 968-972.

Paidipati, J., L. Frantzis, H. Sawyer, and A. Kurrasch. (2008). *Rooftop photovoltaics market penetration scenarios.* NREL/SR-581-42306. Retrieved on September 15, 2010 from: http://www.navigantconsulting.com/downloads/knowledge_center/Final_Report_PV_Markets_Global_EG.pdf.

Paish, O. and J. Green. (2001). *The pico hydro market in Vietnam*. Retrieved on September 16, 2010 from: http://www.research4development.info/PDF/Outputs/Energy/R8150-Vietnam.pdf

Pennock, C. and S. Doron. (2009). Southern bioenergy roadmap. Retrieved from the *Southeastern Agriculture and Forestry Energy Resources Alliance (SAFER)* website at: http://www.saferalliance.net/projects/downloads/reports/RoadmapBook_webres.pdf.

PennWell. (2010, June 7). *Alden to host existing dam hydropower retrofit workshop*. Retrieved from: http://www.hydroworld.com/index/display/article-display/4735617716/articles/hrhrw/hydroindustrynews/newdevelopment/2010/06/alden-to_host_existing.html.

Perlack, R.D., L.L. Wright, A.F. Turhollow, R. Graham, B.J. Stokes, and D.C. Erbach. (2005). *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: Billion-Ton Annual Supply*. ORNL/TM-2005/66 & DOE/GO-102995-2135. Oak Ridge, TN: Oak Ridge National Laboratory.

Recovery Through Retrofit. (2009). *Middle Class Task Force, Council on Environmental Quality, Executive Office of the President of the United States*. Retrieved on October 19, 2009 from: http://www.whitehouse.gov/assets/documents/Recovery_Through_Retrofit_Final_Report.pdf.

Recycled Energy Development (RED). (nd a). *Recycled energy project fact sheet*. Retrieved on September 30, 2010 from: http://www.recycled-energy.com/_documents/projects/fact-sheet-globe.pdf.

Recycled Energy Development (RED). (nd b). *CHP Opportunity at Silicon Manufacturer*. PowerPoint presentation

Renewable Energy Foundation (REF). (2010). *Solar Technology Chapter* (draft).

Renewable Energy World. (2010, March 15). *Southern Company & Ted Turner acquire first solar project.* Retrieved on August 3, 2010 from: http://www.renewableenergy world.com/ rea/news/article/2010/03/southern-company-ted-turner-acquire-first-solar-project.

Renewable Energy World. (2009, October 2). *EC&R completes 780-MW Roscoe Wind Farm*. Retrieved on July 30, 2010 from: http://www.renewableenergyworld.com/rea/news/

article/2009/10/ec-r-completes-780-mw-roscoe-wind-farm.

Renewable Energy Policy Network for the 21st Century (REN21). 2010. *Renewables Global Status Report: 2010 Update*, September. Available at http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf

Renewable Energy Policy Network for the 21st Century (REN21). (2009). *Renewables Global Status Report*. Retrieved from: http://www.ren21.net/pdf/RE_GSR_2009_Update.pdf.

Renewable Energy Policy Network for the 21st Century (REN21). (2007). *Renewables Global Status Report 2006 Update*. Retrieved on May 16, 2007, see Table 4, p. 20.

Rheem. (2010). *Introducing the Rheem hybrid electric water heater featuring heat pump technology*. Retrieved on September 16, 2010 from: http://www.rheem.com/products/ tank_water_ heaters/Hybrid_electric/.

Solarbuzz. (2010).Solar Module Retail Price Environment. Solarbuzz Consulty Report. Retrieved on June 29, 2010, from: http://www.solarbuzz.com/Moduleprices.htm

Sovacool, Benjamin K. and Marilyn A. Brown. 2009. “Scaling the Policy Response to Climate Change,” Policy and Society 27: 317-328

SCS Engineers. (1997). *Comparative analysis of landfill gas utilization technologies*. Prepared for Northeast Regional Biomass Program. Retrieved from: http://www.nrbp.org/pdfs/pub07.pdf.

SEIA. (2010). *US solar industry year in review 2009*. Washington DC: Solar Energy Industries Association.

Shipley, A., A. Hampson, B. Hedman, P. Garland, and P. Bautista. (2008). *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future*. ORNL/TM-2008/224. Oak Ridge, TN: Oak Ridge National Laboratory.

Shukla, A., Buddhi, D., & Sawhney, R. L. (2009). Solar water heaters with phase change material thermal energy storage medium: A review. *Renewable and Sustainable Energy Reviews*, 13(8), 2119-2125.

Smith, Brennan. (2010, July 15). Personal Correspondence. Affiliated with the Water Resources Group, Environmental Sciences Division at Oak Ridge National Laboratory.

Smith, N. and G. Ranjitkar. (2000). *Nepal case study – Installation and performance of the Pico Power Pack*. Retrieved on September 16, 2010 from: http://www.eee.nottingham.ac.uk/ picohydro/documents.html.

Snyder, B. and M.J. Kaiser. (2009). *Offshore wind power in the U.S.: Regulatory issues and models for regulation.* Baton Rouge, LA: LSU Center for Energy Studies.

Solar Alliance. (2010). *Four Pillars of Cost-Effective Solar Policy.* Retrieved from: http://www.solaralliance.org/downloads/four_pillars.pdf.

*Solar Energy*. (2007). In Survey of Energy Resources 2007. World Energy Council. D.Y. Goswami (Ed.). Available at http://www.worldenergy.org/documents/ser2007_final_online_version_1.pdf

Southern Alliance for Clean Energy (SACE). (2009). *Yes we can: Southern solutions for a national renewable energy standard.* Knoxville, TN: SACE. .

State Energy Data System (SEDS). (2010). Table S3. Energy consumption estimates by source, 2008 (Continued). Retrieved on July 28, 2010 from: http://www.eia.doe.gov/emeu/states/ hf.jsp?incfile=sep_sum/plain_html/sum_btu_totb.html.

Steiner, C. (2008, September 15). Gray is the new green. Retrieved from the *Forbes Magazine* website at: http://www.forbes.com/forbes/2008/0915/054.html.

Suniva. (nd). About the company. Retrieved on September 29, 2010 from: http://www.suniva.com/aboutthecompany.php.

Tennessee Valley Authority (TVA). (2010, February 17). *TVA Contracts with Horizon for Renewable Wind Power*. Retrieved on August 3, 2010 from: http://www.tva.gov/news/releases/janmar10/horizon_wind_power.html.

Tian, Z.F., M.H. Huang, B. Zhao, H. Huang, X.M. Feng, Y.J. Nie, P. Shen, and S.T. Tan. (2010). Low-cost dyes based on methylthiophene for high-performance dye-sensitized solar cells. *Dyes & Pigments*, 87(3): 181-187.

Trinity River Authority. (2010). *Trinity River Basin Master Plan*. Retrieved on September 24, 2010 from: http://www.trinityra.org/PDF_files/Master%20Plan%20Justified%20REV.pdf

Trinity River Auhtority. (nd). *Lake Livingston*. Retrieved on October 7, 2010 from: http://data.trinityra.org/Lake_livingston_facts.htm.

U.S. Census Bureau. (2010). Population Finder. Retrieved on October 29, 2010 from: http://factfinder.census.gov/servlet/SAFFPopulation?_submenuId=population_0&_sse=on

U.S. Corps of Engineers. (nd a). *Corps Lakes Gateway: Pine Creek Lake*. Retrieved on September 29, 2010 from: http://corpslakes.usace.army.mil/visitors/projects.cfm?Id=M514030.

U.S. Corps of Engineers. (nd b). *History of the area: Pine Creek Lake*. Retrieved on September 29, 2010 from: http://www.swt.usace.army.mil/recreat/ViewHistoryMessage.cfm?tblMessages__LakeName=Pine%20Creek%20Lake.

U.S. Department of Commerce, National Ocean and Atmospheric Administration (NOAA), National Ocean Service. (2010). Retrieved on August 12, 2010 from: http://www.noaa.gov/.

U.S. Department of Energy (DOE). (2010a). *Approved energy efficient and appliance rebate programs*. Washington, DC: DOE. Retrieved from: http://www.energysavers.gov/financial/70022.html.

U.S. Department of Energy (DOE). (2010b). *Solar America Cities*. Retrieved from: http://www.solaramericacities.energy.gov/.

U.S. Department of Energy (DOE). (2010c). *The green power network*. Retrieved June 29, 2010, from: http://apps3.eere.energy.gov/greenpower/markets/certificates.shtml?page=3.

U.S. Department of Energy (DOE). (2010d). *Wind powering America*. Retrieved on August 16, 2010 from: http://www.windpoweringamerica.gov/wind_maps.asp#potential.

U.S. Department of Energy (DOE). (2008). *Annual report on wind power installation, cost and trends: 2007*. Retrieved from: http://www1.eere.energy.gov/windandhydro/pdfs/43025.pdf.

U.S. Department of Energy: Energy Efficiency and Renewable Energy (DOE/EERE). (2010). *Solar water heaters*. Retrieved on September 15, 2010 from: http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12850.

U.S. Department of Energy: Energy Efficiency and Renewable Energy (DOE/EERE). (2009a). *Water Heating*. Retrieved on March 12, 2010 from: http://www.energysavers.gov/your_home/water_ heating/index.cfm/mytopic=12840.

U.S. Department of Energy: Energy Efficiency and Renewable Energy (DOE/EERE). (2009b). *Heat pump systems*. Retrieved on June 27, 2010 from: http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12610

U.S. Department of Energy: Energy Efficiency and Renewable Energy (DOE/EERE). (2009c, November 19). *Hydropower Upgrades to Yield Added Generation*. Retrieved from: http://www1.eere.energy.gov/windandhydro/news_detail.html?news_id=15606.

U.S. Department of Energy: Energy Efficiency and Renewable Energy (DOE/EERE). (2003). *A consumer's guide: Heat your water with the sun*. DOE/GO-102003-1824. Retrieved on August 12, 2010 from: http://www.nrel.gov/docs/fy04osti/34279.pdf.

U.S. Department of Energy: Energy Efficiency and Renewable Energy (DOE/EERE). (1996). *Solar water heating*. DOE/GO-10096-050. Retrieved on August 12, 2010, from: http://www.nrel.gov/docs/legosti/fy96/17459.pdf.

U.S. Department of the Interior. (2010). *Press release: Salazar signs agreement with 10 east coast governors to establish Atlantic Offshore Wind Energy Consortium*. Retrieved from: http://www.doi.gov/news/pressreleases/Salazar-Signs-Agreement-with-10-East-Coast-Governors-to-Establish-Atlantic-Offshore-Wind-Energy-Consortium.cfm

U.S. Energy Information Administration (EIA). (2010a). *Solar thermal: Tables 2.1 and 2.13*. Retrieved on August 20, 2010 from: http://www.eia.doe.gov/cneaf/solar.renewables/page/solarthermal/solarthermal.html.

U.S. Energy Information Administration (EIA). (2010b). *Average retail price of electricity to ultimate customers by end-use sector, by state, Table 5.6.B*. Retrieved on June 28, 2010 from: http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.html.

U.S. Energy Information Administration (EIA). (2010c). *Natural Gas Monthly: Selected national average natural gas prices.* Retrieved on June 19, 2010 from: http://www.eia.doe.gov/natural_gas/data_publications/natural_gas_monthly/ngm.html.

U.S. Energy Information Administration (EIA). (2010d). *Electric power monthly, Table1.13.B.* Retrieved on July 29, 2010 from: http://www.eia.doe.gov/cneaf/solar.renewables/page/hydroelec/hydroelec.html.

U.S. Energy Information Administration (EIA). (2010e). *Electric Power Annual 2008 – Data tables: 1990 - 2008 Average price by state by provider (EIA-861)*. Retrieved on August 18, 2010 from: http://www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html.

U.S. Energy Information Administration (EIA). (2010f*). Solar photovoltaic cell/module manufacturing activities.* Retrieved June 29, 2010, from http://www.eia.doe.gov/ http://www.eia.doe.gov/oiaf/archive/aeo08/index.html.

U.S. Energy Information Administration (EIA). (2010g). *Assumptions to the Annual Energy Outlook 2009 – renewable fuels module*. DOE/EIA-0554(2009).

U.S. Energy Information Administration (EIA). (2010h). *State Energy Data System*. Retrieved on July 2, 2010 from: http://www.eia.doe.gov/emeu/states/_seds.htm.

U.S. Energy Information Administration (EIA). (2010i). *Annual Energy Outlook: 2010* Washington, DC: U.S. Department of Energy) Report DOE/EIA-0383(2010), May. Available at http://www.eia.doe.gov/oiaf/aeo/.

Energy Information Administration (EIA). (2010j). *International Energy Outlook: 2010* Washington, DC: U.S. Department of Energy) Report DOE/EIA-0484(2010), July. Available at http://www.eia.gov/oiaf/ieo/index.html.

U.S. Energy Information Administration (EIA). (2009a). *2005 Residential Energy Consumption Survey – detailed tables: All water heating tables*. Retrieved on August 14, 2010 from: http://www.eia.doe.gov/emeu/recs/recs2005/c&e/waterheating/pdf/alltables1-11.pdf.

U.S. Energy Information Administration (EIA). (2009b). *Impacts of a 25-percent renewable electricity standard as proposed in the American Clean Energy and Security Act.* Discussion Draft. SR/OIAF/2009-04.

U.S. Energy Information Administration (EIA). (2009c). *An updated Annual Energy Outlook 2009 reference case reflecting provisions of the American Recovery and Reinvestment Act and recent changes in the economic outlook.* SR/OIAF/2009- 03. Retrieved from: http://www.eia.doe.gov/oiaf/servicerpt/stimulus/excel/aeostimtab_18.xls.

U.S. Energy Information Administration (EIA). (2008a). *Annual Energy Review* DOE/EIA-0384(2007). http://www.eia.doe.gov/aer/elect.html

U.S. Energy Information Administration (EIA). (2008b). *Annual Energy Outlook 2008 with projections to 2030*, DOE/EIA-0383(2008).

U.S. Energy Information Administration (EIA). (2003). *National Energy Modeling System: An overview*. Retrieved from: http://www.eia.doe.gov/oiaf/aeo/overview/index.html.

U.S. Environmental Protection Agency (EPA). (2010a). *Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. http://www.epa.gov/otaq/climate/regulations/scc-tsd.pdf

U.S. Environmental Protection Agency (EPA). (2010b) Prevention of Significant Deterioration andTitle V Greenhouse Gas Tailoring Rule. Final Rule. 40 CFR Parts 51, 52, 70, and 71 RIN 2060 – AP86. June 3, 2010. Vol. 75, No. 106.

U.S. Environmental Protection Agency (EPA). (2010c). *Solar power purchase agreements*. Retrieved on June 4, 2010 from http://www.epa.gov/greenpower/buygp/solarpower.htm.

Environmental Protection Agency (EPA). (2009, April). *Energy Portfolio Standards and the promotion of combined heat and power.* Retrieved from: http://www.epa.gov/chp/documents/eps_and_promotion.pdf

“U.S. Wind Energy Industry Breaks All Records, Installs Nearly 10,000 MW in 2009,” American Wind Energy Association (January 26, 2010), web site www.awea.org/newsroom/releases/01-26-10 _AWEA_Q4_and_Year-End_Report_Release.html

Valliant Chamber of Commerce. (2004). *Pine Creek Lake*. Retrieved on September 29, 2010 from: http://www.valliantchamber.org/pine_creek_lake.html.

Varun, P., R., & I. Bhat. (2009). Energy, economics and environmental impacts of renewable energy systems. *Renewable & Sustainable Energy Reviews*, 13(9), 2716-2721.

Wiser, R., G. Barbose, C. Peterman, & N. Darghouth. (2009). *The installed cost of photovoltaics in the US from 1998 – 2008*. Lawrence Berkley National Laboratory.

World Wind Energy Association (WWEA). 2010. *World Wind Energy Report 2009.* (Bonn, Germany: World Wind Energy Association), March. http://www.wwindea.org/home/images/stories/worldwindenergyreport2009_s.pdf

Xu, J.F. (2010). Local implementation of building energy policies in China’s Jiangsu province. Proceedings of the *ACEEE Summer Study on Energy Efficiency in Buildings*, August 17, 2010, Pacific Grove, CA, Volume 8.

Yin, H.T., and N. Powers. (2010). Do state renewable portfolio standards promote in-state renewable generation?. *Energy Policy* 38(2): 1140-1149.

Zogou, O. & A. Stamatelos. (1998). Effect of climatic conditions on the design optimization of heat pump systems for space heating and cooling. *Energy Conversion and Management*, 39(7), 609-622.

# APPENDICES

## A. RENEWABLE ENERGY PROJECTS AND PROGRAMS IN THE SOUTH

The South has a number of available renewable energy programs and established projects. There are three sections of this appendix. The first section describes some of the existing renewable energy projects in the South. The second section describes the funding and grant programs for renewable energy in the region. The last section describes the installed and planned capacity of biomass, solar, and wind energy in the South, as of December 2009.

The lists in the first two sections, though certainly not comprehensive, provide an idea of the breadth of programs and projects available in the South. The recent surge in renewable energy financial programs, largely due to the influx of ARRA funding, can also be seen within the various programs and projects that have been recently initiated.

The list also provides an understanding of where current efforts are concentrated and illuminate possible areas for future expansion or improvement. For instance, the hydropower in the South appears to be divided between newer and older hydroelectric dams, where the newer facilities have larger generation capacities. This provides ample opportunity to increase hydroelectric generation capacity through programs that update older hydroelectric dams with new turbines and technology. Some projects, like those mentioned below, have retrofitted old dams to increase hydroelectric generation, but more could certainly follow.

### A.1 Existing and Upcoming Renewable Energy Projects in the South

### *A. 1.1 Hydropower Projects*

- Raccoon Mountain Pumped Storage hydroelectric facility on the Tennessee River near Chattanooga, Tennessee, has a generating capacity of 1,653 MW. The facility was completed in 1978 (TVA, nd & 2009).
- Bad Creek Pumped-Storage Generating Station in Oconee County, South Carolina, has a generating capacity of 1,065 MW and has been in operation since 1991 (Duke Energy, nd b).
- Rocky Mountain Hydroelectric Plant near Rome, Georgia, is a pumped storage hydroelectric facility that has a total generating capacity of 1,046 MW (Oglethorpe Power, 2008).
- Wilson hydroelectric facility is located on the Tennessee River and has a capacity of 662.7 MW. It was completed in 1924 (TVA, 2009).
- The Jocassee Pumped-Storage Generating Station has a capacity of 610 MW. Located in Pickens County, South Carolina, the station began operating in 1973 (Duke Energy, nd b).

- The Cowans Ford Hydro Station, located in Lincoln County, North Carolina, has a capacity of 350 MW. The station began first operating in 1963 (Duke Energy, nd c).

- Wallace Dam in Georgia has a capacity of 321.3 MW (Georgia Power, 2009).

- The Fontana hydroelectric facility was completed in 1944. This facility has a capacity of 303 MW and is located on the Little Tennessee River (TVA, 2009).

- Pickwick Landing hydroelectric facility is located on the Tennessee River. It has a capacity of 233.1 MW and was completed in 1938 (TVA, 2009).

- Rocky Mountain hydro station in Georgia has a capacity of 215.3 MW (Georgia Power, 2009).

- Barletts Ferry hydro station in Georgia has a capacity of 173 MW (Georgia Power, 2009).

- The Kentucky hydroelectric facility is located on the Tennessee River. Completed in 1944, the facility has a generating capacity of 165.2 MW (TVA, 2009).

- Keowee Hydro Station in Pickens County, South Carolina, first began commercial operations in 1971. It has a capacity of 158 MW (Duke Energy, nd c).

The TVA is the largest hydroelectric provider in the South. Including the Raccoon Mountain Pumped Storage facility and the other three mentioned plants, the TVA has 30 hydroelectric sites with a total generating capacity of 5,191 MW (TVA, nd).

### *A.1.2 Solar Energy Projects*

- DeSoto Next Generation Solar Energy Center, a 25 MW solar power facility in Florida completed in October 2009, is the largest facility of its kind in the nation (FPL, 2010a).

- An 18 MW solar energy project located in Davidson County, North Carolina, will be operational in late 2010. The project is operated by SunEdison. Duke Energy has contracted to purchase 16 MW of the produced electricity (Craver, 2009; SACE, 2009; Duke Energy, nd).

- Duke Energy purchased the 16 MW Blue Wing Solar Project in Texas. The 139 acre project will be completed in late 2010 and will use over 214,000 ground mounted First Solar thin-film panels. A 30 year purchase agreement with CPS Energy, a San Antonio company, came with the purchase of the project (Duke Energy, 2010a).

- North Carolina issued a revised order allowing Duke Energy to install 10 MW of solar panels on residential, business, and school rooftops. The distributed solar energy project will be one of the first large scale projects of its kind in the nation (Duke Energy, nd; SACE, 2009). Phase 1 of the project, where four large non-residential customers received solar panels, was completed in April 2010. The remaining two phases of the project are expected to be completed by December 2010 (Duke Energy, 2010c).

- A 10 MW solar power facility at Kennedy Space Center began production in April 8, 2010 (FPL, 2010b).

- The Volunteer State Solar Initiative program will establish the West Tennessee Solar Farm on 20 acres in Haywood County. The farm will generate 5 MW and will be one of the largest in the Southeast. The Tennessee Valley Authority has agreed to purchase the generated power from the farm (NASEO, 2010).

- Duke Energy owns and operates a 1 MW solar project in Shelby, North Carolina, that began producing electricity early 2010 (Duke Energy, 2010b).

- Progress Energy purchases electricity from seven solar photovoltaic arrays in North Carolina (Progress Energy, 2010):
    - 2.3 MW in Scotland County,
    - 1.3 MW on City of Raleigh property and 1 MW array at SAS software company in Wake County,
    - 1.27 MW on a warehouse roof in Craven County,
    - 1.2 MW on Progress Energy's Sutton Plant in New Hanover County,
    - 650 kW at an industrial park in Person County, and
    - 550 kW at a former Blue Ridge Paper landfill in Haywood County.

- Vanir Energy announced a 1.5 MW solar heating and cooling project to serve a Henderson County, North Carolina, business park without utility involvement (SACE, 2009).

### *A.1.3 Wind Power Projects*

- The Roscoe Wind Farm in Texas was completed in late 2009. The 781.5 MW facility is the largest wind farm in the world and covers over 100,000 acres (Renewable Energy World, 2009).

- The Horse Hollow Wind Farm, located in Taylor and Nolan Counties in Texas, has a total generating capacity 735.5 MW. The farm has 430 Siemens and GE wind turbines. It began commercial operation in 2005 and 2006 (NextEra Energy, nd a).

- The Flat Ridge I Wind Farm in Barber County, Kansas, began operating in February 2009 and has a 100 MW capacity (BP, 2010).

- The Sherbino I Wind Farm, located in Pecos County, Texas, has a 150 MW generating capacity. It has been commercially operational since October 2008 and uses 50 Vestas 3 MW wind turbines (BP, 2010).

- The Silver Star I Wind Farm has a generating capacity of 60 MW. Located 80 miles southwest of the Dallas/Fort Worth metropolitan area, the farm began operations in September 2008 (BP, 2010).

- Capricorn Ridge Wind Farm is located in Sterling and Coke counties in Texas. The 662.5 MW facility began commercial operations in 2007 and 2008 for the first and second phases, respectively (NextEra Energy, nd b).

- In July of 2008, NRG Bluewater Wind signed a power purchase agreement (PPA) with Delmarva Power of Delaware to provide stable priced electricity for 25 years. Bluewater Wind plans to build an offshore wind project with nameplate capacity of 450 MW. The wind park will be 13 miles offshore and will provide enough electricity to power 100,000 Delaware households. Bluewater Wind expects the entire process to take two years from planning to completion. The project was commissioned by the Delaware General Assembly in response to volatile energy prices in a deregulated market, and the state's Renewable Portfolio Standard (RES) (NRG Bluewater Wind, 2010).

- NREL and the University of Delaware partnered to develop a test site for commercial wind turbines off the coast of Delaware. Through work with federal and state agencies over the next five years, the partnership aims to identify and meet any criteria necessary to develop offshore test sites. NREL and UD will design test procedures specifically focused on the effects of the area's harsh offshore environment. They hope to create methods for predicting offshore wind energy costs in the U.S., as well as provide valuable training resources for future wind energy professionals (NREL, 2010).

### *A.1.4 Hybrid Renewable Projects*

- Florida Power and Light began construction on a hybrid solar project combining a 75 MW concentrating solar plant with a 3.8 GW natural gas plant in late 2008 (FPL, 2010c; Mouawad, 2010). The project will be the largest solar thermal plant outside of California. Completion is expected in late 2010 (FPL, 2010c).

## A.2 Existing and Upcoming Renewable Energy Programs in the South

### *A.2.1 Biomass Energy Programs*

- Virginia Biomass Energy Grant Program awarded $10 million of ARRA funding towards 15 biomass and waste-to-energy projects in January 2010. These projects will use energy crops, biomass fuels, and waste materials from logging, manufacturing, and other activities to generate energy (VDMME, 2010).

- Oklahoma State University/Noble Foundation was awarded $4,492,141 to establish pilot plants demonstrating decentralized bioenergy production systems in Stillwater, Oklahoma (Oklahoma Higher Ed, 2009).

### *A.2.2 Geothermal Heat Pump Programs*

- Oklahoma Municipal Power Authority was awarded three million dollars of stimulus funding for audits, installations of ground source heat pumps, and education provision (NASEO, 2010).

- Red River Technology Center was granted $303,160 for the installation of a geothermal HVAC system for a new health building in Duncan, Oklahoma (NASEO, 2010).

### *A.2.3 Hydropower Programs*

- The Alabama Power Company was granted up to $6 million for a project in Mitchell, Alabama, to upgrade three hydroelectric plants on the Coosa River to high-efficiency stainless steel turbines and runners. Due to these improvements, generation is estimated to increase by 7.3% or over 36,000 MWh annually (EERE, 2009).

- Alcoa, Inc. in Robbinsville, North Carolina, was granted up to $13 million to upgrade to high-efficiency stainless steel turbines, generators, and transformers at their Tapoco Cheoah plant. Generating capacity will increase by 22 MW while annual generation will increase by 23% or about 95,000 MWh (EERE, 2009).

- North Little Rock Electric Department in Arkansas was granted up to $450,000 to install a device removing intake obstructions at its 39 MW hydroelectric facility on the Arkansas River. With the upgrade, the facility will operate near peak efficiency while also reducing dredging costs (EERE, 2009).

### *A.2.4 Solar Energy Programs*

- Georgia Renewable Energy Grant Program awarded BFI Waste Systems of North America, LLC, $2 million dollars to construct a one megawatt solar power system at the Hickory Ridge Landfill (NASEO, 2010).

- Electric Cities of Georgia received $460,933 to install solar photovoltaics and solar thermal water heating systems at municipal facilities throughout Georgia and a 4 kW wind energy system in Calhoun, Georgia (NASEO, 2010).

- Hannah Solar, LLC was awarded $250,000 for renewable installations at Clark’s Grove Earthcraft community in Covington, Georgia. Installations of 59 kW of solar power, a 1.2 kW wind turbine, and a solar thermal collector for domestic hot water will occur (NASEO, 2010).

- Lanier Technical College received $503,000 to install solar photovoltaic systems and solar hot water systems at four Lanier Technical College campuses (NASEO, 2010).

- Radiance Energies received $786,067 for solar photovoltaic installations for seven nonprofits within Georgia (NASEO, 2010).

- Tennessee will establish a Volunteer State Solar Initiative program with up to $62.5 million dollars of funding to focus on solar energy education, job creation, energy production, and technology commercialization (NASEO, 2010; Bredesen Proposes, 2009).

- Ninety public schools in Florida have been selected to participate in the SunSmart Schools E-Shelter (Emergency Shelter) Program. The program has $10 million of funding. All participating schools will receive a 10 kW solar electric system with backup, installation, and necessary resources. The system will reduce purchased electricity during normal operations and provide emergency power during outages (Florida Solar, 2010).

- Maryland will nearly triple solar energy production through Project Sunburst, an $8 million dollar program funded by stimulus money (Maryland Energy, 2010a, 2010b). The project will add generation capacity of up to 10 MW upon completion by funding solar installations on government buildings (Maryland Energy, 2010b).

- The Tennessee Solar Institute at the University of Tennessee and ORNL will create a “Solar Opportunity Fund” to underwrite a series of new innovation and installation grants.Approximately $23.5 million in grants will be distributed to help strengthen operations at solar-industry firms or to help install commercial solar photovoltaic systems (NASEO, 2010).

- Mid-sized Solar Grant Program in Maryland, a two year program supported by ARRA funds, was launched to incentivize commercial mid-sized solar energy systems. Up to $1.45 million dollars will be provided for the program (Maryland Energy, 2009).

- Florida’s Solar Energy Rebate Program was granted $14.4 million dollars. The program provides a variety of rebates on photovoltaic systems and solar water heaters in the commercial and residential sector (NASEO, 2010).

- The Solar Energy (Water Heating) Loan in Florida, which provides low interest loans to Florida residents for solar water heater installations, was granted $10 million of ARRA funds (NASEO, 2010).

- The University of Oklahoma Board of Regents was granted $15,715 to install up to eight solar charging stations for electric vehicles on the Norman campus (Oklahoma Higher Ed, 2009; NASEO, 2010).

### *A.2.5 Wind Power Programs*

- The Department of Energy awarded PPG Industries, Inc, in Shelby, North Carolina, $741,754 of funding to support wind blade manufacturing research innovation (U.S. DOE, 2009).

- The Department of Energy also awarded several Southern entities for wind energy transmission, planning, and analysis research (US DOE, 2009).
    - The Electric Power Research Institute in Knoxville, Tennessee, received $399,135 to research “Integrating Midwest Wind Energy into Southeast Electricity Markets.”
    - EnerNex Corporation, also in Knoxville, Tennessee, received $749,868 of funding to research “Documentation, User Support, and Verification of Wind Turbine and Plant Models.”
    - Tennessee Technological University in Cookeville, Tennessee, received $265,677 of funding to research “Multi-Level Energy Storage and Controls for Large-Scale Wind Energy Integration.”
    - University of Texas at Austin received $510,688 to research “Techno-Economic Modeling of the Integration of 20% Wind and Large-scale energy storage in ERCOT by 2030.” This funding was not supplied by ARRA funding, but through DOE’s Office of Electricity Delivery and Reliability’s annually appropriated funds.

- Oklahoma Development of Career and Technology Education was awarded $158,684 to begin the Oklahoma Wind Energy Training Initiative (OWETI) in Stillwater, Oklahoma.OWETI will develop comprehensive wind turbine maintenance technician curricula, certification process and continuing education resources for secondary and postsecondary education institutions (NASEO, 2010).

### *A.2.6 Multiple Renewable Energy Programs*

- Texas Distributed Renewable Energy Technology Program supplies $52 million of competitive grants to governmental entities such as state and local government, educational facilities, public hospitals, and utilities for renewable energy installations. The funding is from federal stimulus money. Included are biomass, geothermal, solar, hydroelectric, and wind energy (SECO, nd). The first round of projects, 32 solar power developments, was approved in March 2010 (Comptroller Awards First Round, 2010).

- Texas Energy Sector Training Center Grants awarded $6 million of ARRA funding for energy efficiency and renewable energy training. Of that amount, $2.74 million was allocated for training service people in the wind, solar, and bioenergy industries (SECO, 2010).

- Arkansas’ Renewable Technology Rebate Fund uses an ARRA allocation of $1.78 million dollars to provide rebates for residential photovoltaic systems, solar water heaters, and wind turbines (Arkansas Energy Office, 2010).

- High Plains Technology Center was awarded $1.2 million to develop and implement an integrated renewable energy system training program in Oklahoma (NASEO, 2010).

- Tulsa Industrial Authority was awarded $*2,580,000* for the demonstration of energy efficient LED lighting, geothermal, and solar energy alternatives in Oklahoma. Over $3.5 million dollars of matching funds were obtained (NASEO, 2010).

- Louisiana received $9,893,772 of funding for the Renewable Energy Development program that encourages applications of under-used commercially available renewable energy sources (NASEO, 2010).

- Mississippi received $5,600,000 for its Market Transformation – Renewable Energy Projects Program. The program provides incentives to deploy commercially available renewable energy technologies. Technologies considered include solar photovoltaics, solar thermal, and bioenergy systems (NASEO, 2010).

- Virginia's Local Government and School Facility Renewable Energy Utilization Program provides $5 million of ARRA funding to support solar energy and wind technology implementation in local governments, schools, and community colleges (VDMME, nd).

Several currently available funding programs throughout the South promote energy efficiency and renewable energy simultaneously. These programs, like the Florida Clean Energy Grant, are not listed above since the percentage of funding allocated towards renewable energy projects is not known. Still, these programs may provide significant funding towards renewable energy related projects.

### A.3 Renewable Capacity by State

The installed and planned capacity, as of December 2009, in the Southern states according to the American Council on Renewable Energy (ACORE) is listed in Table A.1. The total capacity within each state, which includes existing and currently being constructed projects, is also provided. This data is from *Renewable Energy in America*, an ACORE report (2010).

The ACORE data differs from those reported by the Energy Information Administration's 2008 summary renewable electric power industry statistics by state. The EIA data provides additional energy sources and different capacities for some states than ACORE (2010). This data is also provided in Table A.1 for comparison. The District of Columbia is not included in either the EIA or ACORE's listing of state renewable energy capacities and is excluded from Table A.1.

**Table A.1 Renewable Energy Capacity in the South**

| | | ACORE, 2010 | | | EIA, 2010 |
|---|---|---|---|---|---|
| State* | Technology | Installed Capacity as of 12/09 (MW) | Projects Under Construction (MW) | Total Capacity (MW) | Net Summer Capacity, 2008 |
| AL | Biomass | | | | 593 |

**Table A.1 Renewable Energy Capacity in the South**

| | | ACORE, 2010 | | | EIA, 2010 |
|---|---|---|---|---|---|
| State* | Technology | Installed Capacity as of | Projects Under Construction | Total Capacity | Net Summer Capacity, |
| | Hydro Conventional | | | | 3,272 |
| | Grid-Connected Solar | 0.2 | | 0.2 | |
| | TOTAL | 0.2 | | 0.2 | 3,865 |
| AR | Biomass | | 20 | 20 | 317 |
| | Hydro Conventional | | | | 1,321 |
| | MSW/Landfill Gas | | | | 5 |
| | Grid-Connected Solar | 0.2 | | 0.2 | |
| | Wind | 0.1 | | 0.1 | |
| | TOTAL | 0.3 | | 0.3 | 1,643 |
| DE | MSW/Landfill Gas | | | | 7 |
| | Grid-Connected Solar | 3.2 | | 3.2 | |
| | Wind | | 2 | 2 | |
| | TOTAL | 3.2 | 2 | 5.2 | 7 |
| FL | Biomass | 680.4 | 35 | 715.4 | 522 |
| | Hydro Conventional | | | | 55 |
| FL | MSW/Landfill Gas | | | | 470 |
| | Grid-Connected Solar | 38.9 | 119 | 157.9 | |
| | TOTAL | 719.3 | 154 | 873.3 | 1,047 |
| GA | Biomass | 16.7 | 45 | 61.7 | 591 |
| | Hydro Conventional | | | | 2,041 |
| | MSW/Landfill Gas | | | | 10 |
| | Grid-Connected Solar | 0.2 | | 0.2 | |
| | TOTAL | | | | |
| KY | Biomass | 8.8 | 3.2 | 12 | 47 |
| | Hydro Conventional | | | | 824 |
| | MSW/Landfill Gas | | | | 15 |
| | TOTAL | | | | 886 |
| LA | Biomass | | | | 394 |
| | Hydro Conventional | | | | 192 |
| | Grid-Connected Solar | 0.2 | | 0.2 | |
| | TOTAL | 0.2 | | 0.2 | 586 |
| MD | Biomass | 123 | 3 | 126 | 3 |

**Table A.1 Renewable Energy Capacity in the South**

| | | ACORE, 2010 | | | EIA, 2010 |
|---|---|---|---|---|---|
| State* | Technology | Installed Capacity as of | Projects Under Construction | Total Capacity | Net Summer Capacity, |
| | Hydro Conventional | | | | 590 |
| | MSW/Landfill Gas | | | | 132 |
| | Grid-Connected Solar | 6.1 | 1 | 7.1 | |
| | Wind | | 120 | 120 | |
| | TOTAL | 129.1 | 124 | 253.1 | 725 |
| MS | Grid-Connected Solar | 0.1 | | 0.1 | |
| | Biomass | 10 | | 10 | 229 |
| | TOTAL | 10.1 | 0 | 10.1 | 229 |
| NC | Biomass | 59.4 | | 59.4 | 318 |
| | Hydro Conventional | | | | 1,952 |
| | MSW/Landfill Gas | | | | 20 |
| | Grid-Connected Solar | 12.5 | 19.2 | 31.7 | 3 |
| | TOTAL | 71.9 | 19.2 | 91.1 | 2,294 |
| OK | Biomass | 16.8 | | 16.8 | 63 |
| | Hydro Conventional | | | | 851 |
| | MSW/Landfill Gas | | | | 16 |
| | Wind | 1,130 | 380.6 | 1,510.60 | 708 |
| | TOTAL | 1,146.8 | 380.6 | 1,527.4 | 1,637 |
| SC | Biomass | 35.4 | 2 | 37.4 | 220 |
| | Hydro Conventional | | | | 1,337 |
| | MSW/Landfill Gas | | | | 35 |
| | Solar | 0.1 | | 0.1 | |
| SC | TOTAL | 35.5 | 2 | 37.5 | 1,592 |
| TN | Biomass | | | | 167 |
| | Hydro Conventional | | | | 2,639 |
| | MSW/Landfill Gas | | | | 8 |
| | Solar | 0.9 | | 0.9 | |

| Table A.1 Renewable Energy Capacity in the South | | | | | |
|---|---|---|---|---|---|
| | | ACORE, 2010 | | | EIA, 2010 |
| State* | Technology | Installed Capacity as of | Projects Under Construction | Total Capacity | Net Summer Capacity, |
| | Wind | 29 | | 29 | 29 |
| | TOTAL | 29.9 | 0 | 29.9 | 2,842 |
| TX | Biomass | 81.7 | 160 | 241.7 | 209 |
| | Hydro Conventional | | | | 673 |
| | MSW/Landfill Gas | | | | 73 |
| | Grid-Connected Solar | 8.6 | 14 | 22.6 | |
| | Wind | 9,405 | 672 | 10,077 | 7,427 |
| | TOTAL | 9,495.3 | 846 | 10,341.3 | 8,380 |
| VA | Biomass | 190.7 | 23.9 | 214.6 | 422 |
| | Hydro Conventional | | | | 677 |
| | MSW/Landfill Gas | | | | 269 |
| | Grid-Connected Solar | 0.9 | | 0.9 | |
| | TOTAL | 191.6 | 23.9 | 215.5 | 1,368 |
| WV | Hydro Conventional | | | | 1,248 |
| | Wind | 330 | 101 | 431 | 392 |
| | TOTAL | 330 | 101 | 431 | 1,640 |

*The District of Columbia is not included.

Table A.2 displays the rank by Southern state for total biomass, solar, and wind capacity using the data from the ACORE report.

**Table A.2 State Ranking by Renewable Energy Type in the South, ACORE 2010**

BIOMASS

| State | Rank in the South | Capacity (MW) |
|---|---|---|
| Florida | 1 | 715.4 |
| Texas | 2 | 241.7 |
| Virginia | 3 | 214.6 |
| Maryland | 4 | 126 |
| Georgia | 5 | 61.7 |
| North Carolina | 6 | 59.4 |
| South Carolina | 7 | 37.4 |
| Arkansas | 8 | 20 |
| Oklahoma | 9 | 16.8 |
| Kentucky | 10 | 12 |
| Delaware | 11 | 11.4 |
| Mississippi | 12 | 10 |

SOLAR

| State | Rank in the South | Capacity (MW) |
|---|---|---|
| Florida | 1 | 157.9 |
| North Carolina | 2 | 31.7 |
| Texas | 3 | 22.6 |
| Maryland | 4 | 7.1 |
| Delaware | 5 | 3.2 |
| Tennessee | 6 | 0.9 |
| Alabama | 7 | 0.2 |
| Arkansas | 7 | 0.2 |
| Georgia | 7 | 0.2 |
| Louisiana | 7 | 0.2 |
| South Carolina | 8 | 0.1 |
| Mississippi | 8 | 0.1 |

WIND

| State | Rank in the South | Capacity (MW) |
|---|---|---|
| Texas | 1 | 10,077 |
| Oklahoma | 2 | 1,511 |
| West Virginia | 3 | 431 |
| Maryland | 4 | 120 |
| Tennessee | 5 | 29 |
| Delaware | 6 | 2 |
| Arkansas | 7 | 0 |

Table A.2 provides the ranking of the states by renewable energy type given the EIA data, which document the capacity and electricity generation from renewable sources for 2008.

| **Table A.2 State Ranking by Renewable Energy Type in the South as of 2008, EIA 2010** | | |
|---|---|---|
| BIOMASS | | |
| State | Rank in the South | Capacity (MW) |
| Alabama | 1 | 593 |
| Georgia | 2 | 591 |
| Florida | 3 | 522 |
| Virginia | 4 | 422 |
| Louisiana | 5 | 394 |
| North Carolina | 6 | 318 |
| Arkansas | 7 | 317 |
| Mississippi | 8 | 229 |
| South Carolina | 9 | 220 |
| Texas | 10 | 209 |
| Tennessee | 11 | 167 |
| Oklahoma | 12 | 63 |
| Kentucky | 13 | 47 |
| Maryland | 14 | 3 |
| HYDRO-CONVENTIONAL | | |
| State | Rank in the South | Capacity (MW) |
| Arkansas | 1 | 1,321 |
| Alabama | 2 | 3,272 |
| Tennessee | 3 | 2,639 |
| Georgia | 4 | 2,041 |
| North Carolina | 5 | 1,952 |
| South Carolina | 6 | 1,337 |
| West Virginia | 7 | 1,248 |
| Oklahoma | 8 | 851 |
| Kentucky | 9 | 824 |
| Virginia | 10 | 677 |
| Texas | 11 | 673 |
| Maryland | 12 | 590 |
| Louisiana | 13 | 192 |
| Florida | 14 | 55 |

**Table A.2 State Ranking by Renewable Energy Type in the South, EIA 2010**

| MSW/LANDFILL GAS | | |
|---|---|---|
| State | Rank in the South | Capacity (MW) |
| Florida | 1 | 470 |
| Virginia | 2 | 269 |
| Maryland | 3 | 132 |
| Texas | 4 | 73 |
| South Carolina | 5 | 35 |
| North Carolina | 6 | 20 |
| Oklahoma | 7 | 16 |
| Kentucky | 8 | 15 |
| Georgia | 9 | 10 |
| Tennessee | 10 | 8 |
| Delaware | 11 | 7 |
| Arkansas | 12 | 5 |
| SOLAR | | |
| State | Rank in the South | Capacity (MW) |
| North Carolina | 1 | 3 |
| WIND | | |
| State | Rank in the South | Capacity (MW) |
| Texas | 1 | 7,427 |
| Oklahoma | 2 | 708 |
| West Virginia | 3 | 392 |
| Tennessee | 4 | 29 |

## REFERENCES of APPENDIX A

American Council on Renewable Energy. (2010, August). *Renewable energy in America: Markets, economic development and policy in the 50 states*. Discussion Draft. Retrieved on September 23, 2010 from: http://www.acore.org/files/pdfs/Renewable_Energy_in_America_Aug2010.pdf.

Arkansas Energy Office. (2010). *State energy program*. Retrieved on August 2, 2010 from: http://arkansasenergy.org/energy-in-arkansas/energy-policy-and-legislation/recovery-2009/state-energy-program.aspx.

BP. (2010). *Alternative energy: Wind power projects and operations*. Retrieved on July 30, 2010, from: http://www.bp.com/sectiongenericarticle.do?categoryId=9025014&contentId=7046507.

*Bredesen proposes volunteer state solar initiative*. (2009, May 13). Retrieved from TN.gov website at: http://news.tennesseeanytime.org/node/1870.

Craver, Richard. (2009, August 18). *Solar farm under way: SunEdison begins work in Davidson*. Retrieved July 30, 2010 from: http://www2.journalnow.com/content/2009/aug/18/solar-farm-under-way/

Duke Energy. (nd). *Solar energy*. Retrieved on July 29, 2010 from: http://www.duke-energy.com/environment/solar.asp.

Duke Energy. (nd b). *Pumped-storage hydro*. Retrieved on August 3, 2010 from: http://www.duke-energy.com/power-plants/pumped-storage-hydro.asp.

Duke Energy. (nd c). *Conventional hydro.* Retrieved on August 3, 2010 from: http://www.duke-energy.com/power-plants/hydro.asp.

Duke Energy. (2010a, June 9). *Duke Energy commercial solar power project in Texas secures financing*. Retrieved on July 30, 2010 from: http://www.duke-energy.com/news/releases/2010060901.asp.

Duke Energy. (2010b, May 26). *Duke Energy commercial solar power project producing electricity in Shelby, N.C*. Retrieved on July 30, 2010 from: http://www.duke-energy.com/news/releases/2010052601.asp

Duke Energy. (2010c). *North Carolina solar distributed generation*. Retrieved on August 2, 2010 from: http://www.duke-energy.com/north-carolina/renewable-energy/nc-solar-distributed-generation-program.asp

Duke Energy. (2010d). *Power up with wind*. Retrieved on August 3, 2010 from: http://www.duke-energy.com/pdfs/Wind-Power-Projects-Fact-Sheet.pdf.

EERE. (2009, November 19). Hydropower Upgrades to Yield Added Generation. Retrieved from: http://www1.eere.energy.gov/windandhydro/news_detail.html?news_id=15606.

Florida Power and Light (FPL). (2010a). *DeSoto Next Generation Solar Energy Center*. Retrieved on July 29, 2010 from: http://www.fpl.com/environment/solar/desoto.shtml.

FPL. (2010b). *Space Coast Next Generation Solar Energy Center*. Retrieved on July 29, 2010 from: http://www.fpl.com/environment/solar/spacecoast.shtml.

FPL. (2010c). *Martin Next Generation Solar Energy Center*. Retrieved on July 27, 2010 from: http://www.fpl.com/environment/solar/martin.shtml.

Florida Solar Energy Center. (2010). *Emergency shelter schools selected for $10M solar energy program*. Retrieved from the Energy Chronicle website at: http://blog.floridaenergycenter.org/echronicle/2010/04/e-shelter-schools-selected/

Georgia Power. (2009). *Facts & figures*. Retrieved on August 3, 2010 from: http://www.georgiapower.com/about/facts.asp.

Maryland Energy Administration. (2010a, February 16). *Governor O'Malley touts new $8 million stimulus investment and legislation to create clean energy jobs in Maryland*. Retrieved on August 2, 2010 from: http://www.energy.state.md.us/news/press/index.asp.

Maryland Energy Administration. (2010b, April 22). *Governor O'Malley's Project Sunburst puts solar energy on 31 state buildings, nearly tripling solar energy produced in Maryland*. Retrieved from: http://energy.maryland.gov/documents/sunburstawards42010final.pdf.

Maryland Energy Administration. (2009, October 28). *Maryland launches grant program for mid-sized solar energy systems to help local businesses go green*. Retrieved from:http://energy.maryland.gov/documents/midsizedsolarPR102709.pdf.

Mouawad, Jad. (2010, Mach 4). *The newest hybrid model*. Retrieved on July 27, 2010 from the *New York Times* website at: http://www.nytimes.com/2010/03/05/business/05solar.html?ref=energy-environment.

NASEO. (2010). *State energy program* ARRA Update. Retrieved from: http://www.naseo.org/programs/sep/recovery/State_Energy_Program_ARRA_Update-2010-03.pdf.

National Renewable Energy Laboratory (NREL). (2010). *Press release NR-2510: NREL to partner with university of Delaware on offshore wind research*. Retrieved from: http://www.nrel.gov/news/press/2010/859.html.

NextEra Energy. (nd b). *Capricorn Ridge Wind Energy Center*. Retrieved on July 30, 2010 from: http://www.nexteraenergyresources.com/content/where/portfolio/pdf/capricornridge.pdf

NextEra Energy. (nd a). *Horse Hollow I, II & III Wind Energy Center*. Retrieved on July 30, 2010 from: http://www.nexteraenergyresources.com/content/where/portfolio/pdf/horsehollow.pdf.

NRG Bluewater Wind. (2010). *Delaware overview*. Retrieved from: http://www.bluewaterwind.com/de_overview.htm

Progress Energy. (2010). *Sunsense*. Retrieved on July 30, 2010 from: http://www.progress-energy.com/environment/ras/solar.asp

Oglethorpe Power. (2008). *Generating facilities*. Retrieved on August 2, 2010 from: http://www.opc.com/PoweringGeorgia/GeneratingFacilities/HydroelectricPlants/RockyMountainPumped-StorageHydroelectricPlant/index.htm.

Oklahoma Higher Ed. (2009, May). *Grant news*. Retrieved on August 2, 2010 from: http://archive.constantcontact.com/fs061/1101877269269/archive/1102576462326.html.

Renewable Energy World. (2009, October 2). *EC&R completes 780-MW Roscoe Wind Farm*. Retrieved on July 30, 2010 from: http://www.renewableenergyworld.com/rea/news/article/2009/10/ec-r-completes-780-mw-roscoe-wind-farm.

Renewable Energy World. (2010, March 15). *Southern Company & Ted Turner acquire First Solar project*. Retrieved on August 3, 2010 from: http://www.renewableenergyworld.com/rea/news/article/2010/03/southern-company-ted-turner-acquire-first-solar-project.

Southern Alliance for Clean Energy (SACE). (2009). *Yes we can: Southern solutions for a national renewable energy standard.* Retrieved from: http://www.cleanenergy.org/images/files/SERenewables022309rev.pdf.

Southern Company. (2010). *Plant Mitchell biomass conversion*. Retrieved on August 1, 2010 from: http://www.georgiapower.com/environment/plantmitchell.asp.

State Energy Conservation Office (SECO). (nd). *Distributed renewable energy technology program - $52 million*. Retrieved from: http://www.seco.cpa.state.tx.us/arra/sep/renewable/index.php.

State Energy Conservation Office (SECO). (2010). *Energy sector training center grants $6 million*. Retrieved on August 2, 2010 from: http://www.seco.cpa.state.tx.us/arra/sep/training/index.php#awarded

State Energy Data System (SEDS). (2010). Table S3. Energy consumption estimates by source, 2008 (continued). Retrieved on July 28, 2010 from: http://www.eia.doe.gov/emeu/states/hf.jsp?incfile=sep_sum/plain_html/sum_btu_totb.html.

Tennessee Valley Authority (TVA). (2010, February 17). *TVA contracts with Horizon for renewable wind power*. Retrieved on August 3, 2010 from: http://www.tva.gov/news/releases/janmar10/horizon_wind_power.html.

TVA. (nd). Dams and hydro at a glance.

Virginia Department of Mines Minerals and Energy (VDMME). (2010, January 14). *Biomass energy program*. Retrieved on: http://www.dmme.virginia.gov/DE/ARRA-Public/SEPBiomass.shtml.

Virginia Department of Mines Minerals and Energy (VDMME). (nd). *Local government and school facility renewable energy utilization program*. Retrieved on August 2, 2010 from: http://www.dmme.virginia.gov/DE/ARRA-Public/LocalGovSchoolRE.shtml.

U.S. Department of Energy. (2009, July 16). *DOE announces nearly $14 million to go to 28 new wind energy projects*. Retrieved from: http://www.energy.gov/news2009/7653.htm.

U.S. Energy Information Administration (EIA). (2010). *State Renewable Electricity Profiles*. Retrieved on September 24, 2010 from: http://www.eia.doe.gov/cneaf/solar.renewables/page/state_profiles/r_profiles_sum.html.

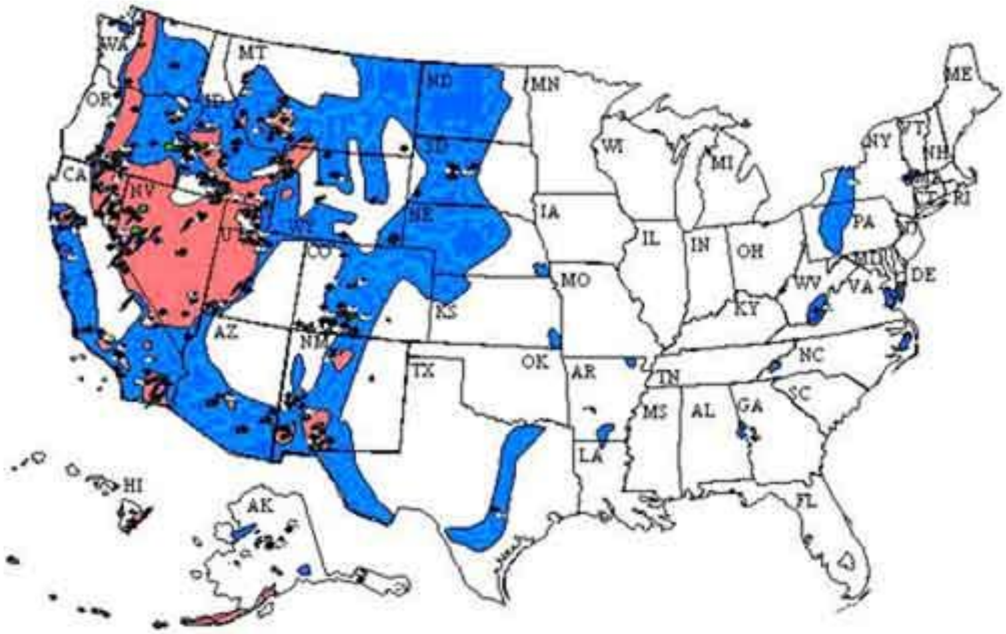
## B. EMERGING RENEWABLE ENERGY TECHNOLOGIES

### B.1 Geothermal Technologies

Geothermal energy taps into the heat beneath the earth’s surface. It is a clean, abundant source of renewable energy, and unlike other renewable energy sources such as wind and solar, geothermal energy is available 24 hours a day, seven days a week. Geothermal supplies a constant supply of electricity, while producing almost no greenhouse gases relative to other sources of energy. Geothermal energy can be used for electric power generation, heat pumps and direct utilization. In the United States, the current installed capacity for geothermal electric power generation is about 3,000 MW (3). Direct uses of geothermal energy include the heating of homes, offices, and greenhouses. The United States currently leads the rest of the world in terms of total installed geothermal capacity (3). It is estimated that 4% of Renewable-based energy consumption in the U.S. is geothermal.

Most of the available geothermal energy in the United States exists in the West where geology favors natural geothermal reservoirs being formed at shallower depths. Currently, almost 4,000 MW of new geothermal energy are under development in the U.S. The states under consideration or development are: Alaska, Arizona, California, Colorado, Florida, Hawaii, Idaho, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. In 2007, geothermal was the fourth largest source of renewable energy in the U.S. It is available mostly in the Western United States, with California having the largest installed capacity of any state.

The map below shows areas of geothermal resources in the United States. The white areas show low temperature areas good for geothermal heat pumps (geoexchange systems) that can work almost anywhere in the United States. The blue areas have hotter water for direct use projects, and the pink areas have the high temperatures required for most geothermal electrical power generation. Geothermal electrical power generation has traditionally been more restricted to the western states where high temperatures are closer to the surface of the Earth.



This Geothermal Energy Uses poster created by the Geothermal Education Office illustrates the typical uses of geothermal energy at various underground temperatures.

Despite current barriers to geothermal energy development and use, there is a great capacity for expansion. The U.S. Geological survey estimates that today's technologies could make use of approximately 40,000 MW of geothermal energy resources in the West (3). In the Eastern United States, geothermal resources are deeper in the earth's crust, and require greater drilling technologies than those located in the Western United States.

Capital Costs-- Costs can vary greatly depending on technology, depth of wells, and the hydrothermal resource (3). The capital cost ranges from $1,600 to $5, 000 per kilowatt of capacity. Although the cost per kilowatt of geothermal energy is comparable, and sometimes higher than conventional fossil fuel power plants, the actual cost of generating electricity is lowered because geothermal plants do not need to purchase fuel to generate electricity. The cost of geothermal energy is also expected to drop as technology develops.

High risk exploratory phase— drilling an exploratory well can cost $12 to $15 million, which can account for 36% of a geothermal plant's total capital cost (3). Improvements in drilling techniques could significantly reduce the costs of constructing a geothermal power plant.

Investment uncertainty—Uncertainties in government funding for geothermal projects create uncertainty for potential project developers.

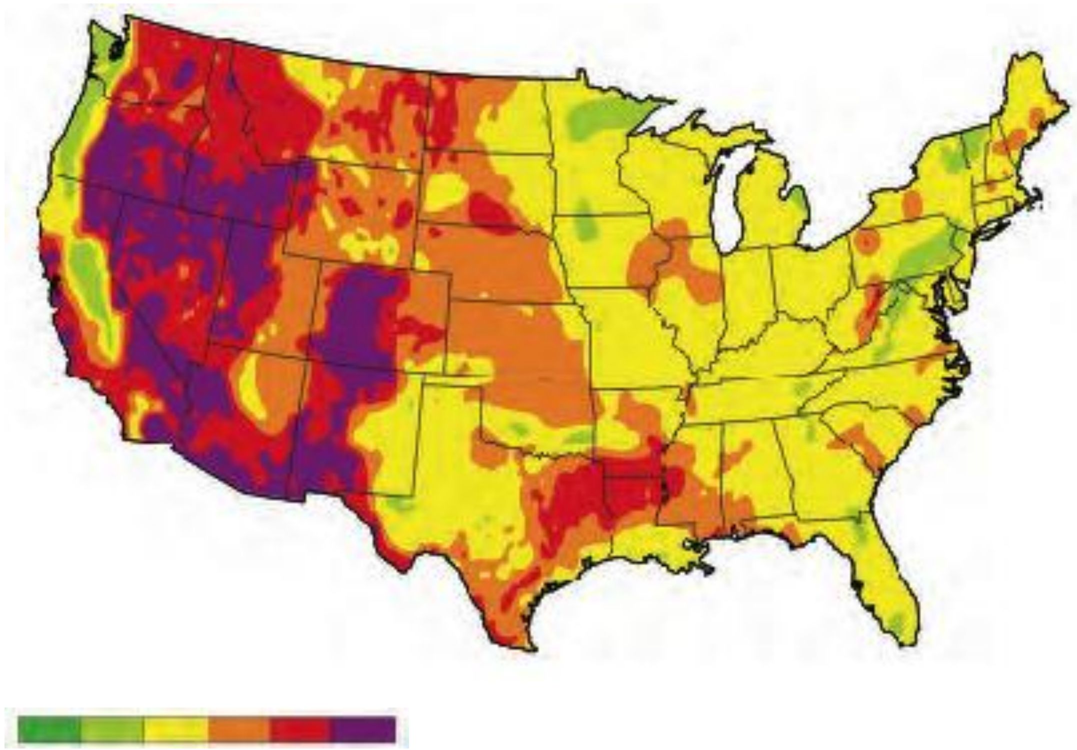
Geographic distribution and transmission—Promising geothermal resources are often great distances from regions of electricity consumption. The need to install transmission capacity can often drive away investments.

A geothermal research program, GeoPowering the West, is seeking to improve the ability to better predict where geothermal resources can be used for electricity generation, as well as direct use applications. Currently, they are researching ways to improve the durability, efficiency and environmental compatibility of geothermal electricity production (4).

Geothermal hydrocarbon co-production (GHCP) and geopressurized resources are two techniques that may have some promise both on and offshore of Texas and Louisiana. The DOE has funded three such projects, one in the South in Liberty County, Texas which is also funded by Universal Geopower. (ORNL citation).

One of the most promising large scale geothermal technologies, Enhanced Geothermal Systems (EGS) can increase the lifespan of existing geothermal resources and can also make use of previously inaccessible reservoirs for electricity production. ***The key to achieving EGS in the South would be accessing greater depths with higher temperatures. Currently drilling technology and costs are prohibitive but reaching 7 to 10 km depths would increase the geothermal potential significantly. Geologic surveys suggest that viable options exist for exploring geothermal resources located in dry oil fields in the Gulf Coast using EGS (4). DOE's GTP has funded multiple demonstration EGS projects.

The map below shows the resources available at a depth of 10 km (MIT study). Of course, this resource is more abundant in the Western United States, than in the Eastern United States.



50°C 100°C 150°C 200°C 250°C 300°C

The Appendix to Chapter 2 enables one to estimate the extended SE EGS resource in EJ ($10^{18}$ joules) at different drilling depths and extraction temperatures. Assuming a plant life of 30 years, temperature dependent thermal conversion efficiency, and an estimated extraction potential (taken as 10% for this analysis) one can estimate MW potential. The extraction potential is a very uncertain value estimated to range from 0.1% to 20%.

Geothermal energy depends on advanced hard-rock drilling technologies that employ the same techniques used when drilling for oil and gas. The Western and Southwestern United States is abundant with geologic reservoirs shallow enough to allow drilling access, while the Eastern and Southeastern United States lack the necessary heat at accessible depths. As drilling techniques and technology progress, geothermal energy in the East and Southeast will become more viable in the renewable energy sector.

1) Geothermal Energy Association http://www.geo-energy.org/currentUse.aspx
2) National Renewable Energy Laboratory http://www.nrel.gov/learning/re_geo_heat_pumps.html
3) Pew Center on Global Climate Change http://www.pewclimate.org/docUploads/Geothermal-Fact-Sheet.pdf
4) Eric Williams, Rich Lotstein, Christopher Galik, HallieKnuffmanhttp://nicholas.duke.edu/ccpp/convenientguide/cg_pdfs/ClimateBook.pdf
5) Office of Geothermal Technologies, Department of Energy http://www1.eere.energy.gov/geothermal/pdfs/directuse.pdf

6) John W. Lund, Tonya L. Boyd, Alex Sifford, R. Gordon Bloomquist. Geothermal Energy Utilization in the United States, 2000. http://geoheat.oit.edu/pdf/tp106.pdf

Here's some additional stuff:

The potential for major expansion of geothermal direct heating is seen to be small because of the limited number of suitable sites (WGA, 2006). Hydrothermal systems generate around 10 GW, and its potential for expansion is large. In the U.S., for instance, usage in 2006 was about 7.5 GW, while its economic potential is estimated to be greater than 66 GW by 2025 (Green and Nix, 2006). EGS represents an even larger resource base (WGA, 2006); however, EGS technology is not currently in large-scale operation because it is expensive and technically complicated. Research and demonstration projects are needed to reduce technical and financial risks of EGS (Tester et al., 2006).

### B.2 Next Generation Solar Technologies

Improvements in building integrated photovoltaic systems (BIPV) may allow greater electricity generation from buildings. Current research in the development of solar paints that can be brush painted has found power conversion efficiencies of 3.6% (Kim, Na, Kang, & Kim, 2010). Such paints may offer low cost electricity generation from a greater number of surfaces, such as dwelling walls. In combination with solar shingles, another BIPV technology, these may further support the development of solar dwellings. Solar shingles mask the PV surfaces with a traditional shingle appearance. These shingles have current efficiencies around 6% (Keoleian & Lewis, 2003).

Dye-sensitized solar cell (DSSC) is another class of low-cost solar cell. As one of the thin film technologies, DSSC is composed of a porous layer covered with a molecular dye that absorbs sunlight. DSSC is made of low-cost materials and requires simple manufacturing process. It will be significantly less expensive than most of other solar cell designs. The performance of DSSCis close to other thin film solar cells with the conversion rate of 8.2% in laboratory tests (Tian, et al, 2010).

Additions to or combinations of existing technologies may further increase the use of solar energy. Solar water heaters thermal performance may increase with the use of phase change materials (PCMs) as heat storage instead of water alone. These PCMs store five to fourteen times more heat than the same volume of mediums like water (Shukla, Buddhi, & Sawhney, 2009). The integration of solar water heaters with photovoltaic panels may further increase solar energy efficiencies. This integrated photovoltaic and thermal solar system has higher efficiencies than the solar water heater system or photovoltaic system alone due to the complementary effects of the two technologies (Huang, Lin, Hung, & Sun, 2001). When the temperature of photovoltaic panels increases, their power conversion efficiencies decrease. When these panels are combined with a solar water heating system, heat from the panels can be removed to improve efficiency while heating water.

### B.3 Hydrokinetics and Pumped Hydro Storage

*Hydrokinetics*show promise for expanding hydro resources, by harnessing the kinetic energy of moving body of water. For example, tidal energy can be collected from tidal streams, the underwater current flow in entrances to bays or other narrow passages, with turbines similar to those used for wind energy In addition, wave energy can be converted to electricity by moving river water through motors connected to generators. There are several installations in the world, including a commercial wave energy plant located in Portugal[36] and the grid-connected Roosevelt Island Tidal Energy project installed in New York City's East River (Verdant Power, nd).

*Pumped Hydro Storage*generates electricity by reversing the flow of water between two water sources, typically including an elevated reservoir or water tower. Such storage technologies can deliver more than 1 GW of capacity and can respond quickly with relatively low operating costs during periods of peak demand when purchasing power at spot market prices can be expensive. The Helms Pump Storage Facility near Fresno, California, for example, has three units totaling 1,200 MW of generation capacity. Worldwide more than 90 GW of pumped hydro storage facilities operated in 2007 (California Independent System Operator, 2008).

### B.4 Biogas for Electricity Generation

*Biomass Power Technologies* differ in their sources as well as their energy conversion processes. Sources tended to be divided into agricultural wastes, residues, and wood wastes; energy crops; and trash and garbage. Processes tend to be thermochemical (i.e., combustion, which burns biomass in some way to produce heat or steam to turn a turbine) or biological (i.e., digestion, which lets waste decompose to produce methane that is then captured and converted into energy). Direct-firing involves burning the biomass material to create steam and drive a turbine, while co-firing involves mixing biomass with coal in a coal-fired power plant; both of these technologies are already quite mature. Gasification and pyrolysis involve high temperatures in a low or no oxygen environment to produce a gas or liquid for use. Anaerobic digestion is generally used for production of methane in a controlled environment. The digestion process mimics the same ones that humans use to eat: waste is presorted to remove plastic, steel, and other nonbiodegradable substances before it is digested by bacteria that excrete both gases (methane) and solid waste.

### B.5 Hybrid Renewable Systems

Different renewable technologies can be integrated together (or with energy-efficiency and fossil or nuclear energy facilities) to create highly reliable hybrid systems. Most of the experience to date has been with renewable-renewable hybrids. For example, installing wind turbines at geothermal power plants creates effective base-load systems as wind data already exist at plant locations to site cooling towers, and plant designs allow for suitable spare land. These plants can rely on geothermal electricity to backup or offset unexpected shortfalls in wind (Harvey, 2008). Similarly, wind farms can be coupled with biomass plants to eliminate their intermittency using agricultural wastes and residues, methane from landfills, energy crops, and trash as sources of fuel (Denholm, 2006).

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[36] Wave Energy system described based on the operational specifications of the only commercial wave energy converters in the world, the Pelamis Converter, developed by Pelamis Wave Power Ltd. (formerly Ocean Power Delivery Ltd.)

A far more extensive hybrid system, called the "Combined Power Plant," exists in Germany. Operated by Schmack Biogas AG, SolarWorld AG, and Enercon, this system relies on an integrated network of wind, solar, biomass, and hydropower installations spread across Germany. Wind and solar units generate electricity when those resources are available; and a collection of biomass and biogas plants, and a pumped hydro facility make up the difference when they are not. The system can immediately adapt to a shortfall in any one resource by drawing on the others. As of early 2009, the 23.2 MW Combined Power Plant consisted of 11 wind turbines at three separate wind farms, four combined heat and power biogas units, 23 distributed solar systems, and a pumped hydro storage plant linked via central control (Figure 11.x). In 2008, the facility produced 41.1 GWh of electricity without a single interruption of supply.

A similar hybrid system exists in the Saxony-Anhalt district of Germany. There, six MW of wind are connected to an 80 MW pumped hydro facility used to back up wind output by pumping water up when the wind is available, and then using gravity to power two 40 MW turbines to balance the system when the wind is not. The wind-hydro system is in the process of being integrated with distributed solar power plants, six biogas systems, and a large five MW cogeneration unit fuelled by recycled vegetable oil. The resulting wind-hydro-solar-biogas-vegetable oil facility, integrated via a digital control station, is expected to provide about 500 million kWh of electricity (Federal Ministry of Economics and Technology, 2008).

In the U.S. at Oberlin College near Cleveland, Ohio, the Adam Joseph Lewis Center for Environmental Studies incorporates a 60 kW photovoltaic array with active and passive systems to heat, cool, and ventilate. The building uses renewable energy flows and advances in architectural design and energy efficiency to supply local electricity, minimize energy waste, produce food, and restore native vegetation (Orr, 2006).

These integrated and reliable renewable energy systems are not limited to Germany and the U.S. In Zambia, an interconnected solar-biomass-micro-hydro network will generate base-load electricity for a collection of local villages. The combined system will include one biomass power plant, one micro-hydroelectric station, and a collection of distributed solar panels with a combined output of 2.4 MW; and it is expected to begin operation in 2010 (UNIDO and Renewable Energy, 2009). In Cuba, a hybrid biomass gasification power plant, four distributed biogas plants, and one wind farm will have a rated capacity of 11 MW and will begin generating base-load electricity for the Isla de la Juventud in 2011 (Ibid). In the village of Xcalak, Mexico, 234 solar panels have been integrated with 36 batteries, six wind turbines, a 40-kW inverter to convert DC power to AC, and a sophisticated control system. The system has so far displaced the need to construct a $3.2 million transmission line extension, and in its first year of operation proved more reliable than the diesel generators that it replaced (although one is still installed as a backup) (US DOE/EERE, 2006).

The development of hybrid renewable electricity technologies has helped increase their potential for commercialization by lowering costs, increasing efficiencies, and improving performance. Such systems would appear to be well suited to the South, where the challenge of intermittent solar and wind resources can be managed by bundling diverse renewable, efficiency, and fossil resources. MORE HERE ABOUT SPECIFIC POSSIBILITIES—E.G., PUMPED STORAGE WITH WIND AND PV….

## C. WIND MODELING METHODOLOGY

This appendix describes the data and steps associated with updating SNUG-NEMS to represent the Expanded Wind Scenario described in Chapter 3. The data comes from National Renewable Energy Laboratory's Wind Powering America (2010).

NREL/AWS Truewind 80m data shows the windy area in three groups

- Windy land area >= 30% gross capacity factor
- Windy land area >= 35% gross capacity factor
- Windy land area >= 40% gross capacity factor

Note that the last two groups are a subset of the first.

However, NEMS categorizes the windy area into three classes using wind speed (Table C.3.1 ) instead of capacity factor. Experts at EIA and ORNL agree that if the windy area with capacity factor >=30% is divided into three groups,

- Windy land area with capacity factor between 30%-35%
- Windy land area with capacity factor between 35%-40%
- Windy land area with capacity factor greater than 40%,

Then the average capacity factor of each group is very close to the capacity factor assumed by NEMS for wind classes 4, 5, and 6, respectively, for the current year (2010).

Table C.1 Wind Speed and Wind Classes

| Wind Class | 4 | 5 | 6 |
|---|---|---|---|
| Wind Speed m/s (mph) | 6.0 (13.4) | 6.4 (14.3) | 7.0 (15.7) |

NREL's 80m wind area data reports the available windy area[37] in each of the three categories for 48 contiguous states. Our study comprises states within NERC regions ERCOT, FRCC, SERC, and SPP. For each of these NERC regions, and for each wind category, we aggregated the NREL available windy land area from states in that region. The new windy land area totals were used to update the SNUG-NEMS input file *wesarea.* We updated the windy land area for all NERC regions, not just the four that make up the South. This was done to ensure there was no false shifting of wind production from areas of lower wind resource availability to those of higher resource availability. The borders of 17[38] out of the 48 states span multiple NERC regions. Assumptions of proportioning states' windy area into different NERC regions are made based on the resource availability in each class of wind in each particular state. Table C.2 summarizes the proportion assumptions for the 17 states. A lower and upper bound is provided in cases where the proper proportioning wasn't obvious. These bounds were used to calculate

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[37] The available windy area excludes areas that are unlikely to be used for wind energy development, such as wilderness areas, parks, urban areas and water features.

[38] Arkansas, California, Florida, Iowa, Louisiana, Maryland, Michigan, Minnesota, Missouri, Montana, Nevada, New Mexico, Pennsylvania, South Dakota, Virginia, Wisconsin, Texas

the total area (in km$^2$) for each class in a region by averaging the summed upper and lower bound estimates for each state in the region.

| Table C.2 Windy Land Area Proportioning Assumptions | | | | | | | |
|---|---|---|---|---|---|---|---|
| State | Region | Class 4 | | Class 5 | | Class 6 | |
| | | Lower | Upper | Lower | Upper | Lower | Upper |
| Arkansas | SERC | 0% | 10% | 0% | 5% | 0% | 0% |
| | SPP | 90% | 100% | 95% | 100% | 100% | 100% |
| California | NWPP | 2% | 5% | 2% | 2% | 5% | 10% |
| | CNV | 95% | 98% | 98% | 98% | 90% | 95% |
| Iowa | MAIN | 95% | 99% | 85% | 95% | 2% | 4% |
| | MCAPP | 1% | 5% | 5% | 15% | 96% | 98% |
| Louisiana | SERC | 85% | 95% | 95% | 100% | 100% | 100% |
| | SPP | 5% | 15% | 0% | 5% | 0% | 0% |
| Maryland | ECARCA | 15% | 25% | 15% | 25% | 15% | 25% |
| | MAAC | 75% | 85% | 75% | 85% | 75% | 85% |
| Michigan | ECARCA | 99% | 100% | 99% | 100% | 100% | 100% |
| | MAIN | 0% | 1% | 0% | 1% | 0% | 0% |
| Minnesota | MAIN | 3% | 7% | 2% | 4% | 30% | 40% |
| | MCAPP | 93% | 97% | 96% | 98% | 60% | 70% |
| Missouri | MAIN | 50% | 67% | 50% | 60% | 0% | 5% |
| | SERC | 33% | 50% | 40% | 50% | 95% | 100% |
| Montana | MCAPP | 10% | 20% | 10% | 15% | 70% | 80% |
| | NWPP | 80% | 90% | 85% | 90% | 20% | 30% |
| Nevada | NWPP | 85% | 90% | 40% | 50% | 40% | 50% |
| | RA | 10% | 15% | 50% | 60% | 50% | 60% |
| New Mexico | SPP | 30% | 40% | 40% | 50% | 60% | 70% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | RA | 60% | 70% | 50% | 60% | 30% | 40% |
| Pennsylvania | ECARCA | 10% | 20% | 10% | 20% | 10% | 20% |
| | MAAC | 80% | 90% | 80% | 90% | 80% | 90% |
| South Dakota | MCAPP | 0% | 10% | 40% | 50% | 95% | 100% |
| | NWPP | 90% | 100% | 50% | 60% | 0% | 5% |
| Texas | ERCOT | 91% | 96% | 80% | 90% | 60% | 70% |
| | SERC | 0% | 1% | 0% | 0% | 0% | 0% |
| | SPP | 6% | 1% | 15% | 5% | 40% | 30% |
| | RA | 3% | 3% | 5% | 5% | 0% | 0% |
| Virginia | ECARCA | 30% | 40% | 30% | 40% | 30% | 40% |
| | SERC | 30% | 40% | 30% | 40% | 30% | 40% |
| Wisconsin | MAIN | 70% | 80% | 85% | 95% | 55% | 65% |
| | MCAPP | 20% | 30% | 5% | 15% | 35% | 45% |

## D. BIOPOWER MODELING METHODOLOGY

This appendix describes the data and steps associated with updating SNUG-NEMS to represent the Expanded Biopower Scenario described in Chapter 4. We characterize the biopower generation that would occur in our expanded renewable scenario as the result of: 1) increased R&D and demonstration on biopower technologies; 2) extended production tax credits; and 3) improved feedstock supply.

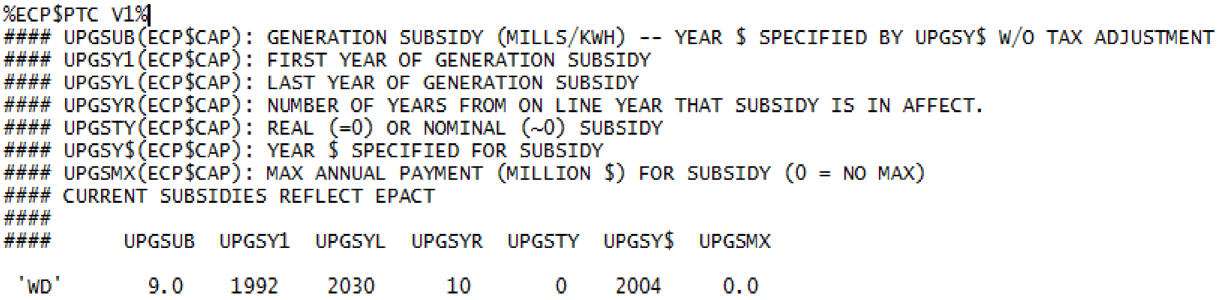
1) **Increased R&D and demonstration on biopower technologies**
   Among the three technological options such as cofiring, direct combustion, and BIGCC, we modeled the advanced heat rate for the BIGCC option. The heat rate of a BAU scenario of the SNUG-NEMS reference scenario is assumed to be 9,450 BTU/kWh in 2010, decrease by 1.76% annually, reach 7,765 BTU/kWh in 2021, and stay the same level until 2030. Instead of a constant heat rate from 2022 to 2030, SNUG-NEMS assumes that the heat rate would keep being improved beyond 2021 until 2030 with the same rate (1.76%) and finally reaches 6,620 Btu/kWh. Table D.1 shows the difference in the heat rate of BIGCC between the reference and the policy scenario.

**Table D.1 Biomass IGCC heat rate (BTU/kWh)**

| Year | Reference | Policy Case |
|---|---|---|
| 2010 | 9450 | 9450 |
| 2011 | 9298 | 9298 |
| 2012 | 9144 | 9144 |
| 2013 | 8991 | 8991 |
| 2014 | 8838 | 8838 |
| 2015 | 8685 | 8685 |
| 2016 | 8531 | 8531 |
| 2017 | 8378 | 8378 |
| 2018 | 8225 | 8225 |
| 2019 | 8072 | 8072 |
| 2020 | 7918 | 7918 |
| 2021 | 7765 | 7765 |
| 2022 | 7765 | 7628 |
| 2023 | 7765 | 7494 |
| 2024 | 7765 | 7362 |
| 2025 | 7765 | 7233 |
| 2026 | 7765 | 7105 |
| 2027 | 7765 | 6980 |
| 2028 | 7765 | 6857 |
| 2029 | 7765 | 6737 |
| 2030 | 7765 | 6618 |

**2) Expanded production tax credits (PTC)**

We model a scenario that the current PTC continues until 2030 and the rate stays at 0.9 cents per kWh. The ECPDAT.txt file contains inputs to modeling generation subsidies for renewable resources. PTC by renewable resource is defined with the rate in mills/kWh (UPGSUB), the first year of the generation subsidy (UPGSY1), the last year of the subsidy (UPGSYL), number of years from on line year that subsidy is in affect (UPGSYR), whether the subsidy is indicated in nominal dollars or in real dollars (UPGSTY), year $ specified for subsidy (UPGSY$), and the maximum annual payment for the subsidy (UPGSMX). Figure D.1 is a snapshot of the input file and shows how we coded the variables listed above.



```
%ECP$PTC V1%
#### UPGSUB(ECP$CAP): GENERATION SUBSIDY (MILLS/KWH) -- YEAR $ SPECIFIED BY UPGSY$ W/O TAX ADJUSTMENT
#### UPGSY1(ECP$CAP): FIRST YEAR OF GENERATION SUBSIDY
#### UPGSYL(ECP$CAP): LAST YEAR OF GENERATION SUBSIDY
#### UPGSYR(ECP$CAP): NUMBER OF YEARS FROM ON LINE YEAR THAT SUBSIDY IS IN AFFECT.
#### UPGSTY(ECP$CAP): REAL (=0) OR NOMINAL (~0) SUBSIDY
#### UPGSY$(ECP$CAP): YEAR $ SPECIFIED FOR SUBSIDY
#### UPGSMX(ECP$CAP): MAX ANNUAL PAYMENT (MILLION $) FOR SUBSIDY (0 = NO MAX)
#### CURRENT SUBSIDIES REFLECT EPACT
####
####      UPGSUB  UPGSY1  UPGSYL  UPGSYR  UPGSTY  UPGSY$  UPGSMX

 'WD'       9.0    1992    2030     10       0    2004     0.0
```

**Figure D.1 SNUG-NEMS input alterations for extended PTC**

**3) Improved feedstock supply**

This study modeled a sales tax exemption program involving all states in the South region and improved loading and transportation systems. This study assumed that these supportive environments could increase the biomass supply by 10%. Biomass supply curves illustrated in Section 4.4.2 in Chapter 4 were updated by shifting supply curves defined by resource, region, and year. Holding prices at the same levels as the reference case, only quantities were increased by 10%. Figure D.2 is an example of the update of the supply curve for urban wastes and mill residues in the SERC region in 2030.

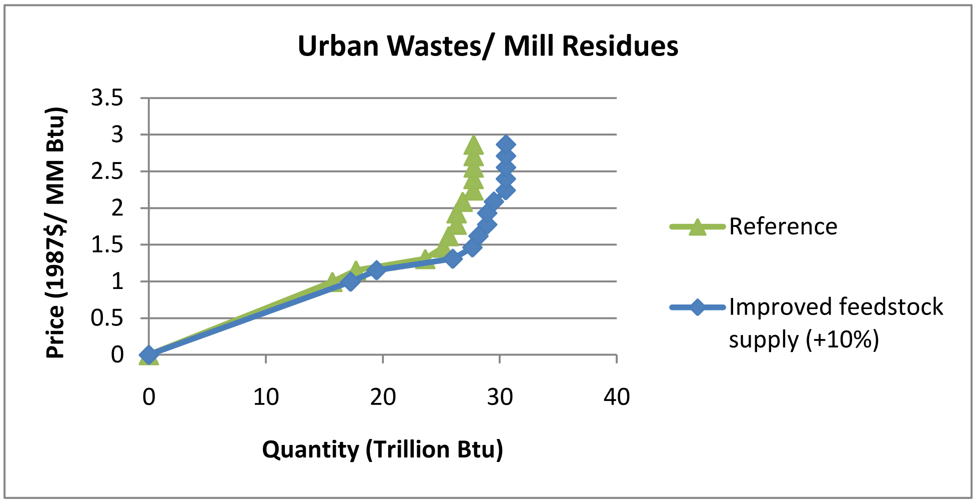
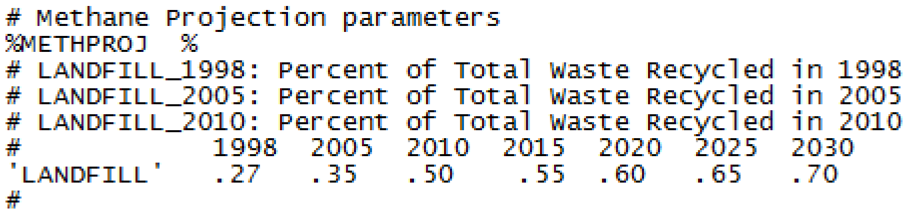


**Figure D.2 Update of supply curve for urban wastes and mill residues in 2030**

## E. MUNICIPAL SOLID WASTE (MSW) MODELING METHODOLOGY

Appendix E describes the data and steps associated with updating SNUG-NEMS to represent the Expanded MSW-Power Scenario described in Chapter 5. The reference scenario of SNUG-NEMS has an assumption consistent with EPA’s recycling goal of the MSW. The recycling rate of the MSW in the reference scenario is assumed to account for 35% of the total waste stream by 2005 and 50% by 2010, and stay the same until 2030.

This study characterizes a MSW-power program that would occur in our expanded renewable scenario. In order to model the scenario, we updated the methane projection parameters in the mswdat.txt input file. The program is assumed to raise the MSW recycling rate by 1% annually from 2011 until 2030.



```
# Methane Projection parameters
%METHPROJ  %
# LANDFILL_1998: Percent of Total Waste Recycled in 1998
# LANDFILL_2005: Percent of Total Waste Recycled in 2005
# LANDFILL_2010: Percent of Total Waste Recycled in 2010
#            1998  2005  2010  2015  2020  2025  2030
'LANDFILL'   .27   .35   .50    .55  .60   .65   .70
#
```

In addition, we raised the methane recovery factor (RECOVERY_FCTR) by 1% annually. Except for these two sets of parameters, all of the assumptions to modeling LFG-to-electricity remain the same as those to the AEO 2009.

Assumptions to the AEO 2009 – LFG to Electricity (EIA, 2010g):

- Unlike other renewable resources, the supply of methane from the municipal solid wastes of a region is highly correlated with macroeconomic indicators such as the Gross Regional Product (GRP) and population. SNUG-NEMS assumes that the GRP and the population of the south grow by 0.82% and 3% annually from 2010 to 2030.
- The waste stream is classified into three categories of readily, moderately, and slowly decomposable material.
- Emission parameters are the same as those used in estimating historical methane emissions in the EIA’s Emissions of Greenhouse Gases in the United States 2003.
- The ratio of “high”, low”, and “very low” methane production sites to total methane production is estimated based on date collected for 156 operating landfills contained in the Government Advisory Associates METH2000 database.
- Cost-of-electricity for each site is estimated by assuming each site to be a 100-acre by 50-foot deep landfill and by using methane emissions factors for “high”, “low”, “very low” methane emitting wastes.

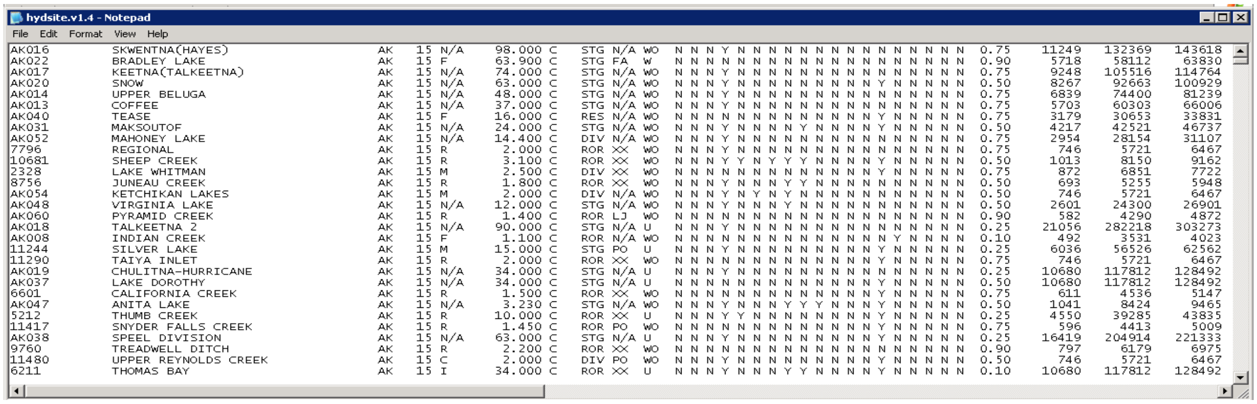
## F. HYDROPOWER MODELING MTHODOLOGY

NEMS models conventional hydroelectricity in its Electricity Market Module and Renewable Fuel Module. Hydroelectricity supply structure is built up by data from two input files, the ‘hydrosite.txt’ file which includes a list of all individual hydroelectric sites by state and NERC region, and the ‘whydo.txt’ file which describes hydropower supply curve.

The small and low power hydro potential in the expanded hydro scenario is modeled based on changes to the ‘hydrosite.txt’ input file. Capacities of feasible small and low power hydro projects by state and NERC region was manually added into the list of individual hydro sites, using the feasibility criteria developed by Hall, et al. (2006, pp. 14-16).

Characteristics of each hydroelectric site are described in the file as well, including the name and number of the project:

- location
- state
- NERC region
- site class code
- capacity
- unit type
- plant type
- project status
- dam status
- wild/scenic protection
- wild/scenic Tributary location
- environmental values
- federal land code
- project environmental suitability factor
- licensing cost
- construction cost
- overnight development cost
- 30 year mitigation costs: Archaeological and historical, Fish and wildlife, Scenic and recreation, Water quality monitoring, Fish passage, and total mitigation cost
- total development cost
- total unit development cost
- levelized cost
- capital cost
- fixed O&M cost
- variable O&M cost
- FERC annual charge
- monthly capacity factor
- annual average capacity factor



```
AK016   SKWENTNA(HAYES)          AK  15 N/A   98.000 C  STG N/A WO  N N N Y N N N N N N N N N N N N N N N  0.75  11249  132369  143618
AK022   BRADLEY LAKE             AK  15 F     63.900 C  STG FA  W   N N N N N N N N N N N N N N N N N N N  0.90   5718   58112   63830
AK017   KEETNA(TALKEETNA)        AK  15 N/A   74.000 C  STG N/A WO  N N N Y N N N N N N N N N N N N N N N  0.75   9248  105516  114764
AK020   SNOW                     AK  15 N/A   63.000 C  STG N/A WO  N N N Y N N N N N N N N N Y N N N N N  0.50   8267   92663  100929
AK014   UPPER BELUGA             AK  15 N/A   48.000 C  STG N/A WO  N N N Y N N N N N N N N N N N N N N N  0.75   6839   74400   81239
AK013   COFFEE                   AK  15 N/A   37.000 C  STG N/A WO  N N N Y N N N N N N N N N N N N N N N  0.75   5703   60303   66006
AK040   TEASE                    AK  15 F     16.000 C  RES N/A WO  N N N N N N N N N N N N N Y N N N N N  0.75   3179   30653   33831
AK031   MAKSOUTOF                AK  15 N/A   24.000 C  STG N/A WO  N N N Y N N N N Y N N N N Y N N N N N  0.50   4217   42521   46737
AK052   MAHONEY LAKE             AK  15 N/A   14.400 C  DIV N/A WO  N N N Y N N N N N N N N N N N N N N N  0.75   2954   28154   31107
7796    REGIONAL                 AK  15 R      2.000 C  ROR XX  WO  N N N Y N N N N N N N N N N N N N N N  0.75    746    5721    6467
10681   SHEEP CREEK              AK  15 R      3.100 C  ROR XX  WO  N N N Y Y N Y Y Y N N N N Y N N N N N  0.50   1013    8150    9162
2328    LAKE WHITMAN             AK  15 M      2.500 C  DIV XX  WO  N N N N N N N N N N N N N Y N N N N N  0.75    872    6851    7722
8756    JUNEAU CREEK             AK  15 R      1.800 C  ROR XX  WO  N N N Y N N N Y Y N N N N N N N N N N  0.50    693    5255    5948
AK054   KETCHIKAN LAKES          AK  15 M      2.000 C  DIV N/A WO  N N N Y N Y N Y N N N N N N N N N N N  0.50    746    5721    6467
AK048   VIRGINIA LAKE            AK  15 N/A   12.000 C  STG N/A WO  N N N Y N N N Y N N N N N N N N N N N  0.50   2601   24300   26901
AK060   PYRAMID CREEK            AK  15 R      1.400 C  ROR LJ  WO  N N N N N N N N N N N N N N N N N N N  0.90    582    4290    4872
AK018   TALKEETNA 2              AK  15 N/A   90.000 C  STG N/A U   N N N Y N N N N N N N N N N N N N N N  0.25  21056  282218  303273
AK008   INDIAN CREEK             AK  15 F      1.100 C  ROR N/A WO  N N N N N N N N N N N N N N Y N N N N  0.10    492    3531    4023
11244   SILVER LAKE              AK  15 M     15.000 C  STG PO  U   N N N Y N N N N N N N N N Y N N N N N  0.25   6036   56526   62562
11290   TAIYA INLET              AK  15 R      2.000 C  ROR XX  WO  N N N N N N N N N N N N N Y N N N N N  0.75    746    5721    6467
AK019   CHULITNA-HURRICANE       AK  15 N/A   34.000 C  STG N/A U   N N N Y N N N N N N N N N N N N N N N  0.25  10680  117812  128492
AK037   LAKE DOROTHY             AK  15 N/A   34.000 C  STG N/A U   N N N N N N N N N N N N N Y N N N N N  0.50  10680  117812  128492
6601    CALIFORNIA CREEK         AK  15 R      1.500 C  ROR XX  WO  N N N N N N N N N N N N N Y N N N N N  0.75    611    4536    5147
AK047   ANITA LAKE               AK  15 N/A    3.230 C  STG N/A WO  N N N Y N N N Y Y Y N N N Y N N N N N  0.50   1041    8424    9465
5212    THUMB CREEK              AK  15 R     10.000 C  ROR XX  U   N N N Y Y N N N N N N N N Y N N N N N  0.25   4550   39285   43835
11417   SNYDER FALLS CREEK       AK  15 R      1.450 C  ROR PO  WO  N N N N N N N N N N N N N Y N N N N N  0.75    596    4413    5009
AK038   SPEEL DIVISION           AK  15 N/A   63.000 C  STG N/A U   N N N Y N N N N N N N N N Y N N N N N  0.25  16419  204914  221333
9760    TREADWELL DITCH          AK  15 R      2.200 C  ROR XX  WO  N N N N N N N N N N N N N N N N N N N  0.90    797    6179    6975
11480   UPPER REYNOLDS CREEK     AK  15 C      2.000 C  DIV PO  WO  N N N Y N N N N N N N N N Y N N N N N  0.50    746    5721    6467
6211    THOMAS BAY               AK  15 I     34.000 C  ROR XX  U   N N N Y N N N Y Y N N N N Y N N N N N  0.10  10680  117812  128492
```

The figure above is the screen shot of the hydrosite.txt file with the variables listed above that were modified in the expanded hydropower scenario. For the capacity additions, wild/scenic protection and tributary location, environmental values and federal land code were set as ‘N’. Environmental values were set equal to 0.90. All the costs (except levelized cost) and capacity factors were set similar to the values of existing hydro sites. The construction cost, capital cost, operation and maintenance cost, licensing cost and other costs for the feasible projects were assigned based on the cost values of existing hydro sites with similar capacities. See the NEMS documentation of the Renewable Fuel Module (page 159-160) for more explanations of these factors listed above. The hydroelectricity supply curve structure described in the ‘whydro.txt’ remains unchanged.

# G. SOLAR MODELING METHODLOGY

## G.1 Photovoltaic Technology

### *G.1.1 Photovoltaic Installations*

**Table G.1 Solar PV Installation in the South***

| State | Installation # | Cumulative Installed Capacity (MW) |
|---|---|---|
| AL | 22 | 0.08 |
| AR | - | - |
| DC | - | - |
| DE | 1 | 0.002 |
| FL | 321 | 42.635 |
| GA | 6 | 0.031 |
| KY | 5 | 0.019 |
| LA | 69 | 0.35 |
| MD | 513 | 2.199 |
| MS | 8 | 0.028 |
| NC | 15 | 2.004 |
| OK | 3 | 0.005 |
| SC | 133 | 5.636 |
| TN | 93 | 0.833 |
| TX | 299 | 2.704 |
| VA | 20 | 0.086 |
| WV | 7 | 0.023 |
| Total | 1515 | 56.635 |
| CA | 54843 | 509.096 |
| U.S. total | 72865 | 825.416 |

*** Source: NREL, 2010c**

Solar PV overnight capital cost in NEMS is derived from the *Technical Assessment Guide 1993* (TGA) by the Electric Power Research Institute. The capital cost for solar thermal technology is derived from *Technology Characterization* draft 1997 by Sandia National Laboratory.

Roof area of a typical residential building is smaller than that of a typical commercial building. The installed PV systems on residential rooftops are smaller than commercial rooftops. In terms of system size, residential panels are smaller than commercial panels by 20 kW or more. NEMS assumes the average PV system size is 3-5 kW for residential rooftop installations and 25-30 kW for commercial buildings. The installed cost for PV systems in NEMS modeling of residential sector is much higher than reported costs from literature.  Installed system cost for commercial rooftops is close to the number reported by SEIA.

### *G.1.2 PV Cost Assumption Update*

PV electricity cost projected by ORNL will drop to 10 cents/kWh at 2020, allowing PV to reach grid parity at around 2020. First Solar claims its 12.6MW system in the Nevada desert has managed to achieve grid parity. The installed system cost is $0.075/kWh without any subsidies. First Solar's low cost may be due to the location and the technology used by the plant. BP announced its roadmap for photovoltaic reaching grid parity in five years by cutting the residential install PV cost by 65 percent by 2015.

The NEMS assumptions of PV capital cost (excluding inverter cost and O&M cost) in the residential and commercial sectors were updated to match the cost numbers from the SEIA report. In contrast to the linear cost decline modeled in NEMS, we assume the capital cost decreases rapidly before 2020 and PV power reaches grid parity at 2020. After 2020, the capital cost continues to decrease but at a slower rate.

**Table G.2 NEMS Assumptions on Capital Cost for PV systems ($2005/kW)**

| | 2011 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|
| NEMS 2009 Assumption - Residential PV | 8,236 | 7,310 | 6,154 | 4,997 | 3,840 |
| SNUG- NEMS Assumption - Residential PV | 6,386 | 5,059 | 3,400 | 3,189 | 2,977 |
| NEMS 2009 Assumption - Commercial PV | 5,931 | 5,356 | 4,637 | 3,919 | 3,200 |
| SNUG- NEMS Assumption - Commercial PV | 5,768 | 4,538 | 3,000 | 2,741 | 2,481 |

### *G.1.3 Expanded Solar PV Scenario – Commercial and Residential Projections*

**Table G.3 Commercial PV Installation Projections in the South**

| Values | West South Central | | | East South Central | | | South Atlantic | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2020 | 2030 | 2011 | 2020 | 2030 | 2011 | 2020 | 2030 |
| Cumulative Installation # | 546 | 2,570 | 36,500 | 253 | 923 | 8,000 | 1,620 | 4,950 | 35,800 |
| Average System Size (kW) | 352 | 505 | 541 | 352 | 378 | 407 | 352 | 527 | 501 |
| Annual Installed Capacity (MW) | 7.7 | 19.3 | 143 | 4.4 | 6.5 | 36.1 | 11.3 | 37.2 | 170 |
| Cumulative Capacity (MW) | 17.0 | 70.8 | 1,600 | 8.0 | 21.3 | 190 | 50.3 | 149 | 1,091 |
| Electricity Generation (TBtu) | 0.10 | 0.42 | 6.53 | 0.04 | 0.11 | 1.07 | 0.25 | 0.77 | 5.97 |
| Investment ($2005 million) | 40.9 | 58.1 | 354 | 23.2 | 19.4 | 89.7 | 60.3 | 112 | 421 |

**Table G.4 Residential PV Installation Projections in the South**

| | West South Central | | | East South Central | | | South Atlantic | | |
|---|---|---|---|---|---|---|---|---|---|
| **Values** | **2011** | **2020** | **2030** | **2011** | **2020** | **2030** | **2011** | **2020** | **2030** |
| Cumulative Installation 1000# | 88.3 | 719 | 1,460 | 2.7 | 205 | 580 | 96.1 | 1,080 | 2,510 |
| Percentage of Installations | 0.9% | 6.5% | 11.8% | 0.0% | 3.3% | 8.7% | 0.6% | 5.5% | 11.1% |
| Average Size (kW) | 3.5 | 9.0 | 8.2 | 3.5 | 9.6 | 9.1 | 3.5 | 9.9 | 9.9 |
| Annual Installed Capacity (MW) | 142 | 715 | 581 | 4.3 | 382 | 325 | 161 | 1,510 | 1,350 |
| Cumulative Capacity (MW) | 309 | 5,100 | 11,300 | 9 | 1,820 | 5,28 | 336 | 8,730 | 22,800 |
| Electricity Generation (TBtu) | 1.77 | 30.1 | 68.3 | 0.05 | 10.0 | 29.5 | 1.83 | 47.0 | 124 |
| Investment ($2005 million) | 906 | 2,430 | 1,730 | 28 | 1,300 | 966 | 1,030 | 5,130 | 4,010 |

### *G.1.4 Levelized Cost Calculation*

The levelized cost of electricity (LCOE) for PV is calculated based on a dynamic model with assumptions of efficiency improvements and cost reduction over time.

The rdgenout.txt and kdgenout.txt files are the output files that provide information about additional installed capacity, total electricity generation and investment for distributed generation in the demand-side. The electricity generation that is used to compute the levelized cost of electricity (LCOE) for PV is the increased generation of the Expanded Solar PV scenario relative to the reference scenario. For distributed generation, the avoided electricity related loss (majorly energy loss during transmission) is also taken as part of the benefit. We assume a continuous linearly declining electricity generation in the time span of 2030 to 2050, because the equipment vantage can continue generating power before full retirement. All the costs and benefits are discounted at the rate of 0.07.

For utility-scale PV, there is no avoided electricity related loss. The generation data was taken from Graphic 2000. Same assumption was made about the generation after 2030 and the discount rate.

## G.2 Solar Water Heating Potential

### *G.2.1 SNUG-NEMS Modeling*

The rtekty input file was altered to model expanded solar water heating in the residential sector. Only one type of solar water heater was listed in NEMS. An ITC subsidy of 30% is in the baseline of NEMS until 2016. From 2017 onwards, SNUG-NEMS implements a continued 30% subsidy until 2030.

A 30% subsidy was provided for solar water heaters was applied to both retail and capital cost in the input file. The change to both retail and capital cost was required to reflect the 30% subsidy. Table G.6 shows the original and altered capital costs for the expanded solar water heating scenario modeling in the residential sector.

**Table G.5 Original and New Costs for Solar Water Heater Modeling**

| Years | NEMS Capital Cost | EF-NEMS Capital Cost |
|---|---|---|
| 2006-2016 | $3,500* | $3,500 |
| 2017-2019 | $4,500 | $3,150 |
| 2020-2029 | $4,000 | $2,800 |
| 2030 | $3,500 | $2,450 |

*Once the 30% subsidy is removed, the original capital cost of the solar water heater is $5,000.

### *G.2.2 SNUG-NEMS Code Changes*

Since NEMS reports only national energy consumption for the water heating end-use, the source code was altered to report census division data. A new text file was generated where the forecasted energy consumption for water heating in the residential sector was outputted by fuel type and census division. This was done by altering the resd.f source code file. See Figure G.1 for the code alterations.

```
!Nparihar: Log water heating consumption in the log file
!Nparihar: Change begin
    IF ((CURIYR.EQ.LASTYR) .AND. (FCRL.EQ.1)) then
      IF(resd_dbg_init.EQ.0) then
        write(*,*) 'Opening resd_south.txt file'
        open(unit=32,file='resd_south.txt',FORM='FORMATTED')
        resd_dbg_init=1
      END IF
      DO 16118 Y=RECSYEAR-BASEYR+1,IJUMPYR
        write(*,*) 'Opening resd_south.txt file'
        WRITE (32,'(3X, A20)') '================'
        WRITE (32,'(3X, I10)') Y+1989
        WRITE (32,'(3X, A20)') '================'
        DO 16117 D=1,MNUMCR-2
          IF (D .LT. 5 .OR. D .GT. 7) GOTO 16117 !Skip non-southern
          DO F = 1, 5
          write(*,*) LABELFUELS(F),' = ', H2OCON(Y,F,D)
            WRITE (32,'(7X,A10,1X,F20.10)') LABELFUELS(F), &
                             H2OCON(Y,F,D)
          END DO ! F
16117   CONTINUE ! D
16118 CONTINUE  ! Y
    END IF
 !Nparihar: Change end

      END SUBROUTINE RSDSM
!*******************************************************************
!     NEW HOME HEATING SYSTEM REPORT
!*******************************************************************
      SUBROUTINE NHTSHR
      IMPLICIT NONE
      COMMON/TESTHT/HTYSSHR(RECSYEAR:ENDYR,15,MNUMBLDG,MNUMCR)
      INTEGER Y, D, B, E, E2, EU, RECCL, EQC, NUMEQC
      REAL*4  NWEQHTSH(RECSYEAR:ENDYR,11),HTYSSHR &
             ,HEATCAL(RECSYEAR:ENDYR,11),TOTALSUM(RECSYEAR:ENDYR)
      CHARACTER*40 FN
!*******************************************************************
!     PRINT SUPLEMENTAL REPORT
!*******************************************************************
```

**Figure G.1 SNUG-NEMS Code Alterations for Census Division Water Heating Results**

### *G.2.3 Levelized Cost Calculations*

The water heating savings are calculated from the data supplied by the resd_south.txt file created by the source code changes. These energy savings are assumed to last after the end of the subsidy in 2030. This is due to an assumed life of twenty years for the equipment. A linear degradation of energy savings from 2030 until 2050 is assumed.

Public costs include both the cost of the tax credits and the administration costs, which are assumed to be $0.13/MBtu total energy savings. Private costs are the amount residential consumers pay for solar water heating systems outside of the tax credit. Operation and maintenance costs are assumed to be $50 per solar water heater. This is a conservative estimate since NREL estimates operation and maintenance costs of $25 to $30 per unit (1996). The total energy savings includes private, public, and operation and maintenance costs.

Levelized cost calculations are calculated differently for the solar water heating section when compared to the other expanded renewable scenarios, which focused on utility-side renewables. This is because solar water heater technology only helps realizes energy savings and does not generate electricity.

Instead, levelized cost calculations were performed in Excel. The total cost associated with the scenario was proportioned into costs that could be attributed to electricity savings and those that could be attributed to natural gas savings. These proportions were calculated by finding the percentage of electricity or natural gas savings of the total energy savings from the scenario in each year. The net present value of all costs was divided by the cumulative energy savings until 2050 for total energy, electricity, and natural gas.  A discount rate of 7 percent was assumed for net present calculations.

# H. HEAT PUMPS

## H.1 Heat Pumps in the Residential Sector

### *H.1.1 SNUG-NEMS Modeling*

The rtekty input file was altered to model expanded heat pump water heating in the residential sector. The heat pump water heaters are not listed as such in NEMS; however, their performance resembles the most efficiency two types of electric water heaters included in the model (ELEC_WH4 and ELEC_WH5). These two water heaters were confirmed to be heat pump water heaters by comparing the efficiencies and costs in the input file with the heat pump water heater technology description in an EIA technology forecast (Navigant Consulting, 2007).

The original capital cost for the two water heaters and their efficiencies are listed in Table G.1.

**Table H.1 Original Rtekty Input File**

| Equipment Name | Efficiency | Duration | Original Capital Cost ($) | Original Retail Cost ($) |
|---|---|---|---|---|
| ELEC_WH4 | 2.3 | 2010 | 980 | 840 |
| | | 2011-2019 | 1,400 | 1,200 |
| | | 2020-2030 | 1,200 | 1,000 |
| ELEC_WH5 | 2.4 | 2010 | 1,190 | 1,050 |
| | | 2011-2030 | 1,700 | 1,500 |

A 30% subsidy was provided for heat pump water heaters was applied to both retail and capital cost in the input file. The change to both retail and capital cost was required to reflect the 30% subsidy.

The original prices for ELEC_WH4, as seen in Table G.1, decreased over time in a step-wise fashion. The costs were altered to decrease in a linear fashion to better reflect real life price decreases. The capital cost in 2010 and 2030 were consistent with the original document. All costs in between linearly decreased from the previous year. Table G.2 displays the altered input capital costs in SNUG-NEMS.

**Table H.2 Revised Rtekty Input File**

| Equipment Name | Efficiency | Duration | Revised Capital Cost ($) | Revised Retail Cost ($) |
|---|---|---|---|---|
| ELEC_WH4 | 2.3 | 2010 | 980 | 840 |
| | | 2011 | 973 | 833 |
| | | 2012 | 966 | 826 |
| | | 2013 | 959 | 819 |
| | | 2014 | 952 | 812 |
| | | 2015 | 945 | 805 |
| | | 2016 | 938 | 798 |
| | | 2017 | 931 | 791 |
| | | 2018 | 924 | 784 |
| | | 2019 | 917 | 777 |
| | | 2020 | 910 | 770 |
| | | 2021 | 903 | 763 |
| | | 2022 | 896 | 756 |
| | | 2023 | 889 | 749 |
| | | 2024 | 882 | 742 |
| | | 2025 | 875 | 735 |
| | | 2026 | 868 | 728 |
| | | 2027 | 861 | 721 |
| | | 2028 | 854 | 714 |
| | | 2029 | 847 | 707 |
| | | 2030 | 840 | 700 |
| ELEC_WH5 | 2.4 | 2010-2030 | 1,190 | 1,050 |

### *H.1.2 SNUG-NEMS Code Changes*

Since NEMS reports only national energy consumption for the water heating end-use, the source code was altered to report census division data. A new text file was generated where the forecasted energy consumption for water heating in the residential sector was outputted by fuel type and census division. This was done by altering the resd.f source code file. See Figure H.1 for the code alterations.

```
!Nparihar: Log water heating consumption in the log file
!Nparihar: Change begin
    IF ((CURIYR.EQ.LASTYR) .AND. (FCRL.EQ.1)) then
      IF(resd_dbg_init.EQ.0) then
        write(*,*) 'Opening resd_south.txt file'
        open(unit=32,file='resd_south.txt',FORM='FORMATTED')
        resd_dbg_init=1
      END IF
      DO 16118 Y=RECSYEAR-BASEYR+1,IJUMPYR
        write(*,*) 'Opening resd_south.txt file'
        WRITE (32,'(3X, A20)') '================'
        WRITE (32,'(3X, I10)') Y+1989
        WRITE (32,'(3X, A20)') '================'
        DO 16117 D=1,MNUMCR-2
          IF (D .LT. 5 .OR. D .GT. 7) GOTO 16117 !Skip non-southern
          DO F = 1, 5
          write(*,*) LABELFUELS(F),' = ', H2OCON(Y,F,D)
            WRITE (32,'(7X,A10,1X,F20.10)') LABELFUELS(F), &
                         H2OCON(Y,F,D)
          END DO ! F
16117   CONTINUE ! D
16118 CONTINUE  ! Y
    END IF
 !Nparihar: Change end

      END SUBROUTINE RSDSM
!*******************************************************************
!     NEW HOME HEATING SYSTEM REPORT
!*******************************************************************
      SUBROUTINE NHTSHR
      IMPLICIT NONE
      COMMON/TESTHT/HTYSSHR(RECSYEAR:ENDYR,15,MNUMBLDG,MNUMCR)
      INTEGER Y, D, B, E, E2, EU, RECCL, EQC, NUMEQC
      REAL*4  NWEQHTSH(RECSYEAR:ENDYR,11),HTYSSHR &
              ,HEATCAL(RECSYEAR:ENDYR,11),TOTALSUM(RECSYEAR:ENDYR)
      CHARACTER*40 FN
!*******************************************************************
!     PRINT SUPLEMENTAL REPORT
!*******************************************************************
```

**Figure H.1 SNUG-NEMS Code Alterations for Census Division Water Heating Results**

## H.2 Economic and Levelized Cost Calculations

The water heating savings were calculated from the data supplied by the resd_south.txt file created by the source code changes. These energy savings were assumed to last after the end of the subsidy in 2030. This is due to an assumed life of twenty years for the equipment. A linear degradation of energy savings from 2030 until 2050 is assumed for all cases except one.

In the case of natural gas savings in residential heat pump water heaters, an increase in natural gas consumption is projected from 2025-2030. Base on the previous trends, it does not appear that this increase in natural gas consumption will continue for another 20 years. Because of this, the linear degradation in 2031 occurs by assuming a starting point of 0.0236 TBtu. This value is from 2024, the last year of projected energy savings before the period of increased natural gas consumption from 2025-2030. Figure H.2 shows the projected natural gas savings from 2010-2050 for the expanded residential heat pump water heating scenario. Negative savings can be interpreted as an increase in natural gas consumption in the expanded heat pump water heating scenario over the baseline consumption.

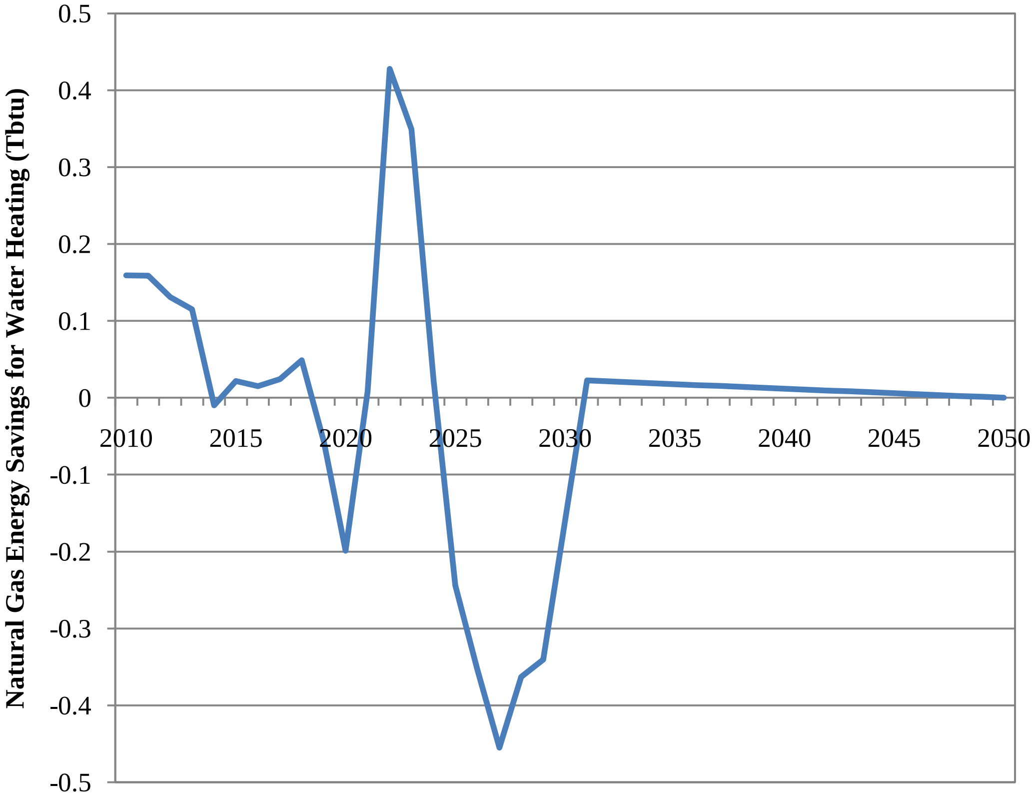


**Figure H.2 Natural Gas Savings for Expanded Heat Pump Water Heating Scenario**

The discount rate assumed for the economic calculations was 7%. Levelized cost calculations were calculated for the heat pump water heating section instead of using the levelized cost calculator employed by other expanded renewable scenarios, which focused on utility-side renewables. Since the heat pump water heater technology does not generate electricity and only helps realize energy savings, the levelized cost calculator could not be applied.

Levelized cost calculations were performed in Excel. The total cost associated with the scenario was proportioned into costs that could be attributed to electricity savings and those that could be attributed to natural gas savings. These proportions were calculated by finding the percentage of electricity or natural gas savings of the total energy savings from the scenario in each year. The net present value of all costs was divided by the cumulative energy savings until 2050 for total energy, electricity, and natural gas.