SOUTH CAROLINA RESOURCE STUDY

PREPARED FOR

South Carolina Energy Advisory Council

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BLSS	Black Liquor Soap Skimmings
CAFO	Concentrated Animal Feeding Operation
CH_4	Methane
CHP	Combined Heat And-Power
CO	Carbon Monoxide
CSP	Concentrated Solar Power
CTO	Crude Tall Oil
d.b.h.	Diameter at Breast Height
DHEC	Department of Health and Environmental Control
DNI	Direct Normal Insolation
DOE	Department of Energy
EIA	Energy Information Administration
ERG	Eastern Research Group, Inc.
FAA	Federal Aviation Administration
FIA	Forest Inventory and Analysis
FOG	Fats, Oils, and Greases
FS	Forest Service
FSC	Forest Stewardship Council
GHI	Global Horizontal Insolation
GIS	Geographic Information System
GSHP	Ground Source Heat Pumps
HIR	High Intensity Residential
HSMM	Hayes Seay Mattern & Mattern, Inc.
HTF	Heat Transfer Fluid
IC	Internal Combustion
IHRED	INL Hydropower Resource Economics Database
INL	Idaho National Laboratory
K	Potassium
kWh	Kilowatt-Hour
km^2	Square Kilometer
LFG	Landfill Gas
LIR	Low Intensity Residential
LMOP	Landfill Methane Outreach Program
m	Meters
m/s	Meters per Second

MBtu	Million British Thermal Units
Mgd	Million Gallons of Water per Day
MOA	Military Operation Areas
MW	Megawatts
MWac	Megawatt Alternating Current
MWh	Megawatt-Hour
Na	Sodium
NASS	National Agricultural Statistical Service
Nm	Nautical Mile
NO_x	Nitrogen Oxide
NPHR	Net Plant Heat Rate
NREL	National Renewable Energy Laboratory
NSA	National Security Areas
ORRAD	Offshore Renewables Resource Assessment and Development
PM	Particulate Matter
PMSS	Project Management Support Services Ltd
PV	Photovoltaics
SCDHEC	South Carolina Department of Health and Environmental Control
SCEAC	South Carolina Energy Advisory Council
SCEO	South Carolina Energy Office
scf	Standard Cubic Feet
SCFC	South Carolina Forestry Commission
SFI	Sustainable Forestry Initiative
SHW	Solar Hot Water
SRECs	Solar Renewable Energy Credits
SWH	Solar Water Heating
TAM	Typical Animal Mass
TPO	Timber Product Output
TS	Total Solids
USDA	US Department of Agriculture
USGS	United States Geological Survey
UWW	Urban Waste Wood
VS	Volatile Solids
VSR	Volatile Solids Reduction
WWTF	Wastewater Treatment Facility

1.0 Executive Summary

The South Carolina Energy Advisory Council (SCEAC) engaged Black & Veatch to update the 2007 GDS Associates/La Capra Renewable Resource study commissioned by Central Electric Power Cooperative (2007 Study). The main objectives of this update are to expand the resource list to include additional resources, such as organic human waste, spent pulping liquors, and waste oil, beyond those in the 2007 Study and to incorporate more current research and analysis for each resource, when available. As part of the expanded list of resources, the SCEAC also requested a review of costs for combined heat-and-power (CHP), solar thermal, and geothermal (for heating/cooling) technologies.

The assessment focuses on developing an inventory of the technical and constrained potential of resources available in South Carolina for use in electricity production only.[1] In addition to literature reviews of existing studies and employing Geographic Information System (GIS) analysis techniques, Black & Veatch also interviewed a number of industry experts and stakeholders to verify the feasibility assessment.

RESOURCES
• Onshore Wind
• Offshore Wind
• Solar Photovoltaic
• Conventional and Small Hydroelectric
• Landfill Gas
• Biomass: - Pre-Commercial Thinning and Southern Scrub Oak - Wood Waste (forest residue, commercial thinning, urban wood waste, and mill residue) - Agricultural Resources (agricultural residues, poultry litter, switchgrass) - Organic Human Waste (fats, oils, and greases [FOG], wastewater treatment facilities) - Organic Animal Waste (manure and swine waste) - Spent Pulping Liquors
• Waste Oil (focus on petroleum-based used oils)

[1] While the inventory focuses on resources for electricity production, some of the resources presented, such as biomass, biogas, and solar, can also provide thermal energy and be a substitute in some fossil-fueled thermal applications.

For this study, the technical potential represents the total potential given certain limitations associated with the quality and availability of the resources themselves or location of the resources. The constrained potential identifies additional development constraints for the realistic deployment of each resource in the near-term (10 to 15 years) using today's technologies and infrastructure. The specific constraints applied for each resource are detailed in their respective sections. The constrained potential, however, does not consider the following:

- the relative cost of generating electricity from each type of resource, including the cost of any associated transmission system upgrades that may be needed;
- the economics compared to conventional generation options or utility avoided cost;
- the social and economic development benefits of the resource; or
- the potential barriers associated with permitting and siting of specific projects.

The potential may be considerably lower if cost or permitting constraints were applied to the estimate of constrained potential.

The technical and constrained resource development potential determined in this analysis are summarized in Table 1-1. The potential for each resource is presented in the form of energy content (MBtu per year) for fuel-based resources, annual generation potential (GWh per year), and capacity (MW). Depending on the resource, the capacity factor or annual generation from each megawatt of installed capacity will vary.[2] For example, the capacity factor for solar in the region is about 15 percent, relying on when the sun is shining, while a biomass plant can operate at 85 to 90 percent capacity factor, which is virtually around-the-clock.

The potential to develop wind resources onshore are quite limited in the near-term, due to the lack of good resources onshore. Offshore wind and solar photovoltaics (PV) show the greatest technical potential, because the resources are abundant in the state. However, challenges associated with integrating large amounts of these types of generation projects into the transmission system, without major upgrades, will tend to limit their near-term, constrained potential. Also, the relatively high capital costs to implement offshore wind and solar PV were not taken into account, but the costs could be a substantial barrier in the near term, though solar PV prices have dropped significantly in the past few years.

South Carolina has already developed much of its hydroelectric potential, so there are limited opportunities expected for additional large-scale hydroelectric generation. The hydroelectric opportunities would be for small scale hydro projects that would not require impoundments. While the technology for small hydro is quite mature and the sites are technically viable for project development, permitting and cost challenges may reduce the constrained potential considerably.

[2] Capacity factor is the ratio of the actual output of a power plant over a period of time and its output if it had operated at full capacity the entire time.

Similar to hydro, many of the best landfill sites in the state have already been developed. The remaining candidate landfill sites may be able to contribute about 12 to 17 MW. Most of these sites are being evaluated for either power or thermal applications.

The next group of resources falls under the broad category of biomass. Woody biomass has the greatest potential among this group of biomass options, which is evidenced by approximately 220 MW of announced biomass fired power projects in the state. The supply is also readily accessible, though collection activities would need to be scaled-up and sustainability issues addressed. Furthermore, combustion of biomass must cope with some of the same emissions issues and regulations as large industrial solid-fueled boilers.

Agricultural biomass includes both agricultural residues and energy crops. Agricultural residues, such as corn stover and poultry litter, have some potential, though certain technical challenges in collecting and utilizing the fuel in conventional biomass generation (direct-firing) need to be addressed. Energy crops, such as switchgrass and miscanthus grown on idle agricultural land, would need to establish large-scale cultivation of the crops in South Carolina, in addition to addressing the same technical challenges as agricultural residue. For instance, to achieve the constrained potential of 23 to 56 MW of capacity using energy crops, about 23,000 acres of land would need to be cultivated.

Anaerobic digestion of organic wastes (derived from humans and animals) could provide some energy, but these projects would be relatively small in scale and would need to be located onsite or near where the waste is generated.

Pulping liquor is an intermediary product of the pulp and paper mills, but it is also integral to both the chemical and energy processes of a mill and cannot be separated from these processes. Therefore, there is no incremental resource potential that can be derived from black liquor.

Waste oil is defined as used oil refined from crude oil or made from synthetic materials. Some of the recovered waste oil is already being combusted for electricity generation in utility boilers in the state, while the remaining recovered waste oil is likely combusted for industrial thermal applications or refined into other products. Since these alternatives to electricity generation tend to be more efficient processes, it is expected that there would not be additional waste oil available for electricity production, unless the recovery rate can be increased beyond current levels.

Overall, while the total technical potential of the resources appear to be quite high due to the abundance of offshore wind and solar resources, the constrained potential for South Carolina is about 5,100 to 6,100 MW, producing 19,300 to 20,600 GWh of electricity per year. Among the biggest contributors of this total are offshore wind and solar PV. However, as discussed previously, these resources still face a number of technical and cost challenges that will need to be resolved to achieve the potential stated. Another large resource category for electricity production is woody biomass, which is a more viable, near-term option for the state.

The costs for the additional technologies that SCEAC requested are provided in Section 9.0 of this report.

Table 1-1 Renewable Energy Potential in South Carolina

RESOURCE	TECHNICAL POTENTIAL			CONSTRAINED POTENTIAL		
	ENERGY (MBTU/YR)	GENERATION (GWH/YR)	CAPACITY (MW)[e]	ENERGY (MBTU/YR)	GENERATION (GWH/YR)	CAPACITY (MW) [e]
Wind						
Onshore	N/A	440-2,920[a]	185-1,215	N/A	440[a]	185
Offshore	N/A	280,000[b]	70,000	N/A	13,000[b]	3,300
Solar Photovoltaic	N/A	67,000[c]	51,000	N/A	1,120-2,230[c]	850-1,700
Hydroelectric[d]	N/A	5,500	(630 MWa) 1,260-1,575	N/A	1,400	(164 MWa) 328-410
Landfill Gas Projects	958,200-1,384,000	90.4-130.6	12.1-17.5	958,200-1,384,000	90.4-130.6	12.1-17.5
Biomass						
Woody Biomass	96,700,000	7,150	960	31,920,000	2,360	317
Agricultural Residues	37,230,000	2,770	370	6,450,000	470	63
Energy Crops	22,750,000-56,870,000	1,690-4,210	227-565	2,310,000-5,700,000	170-420	23-56
Anaerobic Digestion of Organic Waste	3,412,000	350	46	2,090,000	210	28
Pulping Liquors	0	0	0	0	0	0
Waste Oil	1,974,000	254	38	0	0	0

[a]Onshore wind net generation includes 15 percent system losses.
[b]Offshore wind net generation includes 20 percent system losses.
[c]Solar PV generation estimate is based on 15 percent annual capacity factor.
[d]To convert the annual mean MW (MWa) of the hydroelectric potential to hydroelectric capacity potential, a range of capacity factors (40 to 50 percent) is assumed.
[e]All generation capacity is measured in alternating current (AC).

2.0 Introduction

The South Carolina Energy Advisory Council (SCEAC) engaged Black & Veatch to update the 2007 GDS Associates/La Capra Renewable Resource study commissioned by Central Electric Power Cooperative. The main objectives of this update are to expand the resource list to include additional resources beyond renewable energy and to incorporate more current research and analysis for each resource, when available. As part of the expanded list of resources, the SCEAC also requested a review of costs for CHP, solar thermal, and geothermal (for heating/cooling) technologies.

The resources included in this study are as follows:

RESOURCES
• Onshore Wind
• Offshore Wind
• Solar Photovoltaic
• Conventional and Small Hydroelectric
• Landfill Gas
• Biomass: - Pre-Commercial Thinning and Southern Scrub Oak - Wood Waste (forest residue, commercial thinning, urban wood waste, and mill residue) - Agricultural Resources (agricultural residues, poultry litter, switchgrass) - Organic Human Waste (FOG, wastewater treatment facilities) - Organic Animal Waste (manure and swine waste) - Spent Pulping Liquors
• Waste Oil (focus on petroleum-based used oils)

The assessment focuses on developing an inventory of the technical and constrained potential of resources available in South Carolina for use in electricity production applications only.[3] In addition to literature reviews of existing studies and employing GIS analysis techniques, Black & Veatch also interviewed a number of industry experts and stakeholders to verify the feasibility assessment.

[3] While the inventory focuses on resources for electricity production, some of the resources presented, such as biomass, biogas, and solar, can also provide thermal energy and be a substitute in some fossil-fueled thermal applications.

For this study, the technical potential represents the total potential given certain limitations associated with the quality and availability of the resources themselves or the location of the resources. The constrained potential identifies additional development constraints for the realistic deployment of each resource in the near-term (10 to 15 years) using today's technologies and infrastructure. The specific constraints applied for each resource are detailed in their respective sections. The constrained potential, however, does not consider the following:

- the relative cost of generating electricity from each type of resource, including the cost of any associated transmission system upgrades that may be needed;
- the economics compared to conventional generation options or utility avoided cost;
- the social and economic development benefits of the resource; or
- the potential barriers associated with permitting and siting of specific projects.

The potential may be considerably lower if cost or permitting constraints were applied to the estimate of constrained potential.

For the inventory, there were two metrics used to quantify resource potential-electric generation (GWh per year) and capacity (MW). For biomass and biogas resources, the inherent thermal energy content (million British thermal units [MBtu] per year) of the resources was identified first. For these options, a power conversion factor (or efficiency conversion factor) was then applied to the energy content of the biomass and biogas fuels to determine the electric energy potential measured in megawatt-hours (MWh). The electric energy potential was also converted to generation capacity measured in megawatts (MW) using typical capacity factors associated with each resource type. For wind, solar, and hydroelectric, these resources are expressed in electric energy and capacity potential only.

2.1 CURRENT RENEWABLE ENERGY GENERATION

Current renewable energy generation in South Carolina is primarily from hydroelectric, biomass, and landfill gas projects. There is one small utility-owned wind project and numerous solar PV and solar water heating projects in operation. However, the combined capacity of these wind and solar projects is estimated at less than 1 MW. There are a number of announced projects, most of which are biomass, wind, and solar. The current generation capacity of renewable projects in South Carolina is listed in Table 2-1. Planned renewable energy projects (i.e., those projects that have been announced but are not yet operational) are provided in Appendix A, Table A-1.

Table 2-1 Existing Renewable Energy Projects in South Carolina

	NUMBER OF PROJECTS	GENERATING CAPACITY
Wind Projects[a]		
Skystream (Onshore)	1	0.0024 MW
Solar Projects[b]		
Solar Photovoltaic (PV)	408	0.87 MW
Solar Hot Water (SHW)	197	n/a
Biomass Projects[c][d]		
Wood fired (includes exported electricity and onsite consumption)	Multiple	510 MW
Landfill Gas Projects[e]		
Electricity	14	57MW
Direct Use	4	n/a
Hydro Projects		
Conventional	31	1,363 MW
Pumped Storage	3	2,188 MW
Waste Fuels		
Used Motor Oil	3	7.3 MW
Tire Derived Fuel	1	Unknown

[a]Source: Santee Cooper Green Power.

[b]Source: South Carolina Energy Office, "Solar Installations in South Carolina," http://www.energy.sc.gov/publications/SouthCarolinaSolarInstallations1117.pdf.

[c]Source: South Carolina Energy Office, "Renewable Energy Combustion Facilities in SC," http://www.energy.sc.gov/publications/Renewable Energy Combustion Facilities.xls.

[d]Source: Lockwood-Post Online Directory of Pulp & Paper Mills, last modified March 2011.

[e]Source: US EPA Landfill Methane Outreach Program (LMOP) and Santee Cooper.

Hydroelectric energy is currently the largest renewable resource in South Carolina by both capacity and generation. According to the US Energy Information Administration (EIA), the total generating capacity of conventional hydroelectric facilities in South Carolina is more than 1,300 MW.[4] In addition to conventional hydroelectric facilities, there are a number of pumped storage sites.[5]

There are a number of facilities that fire biomass fuels for CHP applications or direct heating applications. The existing facilities in South Carolina that fire biomass fuels are listed in Table A-7 within Appendix A. The most significant of these facilities are pulp and paper mills, which cogenerate power and steam from the firing of woody biomass residues and pulping liquors. The six existing pulp and paper mills in South Carolina have a total power generation capacity of 508 MW,[6] although unspecified quantities of process heat are also produced for use in onsite paper production processes at these facilities. One of the pulp and paper mills in South Carolina, Domtar Marlboro Paper Mill in Bennettsville, has entered into a 15 year power purchase agreement with Santee Cooper for a portion of the electricity generated onsite.[7] In addition to the cogeneration installations at pulp and paper mills, there are at least 20 other industrial facilities, including paper mills, sawmills, and other facilities, that fire woody biomass residues for process heat for onsite consumption.

South Carolina has developed landfill gas (LFG) projects at the majority of the viable landfills in the state. The total LFG electric generation capacity is about 57 MW.[8] One LFG project under development is expected to add another 1.6 MW of capacity.

There is little experience with wind projects in South Carolina due to the lack of strong onshore wind resources. There is one utility-owned wind turbine installation in the state, a 2.4 kW demonstration scale project located in North Myrtle Beach that is expected to generate up to 500 kWh (kilowatt-hour) of electricity per month. Santee Cooper installed and connected this wind turbine to the grid in November 2010.[9]

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[4] "Renewable Energy Consumption and Electricity Preliminary Statistics 2010," US Energy Information Administration, published June 2011, http://www.eia.gov/renewable/annual/preliminary/pdf/preliminary.pdf.

[5] Pumped storage is where water is pumped to a holding area during times of off-peak electricity demand for generation of power during periods of higher demand.

[6] Lockwood-Post Online Directory of Pulp & Paper Mills, last modified March 2011.

[7] Domtar Corporation press release, January 20, 2011, http://www.domtar.com/en/investors/pressreleases/index.asp?location=SecondaryNav.

[8] U.S. EPA Landfill Methane Outreach Program (LMOP), http://www.epa.gov/lmop/.

[9] Santee Cooper Green Power, https://www.santeecooper.com/portal/page/portal/santeecooper/environment/renewables/green_power_generation/wind_power.

To date, the solar installations (including both solar PV and solar water heating) in South Carolina have been on the residential and small commercial scale. As shown in Table 2-1, although there are over 600 solar PV and hot water projects, the total capacity of these installations is less than 1 MW. There is a 2.6 MW rooftop solar PV project being planned which would almost triple the current installed capacity in the state (see Table A-1 for more details).

South Carolina offers multiple incentives to promote renewable energy development in the state, including corporate and personal tax credits for taxpayers who install landfill gas, biomass, CHP/cogeneration, anaerobic digestion, solar and small hydroelectric.[10]

2.2 REPORT ORGANIZATION

Following this Introduction, this report is organized into the following sections:

- Section 3.0 – Wind Resources
- Section 4.0 – Solar (Photovoltaic) Resources
- Section 5.0 – Hydroelectric Resources
- Section 6.0 – Landfill Gas Resources
- Section 7.0 – Biomass Resources
- Section 8.0 – Waste Oil Resources
- Section 9.0 – Capital Cost Estimates for Select Technologies

[10] For a more complete list of incentives and loan programs available in South Carolina for renewable energy projects, refer to: www.dsireusa.org.

3.0 Wind Resources

Wind as a renewable resource can generate electricity by mechanically turning a wind turbine. The size and hub height of the wind turbine along with the wind resource itself will play the most significant role in how much electricity can be produced. Characteristics such as wind speed, air density, elevation, terrain, weather, and surface roughness all influence the amount of output that can be derived from the wind resource. Thus, wind resource maps are developed for a certain hub height and often account for these characteristics.

In this section, Black & Veatch discusses the technical and constrained potential of onshore and offshore wind in South Carolina.

3.1 ONSHORE WIND

The development of large-scale, land-based wind power projects has become widespread through many regions in the US over the past 20 years. The technology to harness wind for power generation is mature, and turbines continue to increase incrementally in capacity as well as hub height. However, there is very little onshore wind activity in South Carolina due to the lack of good resources available in the state for development.

Black & Veatch is aware of only one existing utility-owned wind project in South Carolina. The Santee Cooper Skystream demonstration project is a 2.4 kW turbine located in North Myrtle Beach.

3.1.1 Assessment Methodology and Assumptions

In 2005, the South Carolina Energy Office, in partnership with Santee Cooper, produced a comprehensive set of wind maps across the state.[11] This study, conducted by AWS Truewind, used the MesoMap system in order to map annual mean wind speeds across South Carolina at heights of 30, 50, 70, and 100 meters (m) above ground, as well as annual wind power at 50 and 100 meters. More recently, in 2010, the National Renewable Energy Laboratory (NREL), in collaboration with AWS Truepower,[12] released a national dataset at a spatial resolution of 200 meters and hub heights of 80 meters and 100 meters for each state.[13] Using AWS Truepower's gross capacity factor data, NREL estimated the windy land area and wind energy potential for various capacity factor ranges for each state, including South Carolina.

Black & Veatch chose to use the updated 2010 data at 80 m and 100 m because they better reflect modern wind turbine installations. The annual average wind speeds at 80 m are shown in Figure 3-1. The highest wind speeds are located along the coast of South Carolina. The wind speeds decline dramatically in the interior and western part of the state.

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[11] "Wind Energy Resource Maps of South Carolina," South Carolina Energy Office, prepared by AWS Truewind, June 10, 2005.
[12] AWS Truewind changed its company name to AWS Truepower.
[13] Wind_Potential.xls , NREL, Prepared by NREL and AWS Truepower, February 4, 2010. (accessed July 5, 2011), http://www.windpoweringamerica.gov/docs/wind_potential.xls.

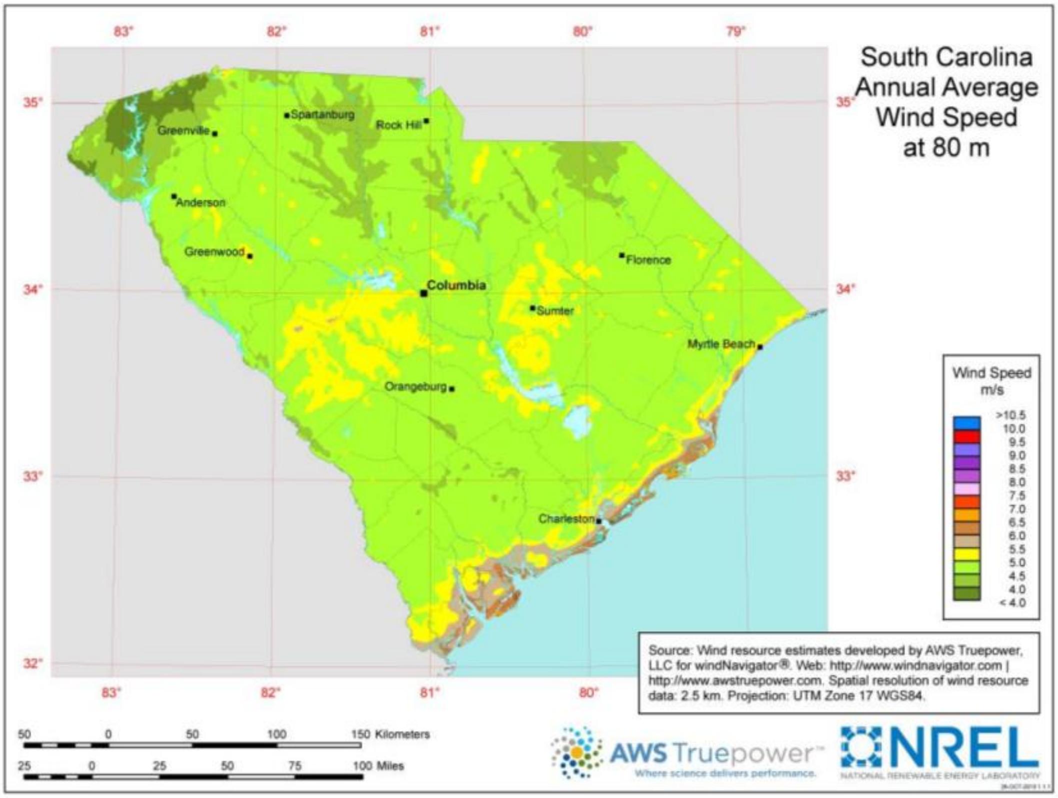

Figure 3-1 South Carolina Annual Average Wind Speed at 80 m

In defining the windy land areas that may be available for wind development, NREL applied exclusion criteria that included parks, wildlife refuges, and other protected areas, as well as airfields, urban areas, wetlands, and water. Below is a table of exclusion criteria used by NREL to define available windy land (numbered in the order they are applied):

Environmental Criteria

- 2) 100 percent exclusion of National Park Service and Fish and Wildlife Service managed lands.
- 3) 100 percent exclusion of federal lands designated as park, wilderness, wilderness study area, national monument, national battlefield, recreation area, national conservation area, wildlife refuge, wildlife area, and wild and scenic river or inventoried roadless area.
- 4) 100 percent exclusion of state and private lands equivalent to criteria 2 and 3, where GIS data is available.
- 7) 50 percent exclusion of remaining USDA Forest Service (FS) lands (including National Grasslands) except ridgecrests.
- 8) 50 percent exclusion of remaining Dept. of Defense lands except ridgecrests.
- 9) 50 percent exclusion of state forest land, where GIS data is available.

Land Use Criteria

- 5) 100 percent exclusion of airfields, urban, wetland and water areas.
- 10) 50 percent exclusion of non-ridgecrest forest

Other Criteria

- 1) Exclude areas of slope > 20 percent
- 6) 100 percent exclusion 3 km surrounding criteria 2-5 (except water)

NREL then applied a factor of 5 MW per square kilometer (km^2) to derive the total installed wind capacity and annual generation potential for the state. Since the annual generation (or gross capacity factor) of a site is highly dependent on the resource at the site, areas with higher wind speeds (or gross capacity factor) are more attractive to develop then areas with lower wind speeds. Additionally, the gross capacity factor used by NREL does not account for system losses onsite, which can reduce the capacity factor by 10 to 20 percent. Areas with gross capacity factors greater than 30 percent were included in the estimate of technical potential. Any wind resources with less than 30 percent gross capacity factor were considered not feasible for development in this assessment.

3.1.2 Technical Potential of Onshore Wind

Figure 3-2 shows NREL's estimate of the cumulative capacity potential in South Carolina that could be installed at 80 m and 100 m hub height above a given gross capacity factor. The cumulative capacity potential above 35 percent gross capacity factor is virtually zero, while the cumulative capacity factor potential above 25 percent gross capacity factor is greater than 2,000 MW at 80 m. As discussed in the previous section, any wind resources less than 30 percent gross capacity factor were considered not feasible for development.

Table 3-1 shows NREL's estimate of the cumulative installed capacity potential for wind resources better than or equal to 30 percent gross capacity factor. When measured at an 80 m hub height, the capacity potential in the state totaled 185 MW--a relatively low potential. At 100 m hub height, since wind speeds are usually greater at higher hub heights for the same location, the total capacity potential was estimated to be 1,215 MW.

Practically speaking, more modern onshore turbines are being installed at hub heights between 75 and 80 m. Larger turbines with taller hub heights of 100 m are also beginning to be installed in the United States but are located in more remote sites.

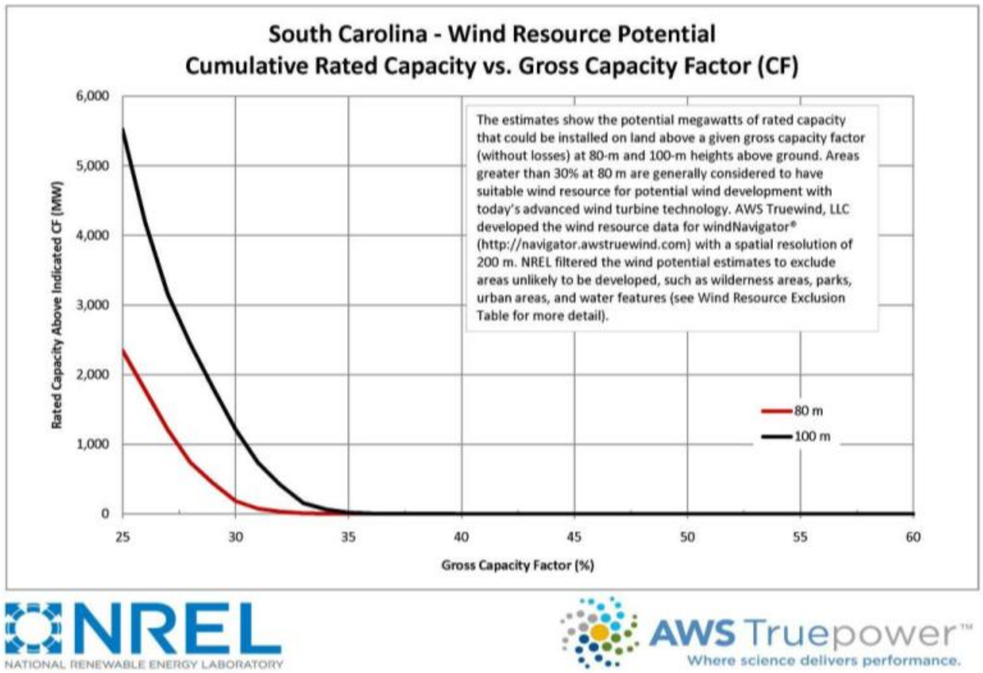

Figure 3-2 NREL Estimate of Wind Resource Potential for South Carolina

Table 3-1 NREL Estimate of Wind Energy Potential at 80 m and 100 m for Onshore Wind

	WINDY LAND AREA >= 30% GROSS CAPACITY FACTOR					WIND ENERGY POTENTIAL		
Hub Height	**Total (km²)**	**Excluded (km²)**	**Available (km²)**	**Available % of State**	**% of Total Windy Land Excluded**	**Installed Capacity (MW)**	**Annual Gross Generation (GWh)**	**Annual Net* Generation (GWh)**
At 80 meters	102.8	65.8	37.0	0.05%	64.0%	185.0	504	438
At 100 meters	483.0	240.0	243.1	0.30%	49.7%	1,215.3	3,362	2,923
*Annual net generation assumes onsite system losses of 15 percent.								

3.1.3 Relevant Information Provided by Stakeholders

Black & Veatch contacted representatives and staff of South Carolina utilities and clean energy organizations to discuss onshore wind resources and the potential to utilize these resources for renewable energy. The comments presented in this section are from individual or multiple stakeholders that Black & Veatch interviewed during this process. These comments are not Black & Veatch conclusions or recommendations but are provided for informational purposes.

Relevant comments provided by these stakeholders include the following:

- In general, there is consensus that onshore wind development will likely be quite limited in South Carolina due to the lack of good quality wind resources in South Carolina.

3.1.4 Constrained Potential of Onshore Wind

The constrained potential for onshore wind in South Carolina will depend on the proximity of these resource areas to transmission. Black & Veatch was unable to access the updated AWS Truepower GIS data to conduct a transmission proximity analysis. Additionally, while projects with hub heights of 100 m can capture better wind resources, these taller structures would need to overcome visual concerns along coastal communities. For the constrained potential in the near term, the estimate of 185 MW at 80 m is a more likely development scenario for South Carolina.

3.1.5 Data Sources and References

- "Wind Energy Resource Maps of South Carolina," South Carolina Energy Office, prepared by AWS Truewind, June 10, 2005.
- Wind_Potential.xls , NREL, prepared by NREL and AWS Truepower, February 4, 2010, accessed July 5, 2011, http://www.windpoweringamerica.gov/docs/wind_potential.xls.

3.2 OFFSHORE WIND

Offshore wind projects have been developed in Europe to some extent, though not nearly as extensively as onshore wind due to the higher cost and technical challenges. By the end of 2010, an estimated 3,000 MW of capacity has come online in Europe. However, in the United States, while there are a number of projects proposed, no offshore wind projects have become operational to date. The technologies used and experience gained in the European projects will likely be employed in the US initially.

Research into the offshore wind potential in South Carolina has been conducted by NREL, as well as several South Carolina organizations. These organizations include state universities, state agencies, and utilities that have past and ongoing research in offshore wind areas, such as state-of-the-art wind mapping, establishment of anemometer stations, SODAR development for offshore use, the Coastal Wind for Schools Program, and extensive study of offshore wind potential. South Carolina also formally created a Regulatory Task Force for Coastal Clean Energy to study the barriers to offshore wind development in South Carolina.[14]

3.2.1 Assessment Methodology and Assumptions

In developing the technical potential of offshore wind off the coast of South Carolina, Black & Veatch used GIS data to categorize wind resource areas, segmented into water depth and distance from shore measurements. The wind resource data were obtained from NREL and are based on 90 meter hub height wind speeds developed by AWS Truepower for offshore wind. The 90 meters is used because that is the typical hub height of modern offshore wind turbines, and the wind resource measured at this height is most appropriate for this analysis. The wind speeds developed by AWS Truepower has been partially confirmed by buoy data, collected over a period of 1 year by Coastal Carolina University as part of the Palmetto Wind Research Project.[15]

NREL had conducted an assessment of offshore wind resources for the state in 2010.[16] NREL measured the area in km^2 that fell within each segment of water depth and distance from shore but did not consider any potential exclusion areas. NREL then used a conversion factor of 5 MW per km^2 to estimate the capacity potential of the non-excluded area.

Table A-2 in Appendix A shows the technical potential estimated by NREL without any exclusions applied. The data are organized into three categories: distance from shoreline; water depth; and wind speed. Overall, NREL estimated a total offshore wind potential of over 130,000 MW or 130 GW of offshore wind capacity.

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[14] Regulatory Task Force for Coastal Clean Energy website, http://www.energy.sc.gov/index.aspx?m=6&t=85&h=904.

[15] Ma, Yanxia, Kehui Xu, Paul T. Gayes, Len Pietrafesa, and Machuan Peng, "Palmetto Wind Research Project," Coastal Carolina University, January 6, 2011.

[16] Schwartz, Marc, Donna Heimiller, Steve Haymes, and Walt Musial, "Assessment of Offshore Wind Energy Resources for the United States," Technical Report NREL/TP-500-45889, June 2010.

For this assessment, Black & Veatch followed a similar approach using NREL's GIS data, but excluded certain areas due to potential sensitivities for development. Having reviewed a number of offshore wind assessments developed for states such as Maryland and North Carolina, as well as the United Kingdom and European Union, there are some common features that warrant exclusion from the technical potential estimate. These include the following:

- Maritime shipping lanes (assumed a 5 nautical mile [nm] buffer).
- Marine protected areas, refuges, critical areas, and ports.
- Coral reefs (assumed a 5 nm buffer).
- Historic sites, such as ship wreck sites (assumed a 5 nm buffer).
- Viewshed within 3 nm of shoreline.

Military airspace is also a potential constraint for offshore wind development. Black & Veatch reviewed Military Operation Areas (MOA) and National Security Areas (NSA) designated by the Federal Aviation Administration (FAA), but these areas were located over land and not off the coast of South Carolina.[17] There are likely additional restricted military zones that are located offshore, but Black & Veatch was unable to obtain the information from US military agencies in time for this publication.

The migratory path of birds is another potential concern, but there is insufficient information available for the exact paths of migratory birds to map, and it is inconclusive whether offshore wind projects would significantly impact these birds. Further study would be needed by avian experts, so this issue was not included as a constraint. The viewshed exclusion within 3 nm of shoreline does partially address shorebird concerns.

The migratory paths and habitats of fish and marine mammals are additional concerns for offshore wind development, but studies to date have been inconclusive regarding the potential impact. Similar to avian impacts, this issue would need to be studied further.

Overall, Black & Veatch excluded the areas listed as sensitive for purposes of constraining technical potential for the state. These exclusion assumptions do not automatically preclude these areas from offshore wind development in the future, but they would require further study by the agencies and entities that manage them.

[17] U.S. Dept. of Transportation: Federal Aviation Administration, "Air Traffic Organization Policy," Order JO 7400.8T, February 7, 2011.

3.2.2 Technical Potential of Offshore Wind

Having applied the exclusions described previously, the remaining development areas are shown in the map below.

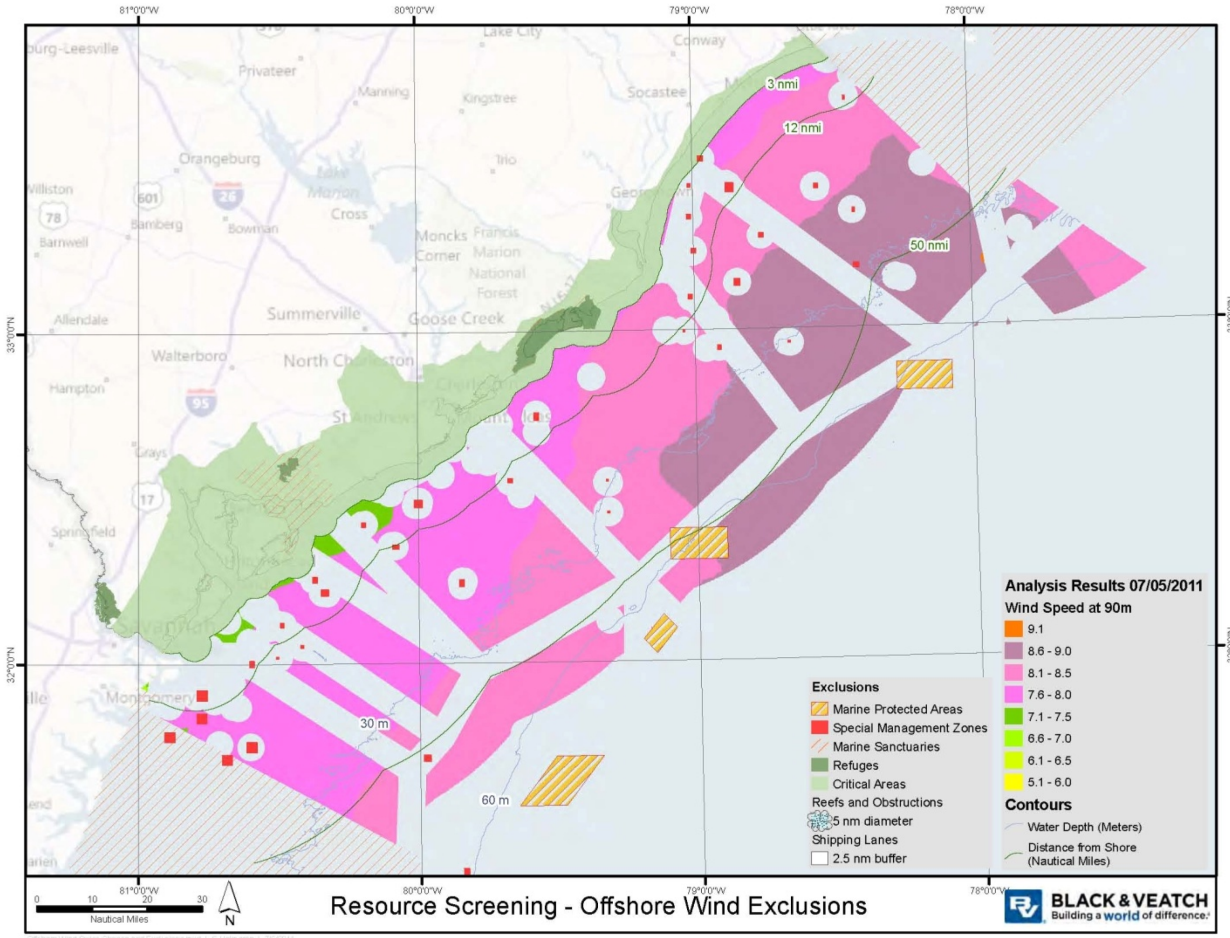


Figure 3-3 Technically Available Areas for Offshore Development

Black & Veatch used the same wind map as NREL, but applied the technical exclusions as described in the methodology section, which results in a lower total potential of 70,000 MW, as shown in Table 3-2. The exclusions greatly reduced the potential of development closer to the shore. This resulting potential still represents a high level of development that well exceeds the peak demand for the state and the capability of the existing transmission network.

Table 3-2 Technical Potential for Offshore Wind

WIND SPEED AT 90 M (M/S)	DISTANCE FROM SHORELINE						TOTAL
	3 - 12 NM			12 - 50 NM			
	DEPTH CATEGORY (M)			DEPTH CATEGORY (M)			
	0 - 30	30 - 60	> 60	0 - 30	30 - 60	> 60	
	AREA (KM^2) *(MW)*	AREA (KM^2) *(MW)*	AREA (KM^2) *(MW)*	AREA (KM^2) *(MW)*	AREA (KM^2) *(MW)*	AREA (KM^2) *(MW)*	AREA (KM^2) *(MW)*
7.0-7.5	162	--	--	2	--	--	164
	(811)	--	--	*(10)*	--	--	*(820)*
7.5-8.0	1,373	--	--	3,137	319	--	4,829
	(6,864)	--	--	*(15,685)*	*(1,596)*	--	*(24,145)*
>8.0	1,117	--	--	5,243	2,792	0	9,153
	(5,584)	--	--	*(26,217)*	*(13,962)*	*(0)*	*(45,763)*

3.2.3 Relevant Information Provided by Stakeholders

Black & Veatch contacted representatives and staff of South Carolina utilities and clean energy organizations to discuss offshore wind resources and the potential to utilize these resources for renewable energy. The information presented in this section includes comments from individual or multiple stakeholders. The comments presented are neither conclusions drawn by Black & Veatch nor recommendations provided by Black & Veatch.

Relevant comments provided by these stakeholders include the following:

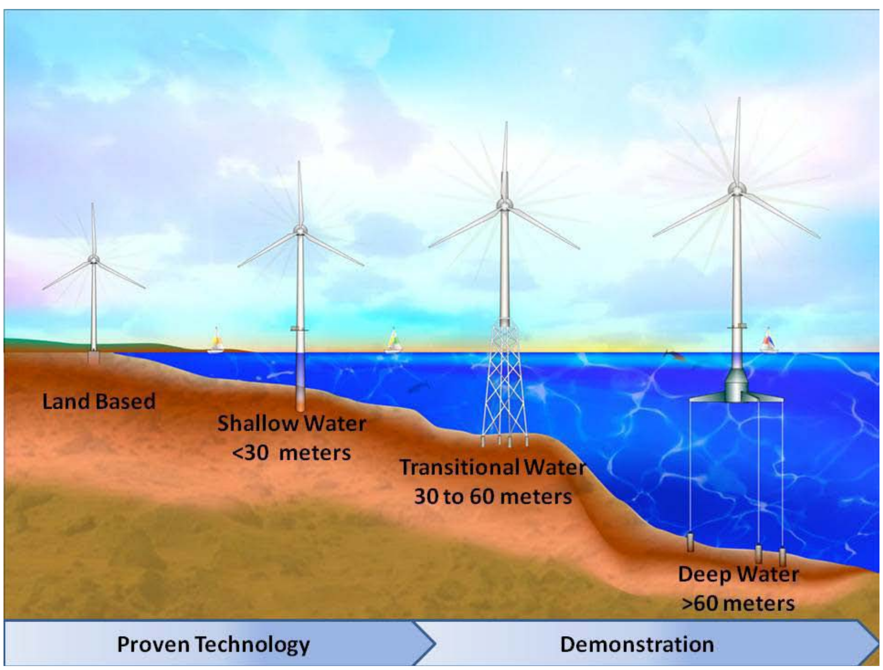
- In general, there is great interest both at the local and state level in studying and developing the offshore wind potential off the coast of South Carolina.
- The resource itself has been proven through buoy tests.
- However, a number of barriers to development including technology, transmission, cost, and environmental issues still need to be studied further and factored into the viability of the technology.

3.2.4 Constrained Potential of Offshore Wind

The constrained potential estimate for offshore wind development in South Carolina is focused on the following three key factors that contribute to near-term development opportunities.

- **Water depth** determines the foundation technology needed.
- **Distance from shore** determines the length of high-voltage submarine cable needed and maintenance requirements as well as viewshed issues.
- **Onshore interconnection** substations constrain the maximum near-term potential.

First of all, water depth determines the type of foundation needed for constructing offshore wind towers. According to NREL, current offshore wind turbine technology uses monopoles and gravity foundations in shallow water, typically 0 meter to 30 meters. In transitional depths (30 meter to 60 meter), tripods, jackets, and truss type towers will be needed. However, while these technologies resemble offshore oil well technologies, they are still in demonstration phases and would be challenging to contribute to near-term development. Deepwater areas (>60 m depth) may require floating structures instead of fixed bottom foundations, but this technology is currently in the early stages of development. Thus, to determine near-term constrained development potential, projects that can best utilize current technologies are included, which would be those in shallow waters of 0 to 30 meters.



Source: Courtesy of NREL

Figure 3-4 Offshore Wind Foundation Technologies and Corresponding Water Depth

The second factor to consider is distance from shore. In addition to increased water depth, greater distances from shore create a number of challenges, such as exposure to more extreme open ocean conditions, long distance electrical transmission on high voltage submarine cables, turbine maintenance at sea, and accommodation of maintenance personnel. All of these factors contribute to much higher capital and operational costs that would impact the viability of projects that are located within 12 to 50 nm from shore. The higher costs can be somewhat offset by better wind resources, which mean higher capacity factor areas. Thus, for this analysis, it is assumed that the constrained potential to develop projects located 12 to 50 nm offshore requires the best wind resources of >8.0 meters per second (m/s) to offset the higher capital and operational costs.

Constraining the potential to projects that are located in shallow waters (<30 m) and projects with access to the best wind resources (>8.0 m/s) that are located 12 to 50 nm from shore, the remaining developable areas still yields a total potential of over 30,000 MW (30 GW). As a point of comparison, this well exceeds the total peak demand 17,000 MW (17 GW) of the state.[18]

Another consideration related to distance from shore is viewshed. European countries with offshore wind projects have already experienced protests to projects too close to shore. To minimize the viewshed issue, the constrained potential assumes lower concentrations of projects near shore. The constraints include the following:

- No projects are developed within 3 nm of shore.
- Only five percent of the potential within 3 to 12 nm are developable.
- Ten percent of the potential within 12 to 50 nm (less visible from shore) are developable.

This results in approximately 3,300 MW of offshore wind capacity development in the near term. Depending on the level of public acceptance in the long-term, additional offshore wind areas beyond the estimated 3,300 MW may be developed.

[18] "South Carolina Utility Demand-Side Management and System Overview 2007," South Carolina Energy Office, June 2008.

Table 3-3 Constrained Offshore Wind Potential

VIEWSHED CONSTRAINT	5 PERCENT	10 PERCENT			
	3 - 12 NM 0 - 30 M	12 - 50 NM 0 - 30 M	TOTAL		
WIND SPEED AT 90M M/S	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	NET CAPACITY FACTOR*	GENERATION GWH
7.0- 7.5	8		8		
	(41)		*(41)*	*39%*	*(139)*
7.5 - 8.0	69		69		
	(343)		*(343)*	*44%*	*(1,323)*
>8.0 m/s	56	524	580		
	(279)	*(2,622)*	*(2,901)*	*46%*	*(11,689)*
			(3,285)		*(13,151)*

*Net capacity factor accounts for 20 percent system losses.

Black & Veatch also reviewed an offshore wind transmission study for South Carolina conducted by Clemson University in June 2010.[19] The Clemson University study examined the ability of substations in the Myrtle Beach and Winyah Bay areas to interconnect offshore wind at different capacity levels. Some of the conclusions from the study include:

- Phase I: the development of 80 MW of offshore wind under 2010 grid conditions can be successfully absorbed by the network.
- Phase II: the additional development of 1,000 MW under 2014 grid conditions, distributed between four utilities (Duke, Progress Energy, Santee Cooper, and SCE&G) can be absorbed, assuming most of the existing Myrtle Beach plant is shut off and the output at the Winyah Bay plant is reduced. Additionally, diversifying the interface buses also helps reduce maximum line flow.
- Phase III: the addition of 2,000 MW more of offshore wind (for a total of 3080 MW), under 2019 grid conditions, distributed between the five utility companies (Southern Company, Duke, Progress Energy, Santee Cooper, and SCE&G) based on load ratio criteria, cannot absorb the full 3,080 MW of offshore wind. Additional transmission lines onshore would be needed to mitigate the issue.

[19] "Offshore Wind Transmission Study." Clemson University Electric Power Research Association and South Carolina Institute for Energy Studies, June 2010.

It appears from the Clemson University study that incorporating 2,080-3,080 MW of offshore wind (Phase II and III) into the existing transmission system would require either transmission additions and/or the turning down of certain existing generation. The study also notes that additional transmission capability may be added in the future for other grid-related reasons, so incremental transmission specifically for offshore wind may not be needed. For this analysis, while some transmission upgrades may be necessary, the 3,300 MW of constrained potential is a reasonable estimate for near-term development.

Realistically, the biggest barrier for offshore wind development today is cost. While the offshore wind resources in the state are quite plentiful, any development would need to overcome the relatively high cost of constructing, interconnecting with high-voltage underwater cables, and maintaining offshore wind projects. In addition, the existing power system in the state and the way it is operated will need to be modified to accommodate any large amounts of variable output generation like wind. Lastly, migratory birds and marine animal impacts, as well as potential conflicts with military restricted zones need to be studied further.

3.2.5 Data Sources and References

- "Coastal Wind Energy for North Carolina's Future: A Study of the Feasibility of Wind Turbines in the Pamlico and Albemarle Sounds and in Ocean Waters Off the North Carolina Coast," University of North Carolina at Chapel Hill, prepared for the North Carolina General Assembly, June 2009.
- "Europe's onshore and offshore wind energy potential: An assessment of environmental and economic constraints," European Environmental Agency, EEA Technical Report No. 6/2009, ISSN 1725-2237, 2009.
- Ma, Yanxia, Kehui Xu, Paul T. Gayes, Len Pietrafesa, and Machuan Peng, "Palmetto Wind Research Project," Coastal Carolina University, January 6, 2011.
- Musial, Walter (NREL) and Bonnie Ram (Energetics), "Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers," Technical Report NREL/TP-500-40745, September 2010.
- "Offshore Wind Transmission Study," Clemson University Electric Power Research Association and South Carolina Institute for Energy Studies, June 2010.
- Project Management Support Services Ltd (PMSS), "Offshore Renewables Resource Assessment and Development (ORRAD) Project," Technical Report, prepared for South West Regional Development Agency, 2010.
- Regulatory Task Force for Coastal Clean Energy website, http://www.energy.sc.gov/index.aspx?m=6&t=85&h=904.
- Rigas, Dr. Nicholas C, "Potential for Offshore Wind Development in the Southeast and South Carolina," Workshop for Offshore Wind Energy Development Director Renewable Energy, Clemson University Restoration Institute, March 24, 2010.

- Schwartz, Marc, Donna Heimiller, Steve Haymes, and Walt Musial, "Assessment of Offshore Wind Energy Resources for the United States," Technical Report NREL/TP-500-45889, June 2010.
- South Carolina Energy Office, "South Carolina Utility Demand-Side Management and System Overview 2007," June 2008.
- "South Carolina's Role in Offshore Wind Energy Development: Prepared in Response to Act 318 of 2008," Wind Energy Production Farms Feasibility Study Committee.

4.0 Solar (Photovoltaic) Resources

This section provides a brief discussion of the solar resource in South Carolina and presents the methodology and results of the solar PV development potential estimates. There are approximately 400 solar PV systems currently installed in South Carolina.[20] However, these are small residential and commercial-scale projects with a combined total capacity of less than 1 MW.

Figure 4-1 Example Solar PV Installations

[20] South Carolina Energy Office, "Solar Water Heating and Photovoltaic Systems in South Carolina." Updated Nov. 17, 2010. Available: http://www.energy.sc.gov/publications/SouthCarolinaSolarInstallations1117.pdf.

There are two main measurements of solar resources: global horizontal insolation (GHI) and direct normal insolation (DNI). The solar resource considered in this study is the global horizontal insolation (GHI), measured in units of kWh/m²/day, as the measure of resource potential for PV installations. Solar PV technologies use GHI as the measure for resource potential, which includes both the direct and diffuse components of solar energy. GHI is more widespread than DNI, which allows solar PV greater siting flexibility compared to solar thermal technologies. In addition, the slope requirements of solar PV are less stringent than those for solar thermal, which allows solar PV access to more land areas. As illustrated in Figure 4-2, most of the country has sufficient GHI resource for solar PV development. For example, although the Northeast has lower GHI (<4 kWh/m²/day) than South Carolina, New Jersey is second only to California for total PV capacity installed.[21] This is attributed to significant policies in the state that foster solar development.

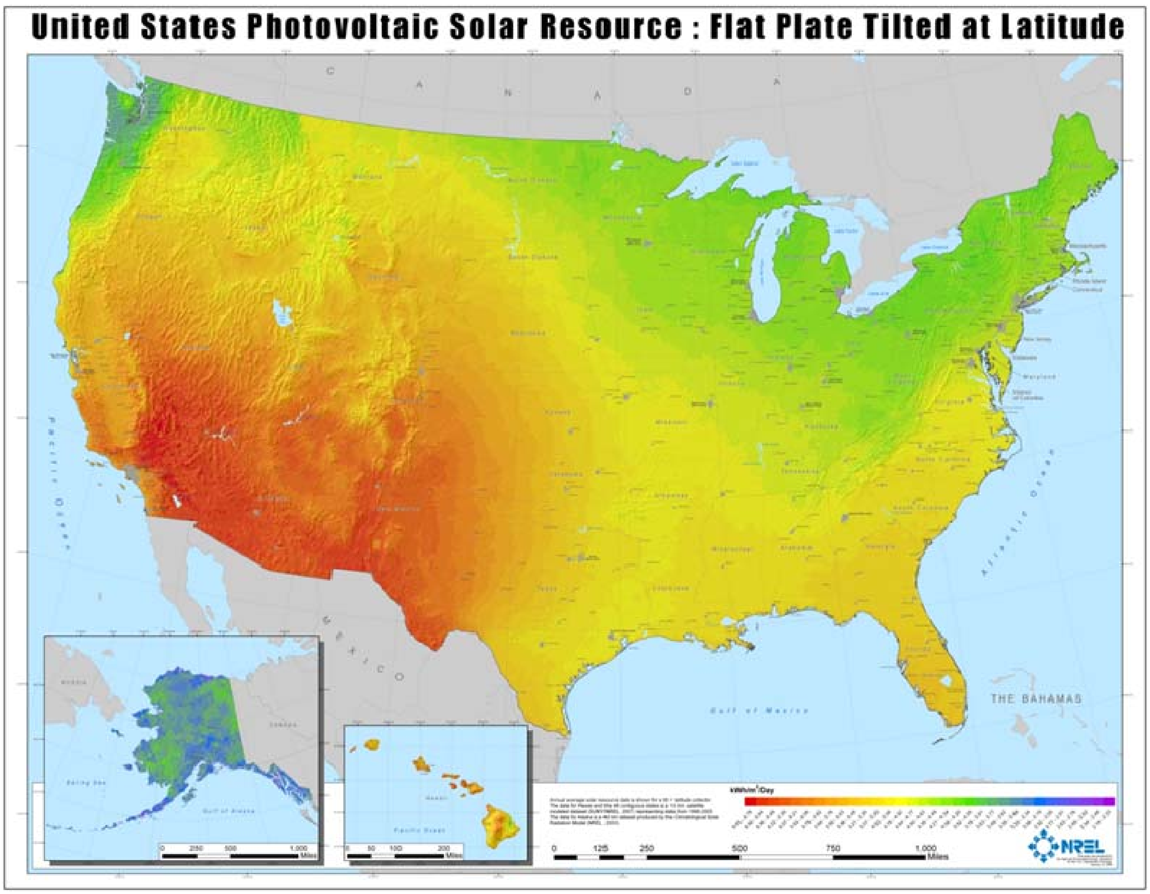


Figure 4-2 US Annual Average Global Horizontal Insolation Resource

[21] From NREL's Open PV Project database: as of July 2011, the installed capacity in California is 1,146 MW and in New Jersey is 161 MW.

Another class of solar power technology, concentrated solar power (CSP),[22] uses direct normal insolation (DNI) resources. In the US, the most favorable region for CSP development is in the Southwest with annual average DNI generally in the range of 6.5 to 8.0 kWh/m²/day. Comparatively, South Carolina has low DNI resources in the range of 4.0 to 4.5 kWh/m²/day. Because of this low DNI value, CSP technologies are not considered to be viable in South Carolina. Therefore, CSP technologies were excluded from consideration in this study. Figure 4-3 illustrates the US annual average DNI resource.

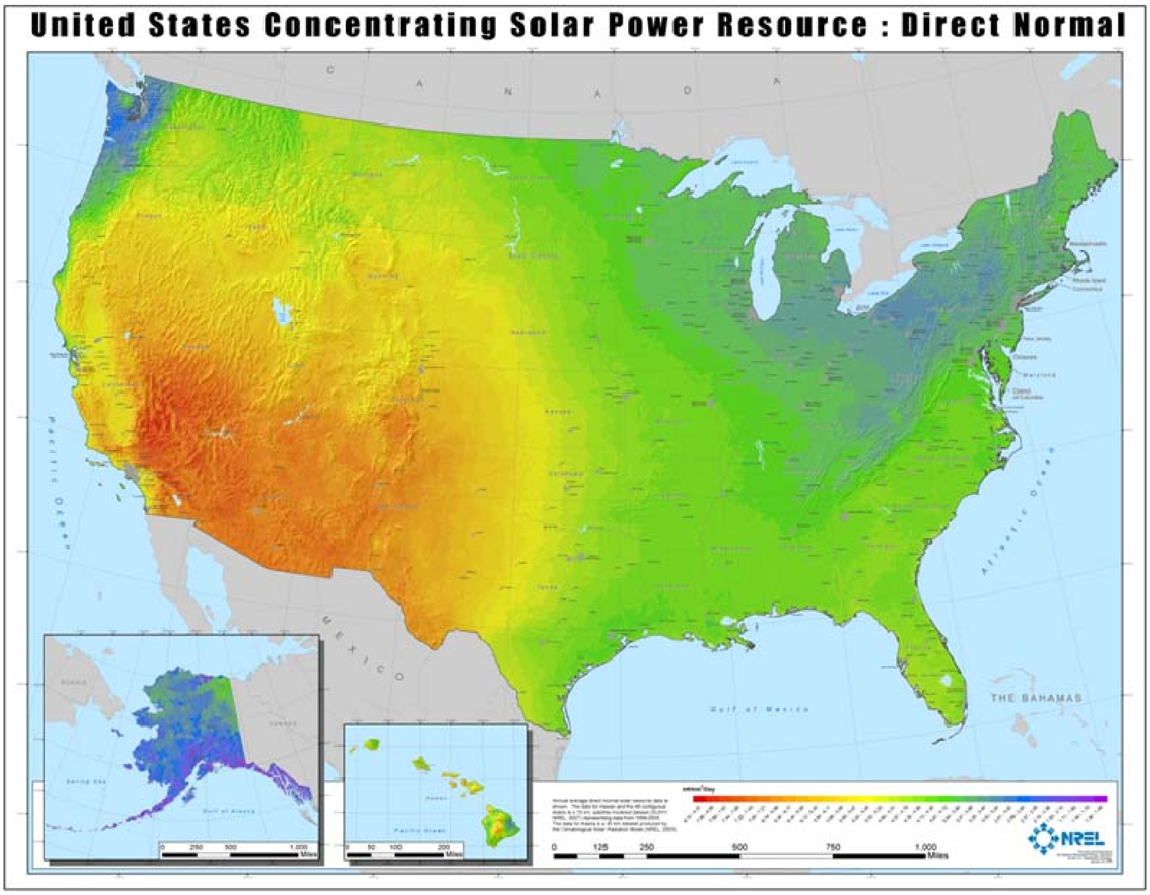


Figure 4-3 US Annual Average Direct Normal Insolation Resource

[22] CSP, also known as solar thermal technologies, include parabolic trough, power tower, dish Stirling, and linear Fresnel. Although the technology details vary, the general function is similar in that they all collect and concentrate DNI which is used to heat a heat transfer fluid. The heated fluid generates steam, which can be used to drive a turbine and generate electricity. Dish Stirling units use heat engines with gas as the working fluid.

4.1 ASSESSMENT METHODOLOGY AND ASSUMPTIONS

Black & Veatch made use of GIS analysis capabilities and solar resource data from NREL for the solar PV resource assessment.[23] Because the solar resource is fairly uniform statewide, Black & Veatch developed land use screening criteria to identify areas best suited for solar PV development. The screening relied on a number of land use categories available through the United States Geological Survey (USGS) Land Cover Institute.[24] Using these land use categories, Black & Veatch grouped land areas into non-developable, urban (distributed generation) developable, and utility-scale developable options, as appropriate.

A number of regions were excluded from the analysis before the USGS land use categories were applied. These exclusions do not necessarily preclude future development on these lands, but they are assumed to be excluded for development in this analysis. These areas include the following:

- Refuges and Wilderness Areas.
- National Parks and Forests.
- State Parks and Forests.
- County, Regional, and Local Parks.
- Lakes and Rivers.

In addition, the following USGS land use categories were considered to be areas where solar development would be limited, given construction would be challenging or not permitted. These land use classifications are described in Table A-3.

- Bare Rock/Sand/Clay.
- Deciduous, Evergreen, and Mixed Forest.
- Emergent Herbaceous and Woody Wetlands.
- Transitional Regions.
- Open Water.

The following USGS land use categories were considered to be areas capable of supporting **utility-scale solar PV** development (>1 MW), where large open spaces are needed. These land use classifications are described in Table A-3.

- Pasture/Hay.
- Row Crops.
- Quarries/Strip Mines/Gravel Pits.

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[23] NREL Dynamic Maps, GIS Data and Analysis Tools. (accessed June 1, 2011)) http://www.nrel.gov/gis/cfm/input.cfm

[24] USGS Land Cover Institute, NLCD Land Cover Class Definitions, June 2011. http://landcover.usgs.gov/classes.php.

The following USGS land use categories were considered to be areas capable of supporting **urban solar PV** development (distributed generation), because these areas are typically built up and are close to load. Urban PV projects are typically located on rooftops or above parking areas and would be smaller than utility-scale projects, often referred to as distributed generation. The types of projects could serve on-site load. These land use classifications are described in Table A-3.

- Commercial/Industrial/Transportation.
- High Intensity Residential (HIR) and Low Intensity Residential (LIR).
- Urban/Recreational Grasses.

The non-developable, urban(distributed generation), and utility-scale development areas identified are illustrated in Figure 4-4. Using the screening layers listed above, Black & Veatch calculated the approximate land area with development potential for both the urban (distributed generation) and utility-scale categories. Since PV development cannot technically occur over all of the surface area defined under urban and utility-scale solar PV development, additional reductions were then applied to the land areas to reach an estimate for the technical solar PV development potential. The additional assumptions Black & Veatch used in this analysis to reach a technical potential estimate are as follows. The basis for these assumptions are provided in greater detail in Table A-3.

- 30 percent of Commercial/Industrial/Transportation areas were assumed to be available for urban scale development.
- 20 percent of HIR and LIR areas were assumed to be available for urban scale development.
- 2 percent of Urban/Recreational Grasses were assumed to be available for urban scale development.
- 5 percent of Pasture/Hay and Row Crops areas were assumed to be available for utility-scale development.
- 10 percent of Quarries/Strip Mines/Gravel Pits areas were assumed to be available for utility-scale development.

For both the urban and utility-scale PV scenarios, Black & Veatch assumed a typical solar PV land requirement of 7 acres per megawatt alternating current (MWac) to estimate the technical development potential. This estimate is representative for solar PV technologies and considered appropriate for the level of detail in this study. This assessment assumes commercial solar PV technologies in a variety of orientations and configurations (refer to Figure 4-1) could be installed in South Carolina, so no one system is preferred.

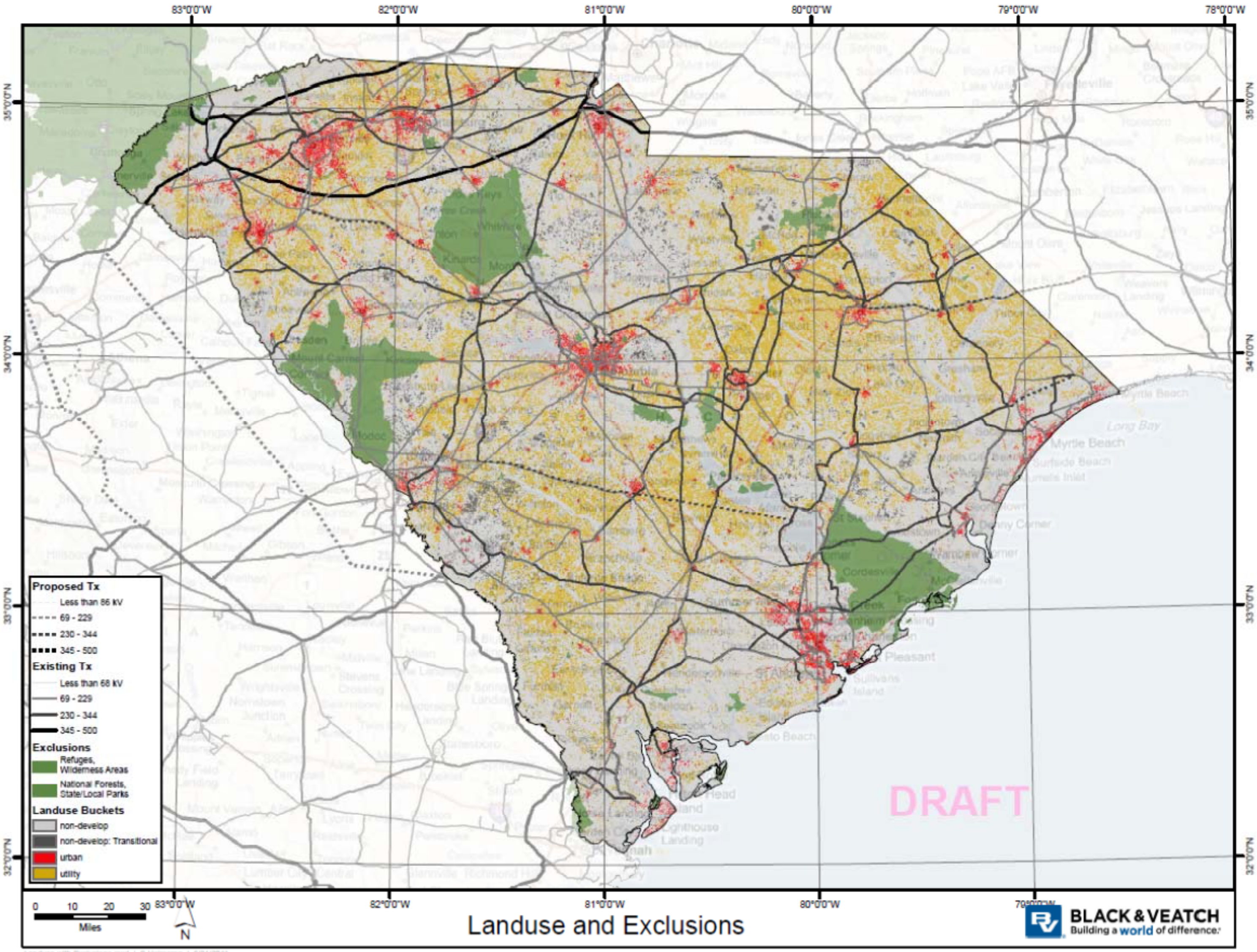

Figure 4-4 **Map of South Carolina Solar PV Land Use Categories**

4.2 TECHNICAL POTENTIAL OF SOLAR PV

The technical potential represents the amount of solar PV that may be feasible to develop, considering the solar resource and land availability of the GIS analysis. Once the available land area was determined, Black & Veatch assumed a certain percentage of each land usage type to be available for development (listed in the previous section). The GIS analysis provided land area in the categories for urban (distributed generation) and utility-scale development, which were then multiplied by the PV land requirement factor of 7 acres per MWac of PV capacity. Results of the technical potential analysis are summarized in Table 4-1.

Table 4-1 Solar PV Technical Potential

CLASS	CATEGORY	TOTAL AREA (SQ. MI.)	ASSUMED AVAILABLE (PERCENT)	TECHNICAL POTENTIAL AREA (SQ. MI.)	TECHNICAL POTENTIAL (MW) *	TECHNICAL POTENTIAL (GWH) **
Urban	LIR	550	20	110	10,100	13,300
	HIR	190	20	38	3,470	4,600
	Commercial	280	30	84	7,780	10,200
	Urban/ Recreational	120	2	2	220	300
	Total	**1,140**	**---**	**234**	**21,400**	**28,100**
Utility	Quarries/Mines	30	10	3	270	400
	Pasture/Hay	1,540	5	77	7,040	9,300
	Row Crops	4,950	5	248	22,630	29,700
	Total	**6,520**	**---**	**328**	**29,900**	**39,300**

*Technical Potential estimated assuming 7 acres per MW and 640 acres per sq. mi.
**GWh potential assumes 15% capacity factor

The total technical potential of about 51 GW identified in Table 4-1 is quite considerable. However, Black & Veatch notes that there are significant challenges with integrating such large amounts of PV to the electric grid because of the variable nature of the technology and the fact that South Carolina's peak load (approximately 17,000 MW or 17 GW)[25] is well below this amount. Therefore, the amount of solar PV that can practically be integrated to an electric system is likely much lower. The constrained potential is discussed in Section 4.4.

[25] "South Carolina Utility Demand-Side Management and System Overview 2007," South Carolina Energy Office, June 2008.

4.3 RELEVANT INFORMATION PROVIDED BY STAKEHOLDERS

Black & Veatch contacted representatives and staff of utilities and solar organizations to discuss solar resources and the potential to utilize these resources for renewable energy. The comments presented in this section are from individual or multiple stakeholders that Black & Veatch interviewed during this process. These comments are not Black & Veatch conclusions or recommendations but are provided for informational purposes.

Relevant comments provided by these stakeholders include the following:

- The consensus of the stakeholder group was that the barriers to the installation of additional solar PV systems in South Carolina are primarily related to a lack of financial incentives rather than resource-related issues.
- Solar energy advocacy groups stated that financial incentives to facilitate solar PV development would include:
  - Implementation of a investment tax credit for solar PV systems similar to that implemented in North Carolina;
  - Development of a market for solar renewable energy credits (SRECs); and
  - Modification of net metering rules that were more favorable to owners of residential- and industrial-scale systems.
- Furthermore, processes for integrating customer-sited solar generation vary across utilities.
- Some stakeholders felt that industrial and utility scale development of PV projects would be necessary to take advantage of economies of scale and reduce the cost of solar in the state.

4.4 CONSTRAINED POTENTIAL OF SOLAR PV

The constrained potential represents the amount of solar PV that may be developed in the state, considering a reasonable level of integration to the electric grid. Because of the variable nature of solar PV, large-scale grid integration presents significant challenges. There are a few studies that have examined the interaction between the penetration of large amounts of PV systems and the limited flexibility of conventional electric generation plants. For electric systems that are highly dependent on inflexible baseload steam plants, studies have shown that maximum PV penetration is about 4 to 15 percent, before excess solar energy must be curtailed.[26,27] These studies also assume that no new grid management technologies or demand response programs are deployed. For purposes of estimating constrained potential of solar PV in South Carolina, Black & Veatch used a range of solar PV penetration of 5 to 10 percent of peak system demand. According to these studies, this level can be increased through measures such as increased system flexibility, increased dispatchable load and energy storage; therefore, 5 to 10 percent is likely a conservative estimate for this analysis.

Based on the most recent data available for state-wide peak demand, South Carolina experienced a peak demand of 17 GW in 2007. Therefore, the constrained development potential in the near-term for solar PV, assuming no grid technology innovations, is estimated to be 850 to 1700 MW. This potential is summarized in Table 4-2. In addition, this estimate does not consider the relative cost of solar to other generation options.

Table 4-2 Solar PV Constrained Potential

TOTAL TECHNICAL POTENTIAL (MW)	PEAK DEMAND (MW)	SOLAR PV PENETRATION LEVEL	CONSTRAINED POTENTIAL (MW) *	CONSTRAINED POTENTIAL (GWH)
51,000	17,000	5%-10%	850-1700	1,100-2,200
*Constrained potential estimated as 5-10 percent of South Carolina peak demand.				

Similar to offshore wind, areas to develop solar resources are plentiful in the state, but the true barrier to achieving the constrained potential is cost. Current incentives available in the state and at the federal level are not sufficient to close the gap between the cost of solar compared the cost of electricity in the state.

[26] Paul Denholm and Robert Margolis, "Very Large-Scale Deployment of Grid Connect Solar Photovoltaics in the United States: Challenges and Opportunities," April 2006.
[27] Kevin S. Meyer et al., Solar Energy Laboratory, University of Wisconsin-Madison, "Assessment of High Penetration of Photovoltaics on Peak Demand and Annual Energy Use," January 2010.

4.5 DATA SOURCES AND REFERENCES

Black & Veatch used the following data sources and additional references in this analysis:

- Chaudhuari Maya et al., "PV Grid Connected Market Potential under a Cost Breakthrough Scenario," September 2004.
- Denholm Paul and Robert Margolis, "Very Large-Scale Deployment of Grid-Connected Solar Photovoltaics in the United States: Challenges and Opportunities," April 2006, http://www.osti.gov/bridge.
- NREL Dynamic Maps, GIS Data and Analysis Tools: http://www.nrel.gov/gis/cfm/input.cfm.
- Public Service Commission of Wisconsin and The Statewide Energy Efficiency and Renewables Administration, Environmental and Economic Research Development Program, "Assessment of High Penetration of Photovoltaics on Peak Demand and Annual Energy Use," Final Report, January 2010, http://www.focusonenergy.com/files/Document_Management_System/Environmental_Research/kleinphotovoltaics_report.pdf.
- South Carolina Energy Office, "Solar Water Heating and Photovoltaic Systems in South Carolina," November 2010, http://www.energy.sc.gov/publications/SouthCarolinaSolarInstallations1117.pdf.
- South Carolina Energy Office, "South Carolina Utility Demand-Side Management and System Overview 2007," June 2008, http://www.energy.sc.gov/publications/2007%20DMS%20Report%20Final%207-31-08.pdf.
- USGS Land Cover Institute, NLCD Land Cover Class Definitions, June 2011, http://landcover.usgs.gov/classes.php.

5.0 Hydroelectric Resources

Hydropower as an energy resource involves generating electricity through mechanically turning a turbine using moving water. The amount of electricity that can be generated is dependent on the flow and the hydraulic head. Hydropower plants may produce power year-round or during certain months depending on the seasonal variation in the flow.[28] They can be operated as run-of-the-river [29] units or controlled flow to optimize usage during peak periods.

South Carolina has about 1195 MW of large conventional hydro (>30 MW) facilities and 170 MW of smaller hydro plants in operation today, as shown in Table A-4. Additionally, there are 2,188 MW of pumped storage facilities in the state.

In this section, Black & Veatch discusses the technical and constrained potential of additional hydropower in South Carolina.

5.1 ASSESSMENT METHODOLOGY AND ASSUMPTIONS

The Idaho National Laboratory (INL) has conducted a number of studies that looked at the hydropower potential in each state in the United States. The more recent studies have been based on GIS analysis that examined the head,[30] in conjunction with flow rate data of streams, to determine the gross hydropower potential for individual streams.

In 2004, the INL completed a report called "Water Energy Resources of the United States with Emphasis on Low Head/Low Power Resources."[31,32] The 2004 analysis applied exclusions to remove project sites in federally protected lands (national parks, national monument, Indian reservations, military bases, and Department of Energy [DOE] sites) and federally protected linear features (National Wild and Scenic Rivers and National Parkways). The analysis also removed power potential that had already been developed.

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[28] Hydroelectric plants can be developed to provide pumped storage where electricity is generated during hours of peak consumption by using water that has been pumped into an elevated reservoir during the hours of low consumption.

[29] Run-of-the-river (ROR) is a type of hydroelectric generation where flow of the river is used to generate power without modification by upstream storage.

[30] The head is the elevation difference between the upstream and downstream ends of a column of water (such as in a penstock). A penstock is a pipe conducting water from the point of takeoff on a stream to a turbine.

[31] The GIS analysis used the National Hydrography Dataset along with US Geological Survey's Elevation Derivations for National Applications (EDNA) dataset to assess the hydropower potential in the country. Elevation data from EDNA were used to calculate hydraulic head. The head, in conjunction with the flow rate data (also in National Hydrography Dataset), was used to determine the gross potential for individual streams.

[32] "Water Energy Resources of the United States with Emphasis on Low Head/Low Power Resources," Idaho National Laboratory, April 2004.

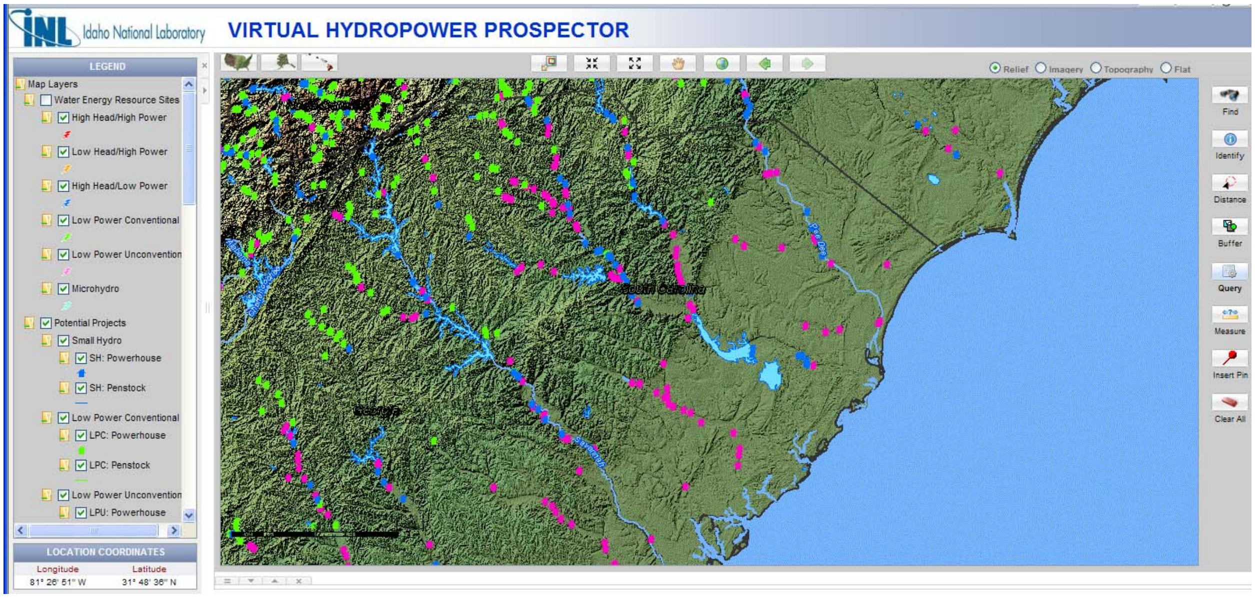


Figure 5-1: INL VHP Sample Map of Potential Project Sites

http://gis-ext.inl.gov/vhp/

The total available power was classified into three main categories based on power and head. The 2004 study classified sites with annual mean power of 1 MWa or more as high power; sites with head of 30 feet or more but less than 1 MWa potential were categorized as high head/low power; and sites with head less than 30 feet and less than 1 MWa potential were categorized as low head/low power. Annual mean power, labeled as MWa, is the statistical mean of the rate at which energy is produced over the course of 1 year. INL also assigned appropriate development technology categories for low head/low power sites. Technology categories assigned included conventional turbines, unconventional system, and microhydro (sites with less than 100 kW potential).

Building on the 2004 study, INL completed "Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants" in 2006.[33] The 2006 analysis by INL determined the feasible hydropower potential for small (between 1 and 30 MWa) and low (less than 1 MWa) power hydro. INL developed successive filters on the total gross potential from the 2004 study to arrive at Feasible Projects for development as described below.

- First, to obtain **Available Potential,** existing hydroelectric plants (sites that already generate power) were removed. INL also excluded environmentally sensitive zones in addition to the federal exclusions in the 2004 study.

[33] "Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants," Idaho National Laboratory, January 2006.

- In assessing the **Feasible Sites** potential, the following criteria were applied to Available Potential sites:
  - Has 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.
- Additional realistic development factors were considered to determine **Feasible Projects** sites. The criteria included the development of the project site without a dam obstructing the main stream channel and without impoundment. The length of the penstock[34] was limited to lengths of existing low power and small hydroelectric plants in the region and flow available for power generation was limited to 50% of total flow of stream.

The resulting hydroelectric potential estimates are presented in Table 5-1.

Table 5-1 2006 INL Hydroelectric Potential for South Carolina

POWER CLASS	TOTAL (MWa)	DEVELOPED (MWa)	FEDERALLY EXCLUDED (MWa)	OTHER EXCLUDED (MWa)	AVAILABLE (MWa)	FEASIBLE SITES (MWa)	FEASIBLE PROJECTS ((MWa)
Total High Power	***1,035***	***322***	***32***	***23***	***658***	***564***	***153***
Large Hydro	286	175	0	0	111	111	0
Small Hydro	749	147	32	23	547	452	153
Total Low Power	***342***	***6***	***7***	***23***	***306***	***176***	***58***
Conventional Turbines	159	4	4	12	139	106	11
Unconventional Systems	81	1	1	9	70	54	25
Microhydro	102	0	1	3	97	16	22
Total Power	**1,378**	**328**	**39**	**46**	**964**	**740**	**211**

[34] A pipe conducting water from the point of takeoff on a stream to a turbine.

In 1998, prior to the GIS-based analysis of hydropower potential, INL also conducted a detailed site survey of potential hydropower project sites and created the INL Hydropower Resource Economics Database (IHRED).[35,36] The project sites listed in the database were categorized as With Power, Without Power, and Undeveloped, with all but one of the sites listed as Without Power (impoundment in place, but no power being generated) and Undeveloped (no impoundment). It is unclear whether all of these sites are included in the "small hydro" and "large hydro" potential identified in the 2006 GIS studies. For reference purposes, these sites are listed in Table A-5 in Appendix A along with development probability factors ranging from lowest 0.1 to highest 0.9.[37] Some of these sites have already been developed (Holidays, Boyds Mill, and Gaston Shoals.) Black & Veatch has not verified the existence of the remaining identified sites, so the total capacity potential from the IHRED has not been added to the total potential determined in the 2006 GIS study.

5.2 TECHNICAL POTENTIAL OF HYDROPOWER

For the hydropower technical potential for South Carolina, Black & Veatch opted to use the Feasible Sites assessment from INL. Since the potential is measured in MWa, which is the average power output over a year, the total capacity potential (MW) would be higher than 628.

Table 5-2 Hydropower Technical Potential in South Carolina

POWER CLASS	FEASIBLE SITES (MWa)
Small Hydro (*1 MWa ≥ and < 30 MWa*)	*452*
Low Power (*< 1 MWa*)	
Conventional Turbines	*106*
Unconventional Systems	*54*
Microhydro	*16*
Total Average Power (MWa)	**628**

[35] INL Hydropower Resource Economics Database. (http://hydropower.inel.gov/resourceassessment/d/ihred-29apr03.xls)
[36] U.S. Department of Energy, "U.S. Hydropower Resource Assessment Final Report," Prepared by Idaho National Engineering and Environmental Laboratory, December 1998. (http://hydropower.inel.gov/resourceassessment/pdfs/doeid-10430.pdf)
[37] The IHERD study assigned a "suitability factor" of 0.1, 0.25, 0.5, 0.75 or 0.9 to identified projects. These suitability factors reflected the probability that a project site would be acceptable for development given environmental and other developability factors.

5.3 RELEVANT INFORMATION PROVIDED BY STAKEHOLDERS

Black & Veatch contacted representatives and staff of utilities to discuss hydro resources and the potential to utilize these resources for renewable energy. The comments presented in this section are from individual or multiple stakeholders that Black & Veatch interviewed during this process. These comments are not Black & Veatch conclusions or recommendations but are provided for informational purposes.

Relevant comments provided by these stakeholders include the following:

- The data derived from INL that relies on GIS may be imprecise as to existing and potential impoundment opportunities.
- Also, the likelihood of developing sites without impoundments, as assumed for INL's Feasible Projects, is questionable.

5.4 CONSTRAINED POTENTIAL OF HYDROPOWER

For constrained potential, Black & Veatch relied on the identified Feasible Projects from NREL, but excluded unconventional systems and microhydro since these technologies are still in development stages. While the technology for conventional small hydro is quite mature, costs associated with small installations can be significant, as well as permitting challenges. Since the 2006 GIS Study was based on GIS data, the actual development for each site requires onsite measurements and evaluations to validate the site's feasibility for development and ability to get permitting. Therefore, actual development may be lower than the total of Feasible Projects estimated here.

Table 5-3 Hydropower Constrained Potential in South Carolina

POWER CLASS	FEASIBLE PROJECTS (MWa)
Small Hydro (*1 MWa ≥ and < 30 MWa*)	*153*
Low Power (*< 1 MWa*)	
Conventional Turbines	*11*
Unconventional Systems	-
Microhydro	-
Total Average Power (MWa)	**164**

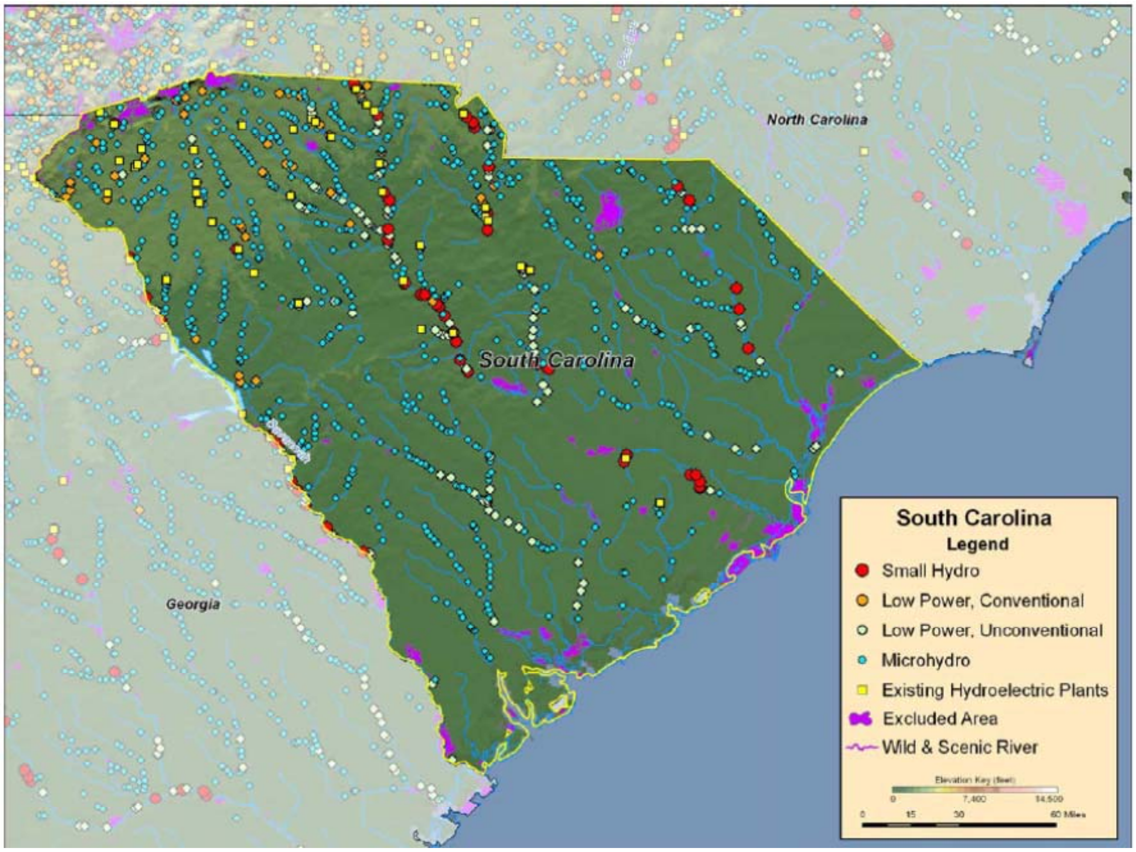


Figure 5-2 Low Power and Small Hydro Feasible Projects and Existing Hydroelectric Plants in South Carolina

5.5 DATA SOURCES AND REFERENCES

- Idaho National Laboratory, "Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants," January 2006, http://hydropower.inel.gov/resourceassessment/pdfs/main_report_appendix_a_final.pdf.
- Idaho National Laboratory, Hydropower Resource Economics Database, http://hydropower.inel.gov/resourceassessment/d/ihred-29apr03.xls.
- Idaho National Laboratory, "Water Energy Resources of the United States with Emphasis on Low Head/Low Power Resources," April 2004, http://hydropower.inel.gov/resourceassessment/pdfs/03-11111.pdf.
- US Department of Energy, "US Hydropower Resource Assessment Final Report," Prepared by Idaho National Engineering and Environmental Laboratory, December 1998, http://hydropower.inel.gov/resourceassessment/pdfs/doeid-10430.pdf.
- US Energy Information Administration, Existing Units Database for 2008, http://www.eia.gov/cneaf/electricity/page/capacity/existingunitsbs2008.xls.
- Wachob, Andrew, A. Drennan Park, and Roy Newcome, Jr., "South Carolina State Water Assessment, 2nd Ed.," 2009, http://www.dnr.sc.gov/water/hydro/HydroPubs/assessment.htm.

6.0 Landfill Gas Resources

LFG is produced by the decomposition of the organic portion of waste deposited in landfills. Typically, the methane content in LFG falls in the range of 45 to 65 percent. Methane is a potent greenhouse gas, 21 to 23 times more harmful than carbon dioxide. In many landfills, gas collection systems have already been installed due to environmental and safety requirements, with most of the LFG being flared or utilized in thermal and power applications rather than being released to the atmosphere. Adding gas upgrading or power generation equipment allows the LFG to be used for energy generation or process heat. LFG energy recovery is currently regarded as one of the more mature and successful waste-to-energy technologies.

Gas production at a landfill is primarily dependent on the depth and the age of the waste in place and the amount of precipitation received by the landfill. The life of an LFG resource is limited. After waste deliveries to the landfill cease and the landfill is capped, LFG production will decline, typically following a first order decay curve. Project lifespan for an LFG project is expected to be 15 to 20 years, so sites that are in operation or were recently closed are more suited for energy recovery.

The LFG can be used for direct thermal energy applications, power generation or CHP. LFG can serve as fuel for boilers and dryers to provide thermal energy. Power generation can be accomplished using technologies such as reciprocating internal combustion (IC) engines, gas turbines, microturbines, and steam turbines. To date, reciprocating engines are the most widely used technology in the United States. Table A-6 shows South Carolina landfills currently utilizing LFG. There is about 57.3 MW of generation capacity installed to date. In addition, several landfills also use LFG for direct thermal applications.

6.1 ASSESSMENT METHODOLOGY AND ASSUMPTIONS

EPA's LMOP created a database of existing and candidate LFG projects at landfills across South Carolina. This database was the starting point in identifying potential LFG opportunities in South Carolina. Since newer projects may not be updated in the LMOP database, additional sources for project information were used to remove landfill sites that have already been developed.

The database includes information on status, size, amount of waste in place, and, in some instances, gas generation potential. Status categories include Operational, Shutdown, Candidate, or Potential. Shutdown indicates that the LFG was used previously but the project has been closed, likely due to resource depletion. LMOP defined Candidate landfills as having a minimum of 1 million tons of waste-in-place, depth of 50 feet, open or has been closed less than five years ago, and receiving at least 25 inches of precipitation every year. Potential sites do not yet meet LMOP's Candidate criteria but could in the future. Table 6-1is a summary of the sites.

Table 6-1 Summary of Landfills in South Carolina

STATUS	NUMBER OF LANDFILLS	TOTAL GAS (MMSCFD)*	TOTAL GENERATION (MW)
Operational	20	23	55.8*
Shutdown	3	--	4.4*
Candidate	7	12.6	N/A
Potential	28	N/A	N/A

*From LMOP database. Capacity total for all Operational and Shutdown project is not listed in the database thus the values reflect capacity for which the data is available.

For this study, the technical potential includes any sites defined by LMOP as Candidate or Potential landfills that are not currently generating power or thermal energy production and have been closed for no more than 10 years with at least 0.5 million tons of waste-in-place. Black & Veatch opted to use 0.5 million tons of waste-in-place as the minimum requirement (less than the Candidate criteria used by LMOP), because South Carolina receives far greater precipitation than the 25 inch per year minimum. The higher precipitation increases the amount of LFG that may be produced from a given amount of waste-in-place. Though higher LFG production is possible, 0.43 MMSCFD per 1.0 million tons of waste in place was used to obtain a conservative technical potential estimate. The smallest reciprocating engines that are used with LFG require a minimum of 0.5 MMSCFD. Potential landfills with missing waste-in-place and/or closing data were not considered in the technical potential.

6.2 TECHNICAL POTENTIAL OF LANDFILL GAS

The LMOP database includes five landfills that are either open or have been closed for less than 10 years and have at least 0.5 million tons of waste-in-place. Using EPA's estimate of 0.43 MMSFD of LFG per 1.0 million tons of waste in place, the total LFG production per day from the five sites is about 5.8 MMSCFD or 958,200-1,384,000 MBtu per year. Assuming a heat rate of 10,600 Btu per kWh for a reciprocating engine, this is equivalent to 90.4 to 130.6 GWh (methane portion ranging from 45% to 65%) per year of electricity production. The Twin Chimneys Landfill is a fairly new site and has the potential to expand LFG production as the site receives more waste over time.

Table 6-2 Landfills in South Carolina with Potential for LFG-to-Energy Projects

LANDFILL	LANDFILL CITY	DAILY LFG (MMSCFD)	ESTIMATED FUEL POTENTIAL[b] MBTU/YEAR	TOTAL GENERATION POTENTIAL[c] GWH/YR	TOTAL[d] CAPACITY MW
Northeast Sanitary Landfill	Eastover	0.86[a]	141,000-203,700	13.3-19.2	1.8-2.6
Hickory Hill MSWLF	Ridgeland	2.36[a]	387,200-559,300	36.5-52.8	4.9-7.1
Oakridge Landfill Inc.	Dorchester	1.38[a]	225,900-326,300	21.3-30.8	2.9-4.1
Bees Ferry Road LF	Spartanburg	0.99[a]	163,200-235,700	15.4-22.2	2.1-3.0
Twin Chimneys Landfill	Honea Path	0.25[e]	40,800-58,900	3.9-5.6	0.5-0.8
Total		5.8	958,200-1,384,000	90.4-130.6	12.1-17.5

Notes: Potential based on a range of methane content in LFG of 45 percent to 65 percent.
[a]Assumes 1 million tons of waste in place can generate 0.432 MMSCF of LFG per day.
[b]Assumes 1000 Btu/cubic ft of methane.
[c]Assumes heat rate of 10,600 Btu/kWh.
[d]Assumes 85 percent Capacity Factor.
[e]This site is included as it may generate a greater amount of LFG in the future with increased waste deposits.

6.3 RELEVANT INFORMATION PROVIDED BY STAKEHOLDERS

Black & Veatch contacted representatives and staff of South Carolina utilities to discuss landfill gas resources and the potential to utilize these resources for renewable energy. The comments presented in this section are from individual or multiple stakeholders that Black & Veatch interviewed during this process. These comments are not Black & Veatch conclusions or recommendations but are provided for informational purposes.

Relevant comments provided by these stakeholders include the following:

- Santee Cooper has developed a number of LFG projects in recent years, and LFG projects now contribute nearly 24 MW of renewable capacity to Santee Cooper's generation portfolio.
- Duke Energy is the off-taker of power generated by a 3.2 MW LFG project located in Greenville County.
- There are four other landfills in South Carolina that may be developed for LFG projects (as listed in Table 6-2), but it is expected that these projects will be developed by the landfill owners. It is uncertain whether these projects will generate power or use the gas for direct heating purposes.

6.4 CONSTRAINED POTENTIAL OF LANDFILL GAS

All five of the landfills with technical potential are considered practical for development.

6.5 DATA SOURCES AND REFERENCES

- Combustion Renewable Energy Users in South Carolina, last modified January 2009, http://www.energy.sc.gov/publications/Renewable%20Energy%20Combustion%20Facilities%202-1-09.pdf.
- Santee Cooper, https://www.santeecooper.com/portal/page/portal/santeecooper/aboutus/energymatters?cmpID=EM.
- US Environmental Protection Agency, "An Overview of Landfill Gas Energy in the United States," LMOP, http://www.epa.gov/lmop/documents/pdfs/overview.pdf.
- US Environmental Protection Agency, LMOP, "Project Development Handbook," http://www.epa.gov/lmop/publications-tools/handbook.html.
- US Environmental Protection Agency, LMOP, http://www.epa.gov/lmop/.

7.0 Biomass Resources

Biomass is any material of recent biological origin. The most prevalent biomass fuels utilized for energy production are wood and woody residues, although biomass fuels may include agricultural residues, energy crops, animal wastes, and organic human wastes.

For the generation of electricity, solid biomass fuels may be either directly combusted or gasified. Biomass fuels with very high moisture contents, such as animal manures, sewage sludge, or discarded greases may be anaerobically digested. These conversion options are briefly defined as follows:

- **Direct biomass combustion** power plants fire biomass in either a stoker boiler or a fluidized bed boiler, and steam generated in the boiler is expanded through a steam turbine generator to produce electricity. This process utilizes the same proven technologies that have been used to generate electricity for decades.
- **Biomass gasification** is a thermal process to convert solid biomass into a gaseous fuel or syngas, which is then subsequently fired in a reciprocating engine, boiler, or combustion turbine, similar to natural gas.
- **Anaerobic digestion** is the use of bacteria to break down carbon containing material without air but in the presence of water and heat to produce a methane-rich biogas. Similar to syngas, biogas must be subsequently fired in a reciprocating engine or gas fired boiler to generate electricity.

For purposes of estimating resource potential, this study uses the performance parameters for direct biomass combustion--rather than biomass gasification--for the conversion of solid biomass fuels to electricity because (1) direct combustion processes are employed for nearly all of the world's biomass power facilities; and (2) gasification technologies are generally not yet economically competitive with direct combustion options.[38] The choice of combustion conversion technology rather than gasification, however, does not significantly affect the conclusions of the resource potential in the state and does not limit the use of gasification technology in the future if it becomes commercially available.

[38] Advanced biomass gasification concepts such as Biomass Integrated Gasification Combined Cycle (BIGCC) and plasma arc gasification offer potential advantages when compared to conventional combustion technologies, such as marginally increased efficiency and ability to handle problematic waste materials. However, these advanced processes have not yet been technically demonstrated at commercial scales and have considerably higher capital costs than biomass combustion technologies.

Biomass fuels contain little sulfur compared to coal and so produce less sulfur dioxide. Unlike coal, biomass fuels typically contain only trace amounts of toxic metals, such as mercury, cadmium, and lead. On the other hand, biomass combustion still must cope with some of the same emission issues as larger coal plants and other large industrial solid-fueled boilers. Primary constituents of concern are nitrogen oxides (NO_x), particulate matter (PM), and carbon monoxide (CO). Conventional air quality control technologies are used to manage these emissions.

For the purposes of this Resource Assessment, biomass resources under consideration include the following:

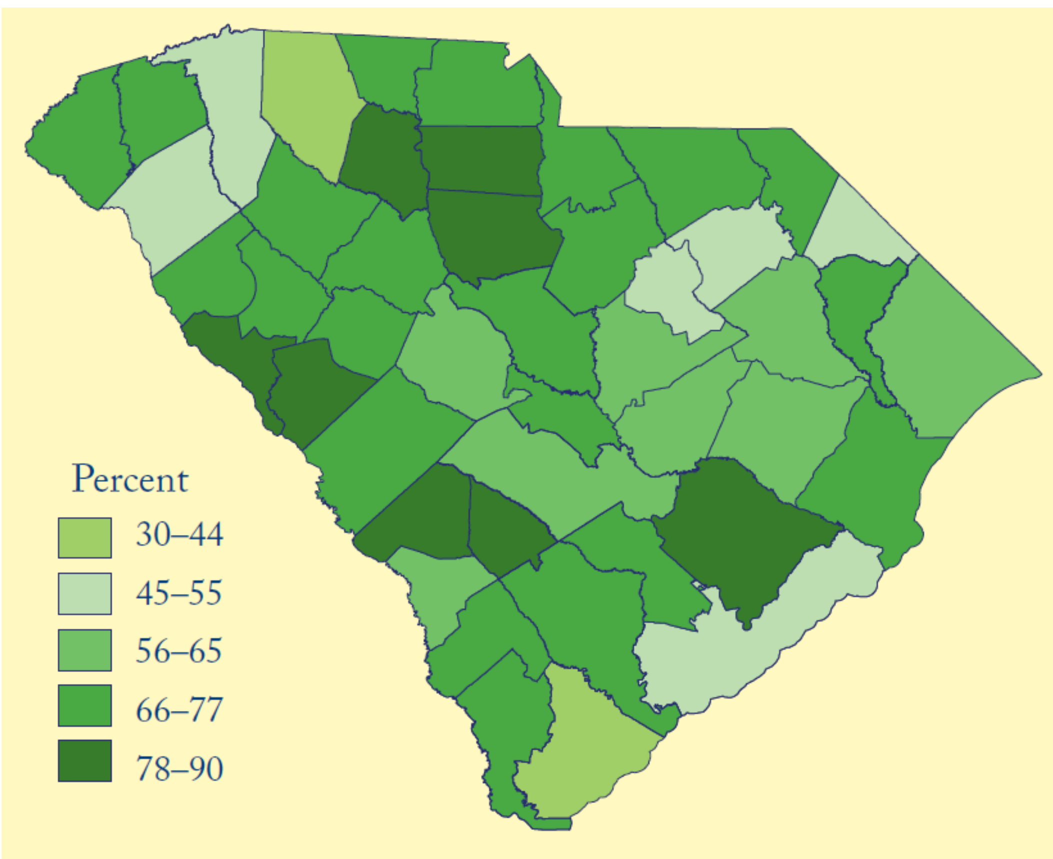
- Woody biomass.
- Agricultural biomass.
- Organic wastes (including human and animal wastes).
- Pulping liquors.

The technical and constrained potentials of these biomass resources are presented in the following sections.

There are a number of facilities that fire biomass fuels for CHP applications or direct heating applications, as shown in Table A-7. Facilities that co-generate electricity and steam for process heating include the six existing pulp and paper mills within the. The total electrical generation capacity of these facilities is 510 MW. In addition, there are at least 20 other industrial facilities, consisting of paper and pulp mills, sawmills and other facilities, that fire woody biomass residues to produce process steam for onsite use.

7.1 WOODY BIOMASS RESOURCES

Because forestlands are prevalent and well-distributed throughout the Piedmont, Northern Coastal Plain, and Southern Coastal Plain regions of South Carolina (as shown in Figure 7-1), woody biomass resources are also prevalent and well-distributed throughout the state. According to the South Carolina Forestry Commission, timber is the state's leading commodity, with annual sales of approximately $780 million. The total economic impact of the forest product industry within the state is estimated to be approximately $17 billion on an annual basis.[39] Total timber removals from forested lands in South Carolina (including removals for roundwood, logging residues, and other removals as determined by USDA Forest Service[40]) during 2009 (the most recent year for which data are available) are illustrated in Figure 7-2.



Source: South Carolina 2006 Forest Inventory & Analysis Factsheet. Issued by USDA Forest Service, November 2008.

Figure 7-1 Percentage of South Carolina Lands in Forest by County

[39] "The State of South Carolina's Forests," South Carolina Forestry Commission, issued January 2011.
[40] Data obtained from USDA Forest Service Timber Product Output (TPO) Reports web page, http://srsfia2.fs.fed.us/php/tpo_2009/tpo_rpa_int1.php.

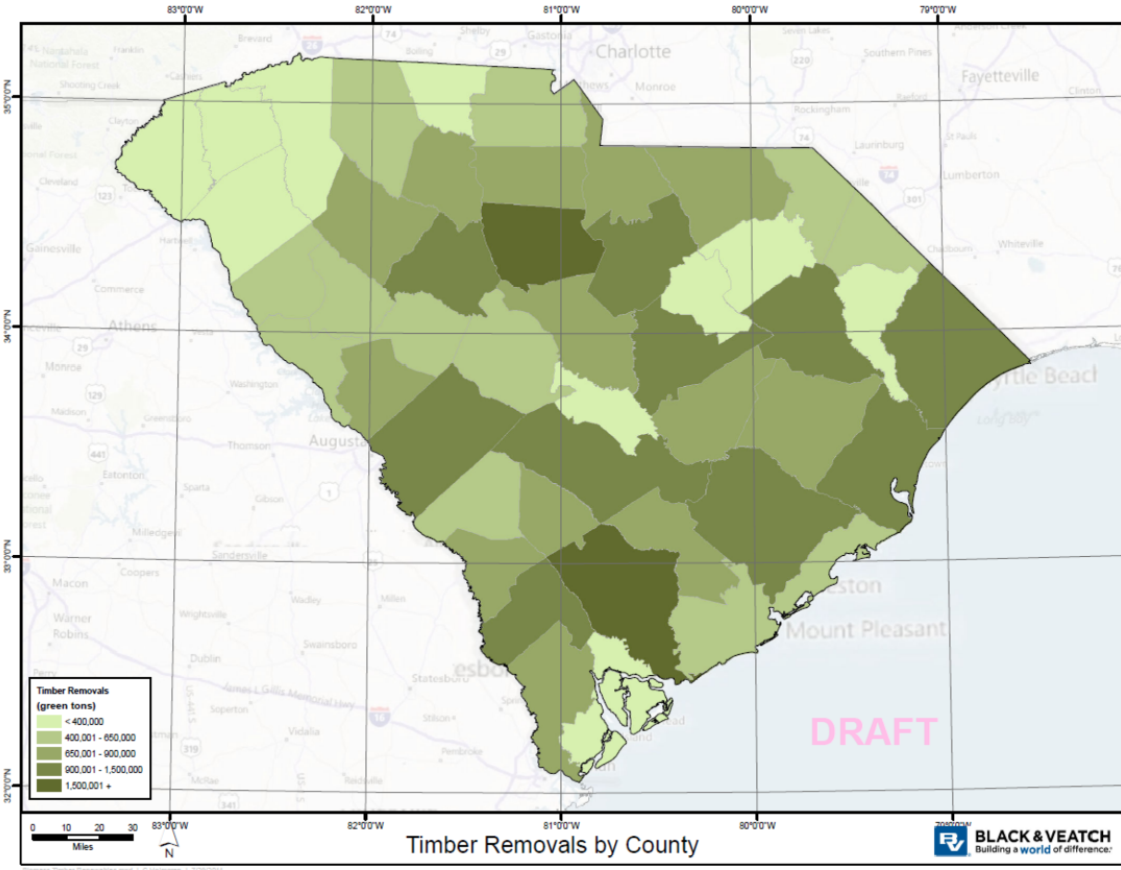


Figure 7-2 Total Timber Removals from South Carolina Forests (2009)

For the purposes of this Resource Assessment, woody biomass resources considered for the production of biomass-derived energy include the following types:[41]

- **Logging residues –** Logging residues are a component of timber removal data published by the USDA Forest Service as part of periodic Forest Inventory and Analysis (FIA) activities. The available supplies of logging residues are estimated by the USDA Forest Service based on reported harvesting activities on timberland acres. Logging residues include unutilized felled trees and non-merchantable portions of felled trees such as tops, limbs, and stumps. The USDA Forest Service estimates that 60 percent of the total quantified logging residues may be recovered when employing conventional logging equipment. This assumption may be considered by some to be conservative.[42]
- **Residual (standing) inventory –** The quantities of residual (standing) inventory following tree harvesting activities are estimated by the USDA Forest Service (2009) based on FIA data. These estimates include all live biomass greater than 1.0-inch diameter at breast height (d.b.h.) on final harvest acres (including rough and rotten trees) and all rough and rotten trees greater than 1.0-inch d.b.h. on all other acres with evidence of tree cutting.
- **Pre-commercial thinnings –** Pre-commercial thinnings are defined as existing, overstocked sapling-seedling stands with no evidence of tree cutting. The USDA Forest Service estimated the quantities available assuming that 10 percent of the overstocked sapling-seedling acres would be treated in a given year, and the treatment would remove 75 percent of the biomass in live trees in the size range of 1.0 to 5.0 inches d.b.h.
- **Commercial thinnings –** According to the USDA Forest Service, commercial thinning typically removes trees of poletimber size (5.0 – 8.9 d.b.h for softwoods and 5.0 – 10.9 inches d.b.h. for hardwoods), which are typically utilized as pulpwood supply for pulp and paper mills. The trees removed through commercial thinning are larger than those from pre-commercial thinning.
- **Mill residues –** The primary wood products industry consists of sawmills, pulp chip producers, and pulp and paper mills. The USDA Forest Service classifies mill residues into three categories: coarse residues, such as slabs, edgings, trim, veneer cores, and ends suitable for chipping; fine residues, such as sawdust, shavings, and veneer residue not suitable for chipping; and bark (used mainly for industrial fuel).

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[41] Logging residues, residual (standing) inventory, pre-commercial thinnings, commercial thinnings, and mill residues are defined for this study as they are defined in *Assessing the Potential for Biomass Energy Development in South Carolina* (Connor, Adams, and Johnson, USDA Forest Service Research Paper SRS-46, 2009).

[42] A study of renewable energy resources in North Carolina assumed that 85 percent of logging residues may be recovered.
North Carolina Energy Policy Council. "North Carolina's Renewable Energy Policy," Prepared by La Capra Associates, 2011.

Estimates of these residues were based on data obtained from a survey conducted by the USDA Forest Service of all major primary mill operators in South Carolina. Historically, a very high proportion (as high as 98 percent) of the mill residues generated in South Carolina have been utilized for various end uses (for example, to produce primary products such as paper, particleboard, or medium-density fiberboard; to produce secondary products such as mulch and animal bedding; or to supply wood fired boilers and dry kilns).

- **Urban wood waste –** Urban wood waste is a broad category including wood and plant wastes from residential and commercial yard work (green waste); tree trimmings, construction and demolition debris; land clearing; and other urban activities. Urban wood wastes are often the most economical resources for use as biomass fuel, as the producers of such residues often have to pay tipping fees to dispose of them in local landfills. In some cases, it may even be possible to obtain urban wood waste resources at a negative cost.
- **Southern scrub oak –** Scrub oak species are hardwood species with limited merchantable timber value. Mature trees of these species, such as turkey oak, reach heights of 20 to 50 feet with an average diameter of 7 inches and typically grow in dry, sandy soils. While the Southern scrub oak forest type extends from southeast Virginia to central Florida and west to southeast Louisiana, scrub oak species in South Carolina are concentrated along the Fall Line, in particular in the counties of Aiken, Calhoun, Chesterfield, Edgefield, Kershaw, Lexington, and Sumter.[43]

[43] Harris et al., "Potential for Biomass Energy Development in South Carolina," Final Report to the South Carolina Forestry Commission, 2004.

7.1.1 Assessment Methodology and Assumptions

To determine the technical potential of woody biomass in South Carolina, Black & Veatch reviewed existing estimates of biomass resources within South Carolina. These sources included one assessment conducted by NREL and two assessments initiated and partially funded by the South Carolina Forestry Commission (SCFC): a 2004 report authored by Harris et al. ("Harris Report") and a 2009 report issued by the US Department of Agriculture Forest Service--Southern Research Service ("USDA Forest Service Report"). The 2009 USDA Forest Service Report is an update of the 2004 Harris Report, which reflects the change in age and size distribution of forest resources in South Carolina, attributable to the "Wall of Wood" phenomenon.[44] Because the 2009 USDA Forest Service Report was an update to the 2004 Harris Report, Black & Veatch relied on the USDA Forest Service Report as the primary source for woody biomass supplies in South Carolina.[45]

Using the estimated quantities of woody biomass from the USDA Forest Service Report, the next step was to convert the quantities to potential generation capacity (in terms of MW) and electricity production (in terms of GWh). This process required a set of assumptions that reflect a representative standalone biomass plant that would utilize the woody biomass. The assumptions are as follows:

- The generation capacity of each standalone biomass power plant is in the range of 15 MW to 50 MW.
- The average net plant heat rate (NPHR) for biomass power plants across the anticipated size range of 15 MW to 50 MW is assumed to be 13,500 Btu/kWh.[46]
- The average capacity factor for a wood fired biomass power plant is assumed to be 85 percent.
- The heating value of woody biomass is assumed to be 8,500 Btu/lb (dry basis) with moisture content for woody biomass of 40 percent, which is consistent with green wood. The as-received heating value of woody biomass for this study is 5,100 Btu/lb (as-received), or 10.2 MBtu/green ton.

[44] At the present time, the age and size distribution of forests in South Carolina is significantly affected by the "Wall of Wood" phenomenon. The wall of wood arose as a result of two significant forest stand establishment efforts that occurred in the late 1980s and early 1990s: re-planting of trees following Hurricane Hugo and the coincidental implementation of the Conservation Reserve Program (CRP) cost-share program. The age and size distribution of trees in South Carolina is skewed toward the age and size of the trees that make up the wall of wood. In 2004, the trees that made up the wall of wood were predominantly in small-diameter size classes, and the Harris Report reflected this distribution. By 2009, these trees had grown and were categorized in sawtimber-sized classes, which were reflected in the findings of the 2009 USDA Forest Service report.

[45] While this methodology is appropriate for the purposes of this state-level Resource Assessment, biomass project developers will likely conduct more detailed resource assessments of the region immediately surrounding specific project locations. It is possible that these project-specific resource assessments may yield different results than those of this study.

[46] An average NPHR of 13,500 Btu/kWh is considered to be representative across this range of potential plant scales, as the NPHR for a 50-MW plant may range from 12,000 to 13,000 Btu/kWh, and the NPHR for a 15 MW plant may be in excess of 14,000 Btu/kWh.

Black & Veatch notes that while the majority of the existing and announced biomass projects are standalone biomass power plants, it may be possible to co-fire woody biomass in existing, utility-scale coal fired power plants. Co-firing of biomass and coal in utility-scale facilities may increase the potential generation for biomass relative to standalone facilities, since the conversion efficiency of biomass to electricity can be improved when co-firing in larger facilities.

7.1.2 Technical Potential of Woody Biomass

A comparison of the findings of the NREL (2005), Harris et al. (2004), and USDA Forest Service (2009) studies is provided in Table 7-1. The NREL study included only logging residues, mill residues, and urban wood waste. For these resources, NREL's estimates are similar to estimates provided in the Harris Report and the USDA Forest Service Report.

While the 2004 Harris Report identified 5.3 million green tons of commercial thinnings as a potential resource for biomass energy production, the 2009 updated USDA Forest Service Report concluded that this supply, which is attributable to the "Wall of Wood" phenomenon, may not be sustainable over time and would not result in additional supply.[47] Therefore, commercial thinnings are not included in the potential supply of unutilized woody biomass resources. Commercial thinning, hower, may be a viable fuel for biomass fired facilities in the future if volumes increase through additional plantings and harvesting of these resources is conducted in a sustainable fashion.

While the Southern scrub oak resource was quantified in the Harris Report, its potential was not separately calculated in this study because the quantity was negligible (0.2 percent) relative to the total biomass potential in the state.

[47] The USDA Forest Service used the following criteria to estimate commercial thinning potential: (1) all-live poletimber volume had increased significantly based on estimates from 2001 and 2006 inventories, and (2) the analysis indicated that this increase could be sustained in the future. However, the USDA Forest Service concluded that the levels were not sustainable over time, so the estimate for commercial thinning was zero.

Table 7-1 Annual Availability of Woody Biomass Resources in South Carolina

WOODY BIOMASS RESOURCE	NREL DATA (GREEN TONS/YEAR)*	HARRIS REPORT DATA (GREEN TONS/YEAR)	USDA FOREST SERVICE DATA (GREEN TONS/YEAR)
Logging Residues	2,887,000	4,400,000	7,801,000
Residual (Standing) Inventory	Not reported	Not reported	3,736,000
Pre-Commercial Thinnings	Not reported	8,600,000	540,000
Commercial Thinnings	Not reported	5,300,000	0
Southern Scrub Oak	Not reported	50,000	Not reported
Mill Residues	4,175,000	3,300,000	6,164,000
Urban Wood Waste	778,000	500,000	2,081,000
Total	**7,840,000**	**22,150,000**	**20,320,000**

Sources: NREL (2005), Harris et al. (2004), and USDA Forest Service (2009)
*NREL reported biomass supplies in terms of dry tons per year. To be consistent with Harris Report and USDA Forest Service Report data, the NREL data have been adjusted from dry tons to green tons assuming an average moisture content of 40 percent.

The USDA Forest Service study also estimated quantities of logging residues, residual (standing) inventory, and pre-commercial thinning available for use at different price points for delivered biomass, as shown in Table A-8 in the Appendix. The study also stated that existing supplies of mill residues and urban wood waste are highly utilized. The USDA Forest Service estimated that as much as 98 percent of mill residue supply and 73 percent of the urban wood waste supply is currently utilized for some productive purpose (for example, paper, particle board, or other wood-based products, mulch, boiler fuel, etc.).

At the upper end of the delivered cost range ($30/ton), the USDA Forest Service Report estimates a total potential supply of 16.5 million green tons per year, of which 7.7 million green tons are from mill residues and urban wood wastes. The mill residues and urban wood wastes are likely being fired in existing biomass facilities for heat and power, as listed in Table A-7. The renewable energy provided by these existing wood fired facilities is not included in the estimates of either technical or constrained potential. Given a large portion of mill residues and urban wood waste are already being utilized, Black & Veatch excluded the utilized supply from the estimate of technical potential, focusing on only the unutilized portion of the total woody biomass supply.

The remaining supply of unutilized woody biomass is slightly less than 9.5 million green tons per year, as shown in Table 7-2.

Table 7-2 Unutilized Woody Biomass in South Carolina

WOODY BIOMASS RESOURCE	TOTAL QUANTITIES AVAILABLE[a] (GREEN TONS/YEAR)	ESTIMATED UTILIZATION RATE (PERCENT)	UNUTILIZED QUANTITIES AVAILABLE (GREEN TONS/YEAR)
Logging Residues	4,530,000	0	4,530,000
Residual (Standing) Inventory	3,736,000	0	3,736,000
Pre-Commercial Thinnings	540,000	0	540,000
Commercial Thinnings	0	0	0
Mill Residues	5,610,000	98	112,000
Urban Wood Waste	2,081,000	73	562,000
Total	**16,497,000**		**9,480,000**

Source: USDA Forest Service (2009).
[a]Total quantity available at the upper end of the range of delivered costs, as estimated by USDA Forest Service (2009).

The estimated supply of unutilized woody biomass resources was converted to technical capacity and generation potential for these resources, as shown in Table 7-3. The total technical potential is 960 MW, which would generate around 7,150 GWh per year of electricity.

Table 7-3 Technical Potential of Woody Biomass in South Carolina

WOODY BIOMASS RESOURCE	UNUTILIZED QUANTITIES AVAILABLE (GREEN TONS/YEAR)	ESTIMATED FUEL POTENTIAL[a] (MBTU/YEAR)	TECHNICAL POTENTIAL CAPACITY[c] (MW)	TECHNICAL POTENTIAL GENERATION [b] (GWH/YEAR)
Logging Residues	4,530,000	46,210,000	459	3,420
Residual (Standing) Inventory	3,736,000	38,110,000	379	2,820
Pre-Commercial Thinnings	540,000	5,510,000	55	410
Commercial Thinnings	0	0	0	0
Mill Residues	112,000	1,140,000	11	80
Urban Wood Waste	562,000	5,730,000	56	420
Total	**9,480,000**	**96,700,000**	**960**	**7,150**

[a]Assumed (green) woody biomass has a heating value of 8,500 Btu per lb (on a dry basis) and an average moisture content of 40 percent, corresponding to an as-received heating value of woody biomass of 10.2 MBtu per green ton.
[b]Assumed the NPHR of the biomass fired generation facility is 13,500 Btu/kWh.
[c]Assumed the capacity factor of the biomass fired generation facility is 85 percent.

7.1.3 Relevant Information Provided by Stakeholders

Black & Veatch contacted representatives and staff of South Carolina utilities, consultants, clean energy organizations, and biomass industry representatives to discuss woody biomass resources and the potential to utilize these resources for renewable energy. The comments presented in this section are from individual or multiple stakeholders that Black & Veatch interviewed during this process. These comments are not Black & Veatch conclusions or recommendations but are provided for informational purposes.

Relevant comments provided by these stakeholders include the following:

- The stakeholders generally agreed that there are significant woody biomass resources in the state of South Carolina, and woody biomass is the most practical biomass fuel, relative to agricultural residues and animal wastes, for renewable electricity generation.
- The utility stakeholders commented that renewable energy projects utilizing woody biomass are among the most economically attractive renewable energy projects in South Carolina (with landfill gas projects being the most attractive).
- Several stakeholders noted that a practical definition of woody biomass resources to be considered as "renewable biomass" must be established. The definition should be clearly specified such that case-by-case determinations would not be required and include sustainability considerations. Depending on how biomass is defined, the potential may be less or more than presented in this study.
- Multiple stakeholders commented that third-party certification of forestry practices, such as certification by the Sustainable Forestry Initiative [SFI] or the Forest Stewardship Council [FSC], is a means to demonstrate sustainable forest management practices, but incentives or other financial compensation must be provided to forest landowners to offset the cost of acquiring these certifications.

7.1.4 Constrained Potential of Woody Biomass

Forest-derived woody biomass resources, such as logging residues, residual (standing) inventory, and pre-commercial thinnings, are not presently collected in large quantities. As demand for these resources is established, it is anticipated that increasing quantities would need to be collected, which would require loggers and timber suppliers to invest in additional equipment and expand operations. In addition, financiers of biomass energy projects typically require verification that accessible supplies exceed demand by a significant factor (typically a factor of 3.0). Biomass fuel availability and pricing are key risks for biomass energy projects. A fuel supply that is significantly greater than the demand of the energy projects results in a reliable supply at relatively stable pricing, mitigating some concerns of potential fuel shortages or price volatility. Therefore, the constrained potential of woody biomass resources is assumed to be one-third of the technical potential of these resources, to ensure there is sufficient supply for project development. As development of biomass projects in South Carolina progresses and supply chains for woody biomass fuels mature in the long term, it is possible that biomass capacity could exceed the estimated constrained potential.

The constrained potential of woody biomass resources in South Carolina, as shown in Table 7-4, is equal to 317 MW in capacity, producing 2,360 GWh of electricity per year.

Table 7-4 Constrained Potential of Woody Biomass in South Carolina

WOODY BIOMASS RESOURCE	UNUTILIZED QUANTITIES AVAILABLE (GREEN TONS/YEAR)	ESTIMATED FUEL POTENTIAL[a] (MBTU/YEAR)	CONSTRAINED POTENTIAL CAPACITY[c] (MW)	CONSTRAINED POTENTIAL GENERATION[b] (GWH/YEAR)
Logging Residues	1,494,909	15,250,000	152	1,130
Residual (Standing) Inventory	1,232,880	12,580,000	125	930
Pre-Commercial Thinnings	178,200	1,820,000	17	130
Commercial Thinnings	0	0	0	0
Mill Residues	100,800	1,030,000	11	80
Urban Wood Waste	185,500	1,890,000	19	140
Total	**3,128,400**	**31,920,000**	**317**	**2,360**

[a]Assumed (green) woody biomass has a heating value of 8,500 Btu per lb (on a dry basis) and an average moisture content of 40 percent, corresponding to an as-received heating value of woody biomass of 10.2 MBtu per green ton.

[b]Assumed the NPHR of the biomass fired generation facility is 13,500 Btu/kWh.

[c]Assumed the capacity factor of the biomass fired generation facility is 85 percent.

Additional considerations for the constrained potential for woody biomass resources include the following:

- As shown in Table A-1, project developers have announced intentions to install various wood fired projects totaling approximately 220 MW in South Carolina. These projects would likely access the unutilized woody biomass resources identified in this study. Even if all of these projects achieve commercial operation, there should be sufficient woody biomass resources to supply additional wood fired generation projects.

- To fully develop the constrained potential of woody biomass resources, in particular the constrained potential of logging residues, the supply chain for these resources must be expanded to accommodate the increased demand. This supply chain development includes the identification of best management practices for the collection of logging residues and the provision of necessary incentives to motivate timber producers to invest in the equipment required to efficiently collect these residues.
- Urban waste wood (UWW) is likely to be aggressively sought by biomass project developers, as this material is generally lower in cost than forest-derived woody biomass. It is likely that biomass energy facilities will be able to compete for the acquisition of boiler fuel more favorably relative to traditional forest biomass markets. Therefore, biomass energy facilities may be able to acquire a portion of the UWW supplies that are currently utilized for other purposes.
- Wood fired power projects must maintain a delicate balance to ensure long-term sustainability of supply with minimal environmental impact. Several states impose specific criteria on wood fired power plants if the energy generated is to be considered a renewable resource. A key concern is sustainability of the feedstock. Most biomass projects target utilization of biomass-derived residues and byproducts for energy production, saving valuable landfill space. Targeting certain residues for power production can also address other emerging problems. For example, forest thinning activities may reduce the threat of wildfires and simultaneously provide fuels for biomass power facilities. Projects relying on wood (or agricultural) residues must be careful to ensure that fuel harvesting and collection practices are sustainable and provide a net benefit to the environment.
- Co-firing of biomass in utility-scale coal fired power generation facilities could increase the potential generation from woody biomass resources, as the conversion efficiency of biomass to electricity is improved when co-fired in larger facilities along with coal. The potential for co-firing with biomass would need to be studied on a project-by-project basis.
- This study did not consider impacts of other energy projects that could consume woody biomass fuels, such as cellulosic ethanol facilities or woody biomass pellet manufacturing for export or heating, which could potentially compete for the use of woody biomass resources.

7.1.5 Data Sources and References

- Connor, Roger C. Tim O. Adams, and Tony Johnson, “Assessing the Potential for Biomass Energy Development in South Carolina,” USDA Forest Service Research Paper SRS-46, 2009.
- Harris, Robert A., Tim Adams, Vernon Hiott, David Van Lear, Geoff Wang, Tom Tanner, and Jim Frederick, “Potential for Biomass Energy Development in South Carolina,” Final Report to the SCFC, 2004.
- La Capra Associates. “North Carolina’s Renewable Energy Policy,” Prepared for North Carolina Energy Policy Council, 2011.
- Milbrandt Anelia, “A Geographic Perspective on the Current Biomass Resource Availability in the United States,” NREL Technical Report NREL/TP-560-39181, 2005.
- South Carolina Forestry Commission, “South Carolina’s Statewide Forest Resource Assessment and Strategy: Conditions, Trends, Threats, Benefits and Issues,” 2010.
- South Carolina Forestry Commission, “State of South Carolina’s Forests Card 2011,” January 2011.
- USDA Forest Service Timber Product Output (TPO) Reports, http://srsfia2.fs.fed.us/php/tpo_2009/tpo_rpa_int1.php.

7.2 AGRICULTURAL RESOURCES

Agricultural resources in this section are grouped by crop residues, poultry litter, and energy crops. Existing agricultural biomass residues such as crop residues and poultry litter may be able to augment woody biomass resources for the production of renewable energy in South Carolina. Energy crops such as switchgrass, miscanthus and sorghum may provide additional biomass fuels for energy production if these crops are cultivated on a large scale.

While agricultural activity is distributed throughout the state of South Carolina, the majority of crop production occurs in the Northern and Southern Coastal Plain regions, as illustrated in Figure 7-3. Currently in South Carolina, crop residues are not typically harvested; instead, these residues remain in the field to return nutrients to the soil and provide erosion control. [48]

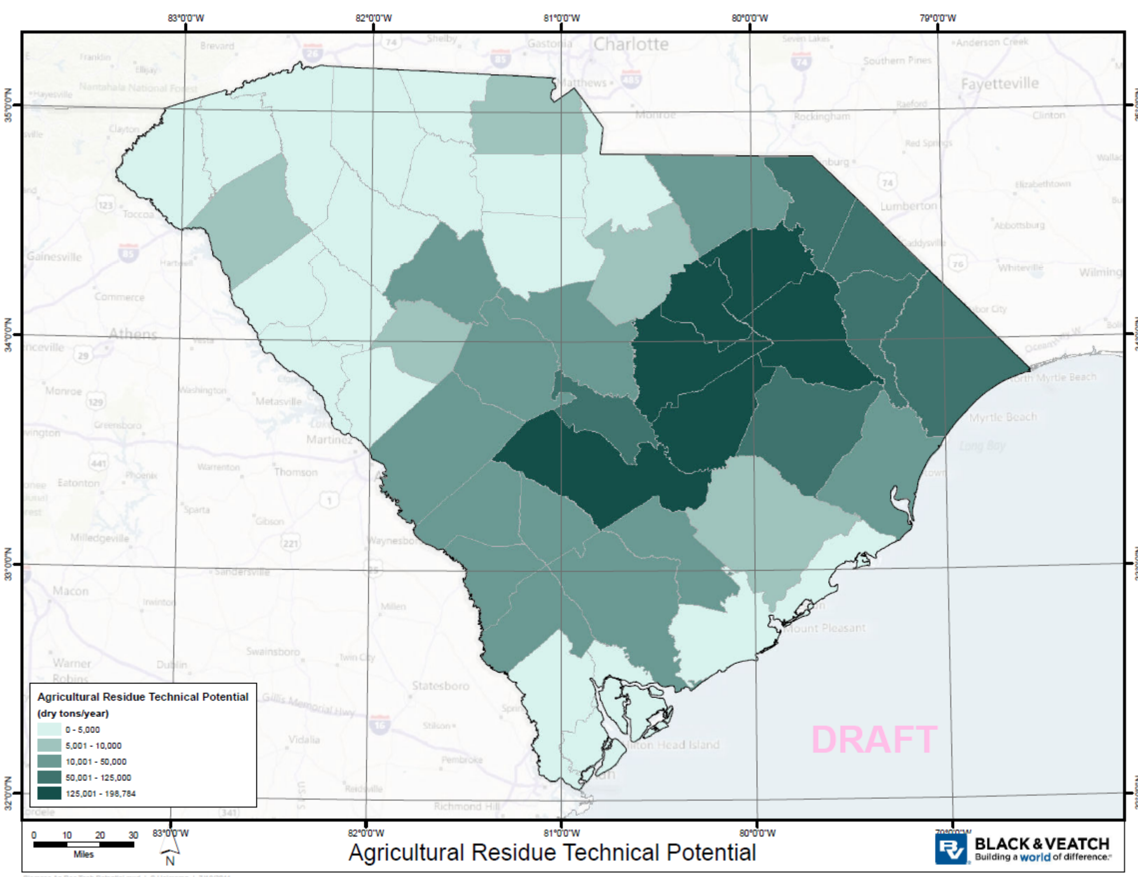

Figure 7-3 Crop Residue Technical Potential by County in South Carolina

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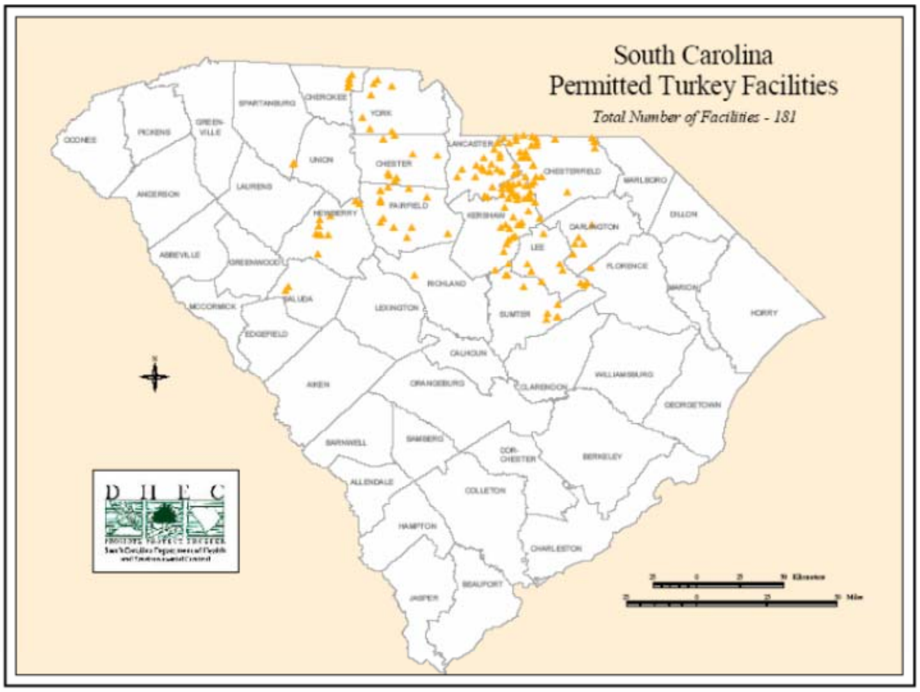
[48] Harris et al., "Potential for Biomass Energy Development in South Carolina," Final Report to the South Carolina Forestry Commission, 2004.

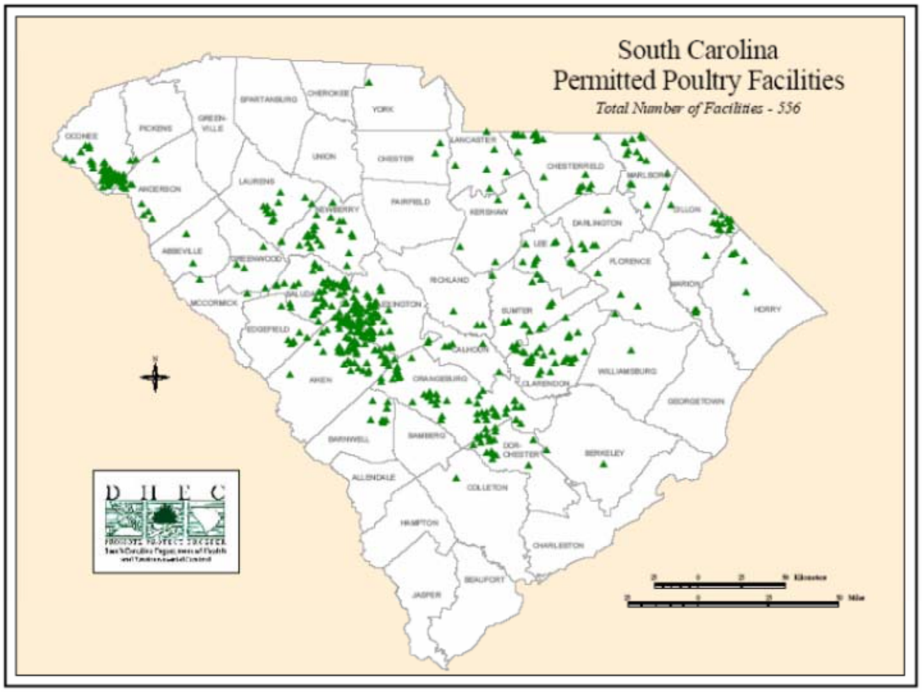
Poultry facilities are located primarily in the northern half of the state, with turkey facilities concentrated in north central South Carolina and chicken facilities concentrated in east central South Carolina, as illustrated in Figure 7-4 and Figure 7-5. Similar to crop residues, poultry litter is typically applied to farmland as fertilizer.[49]



Source: Flora and Riahi-Nezhad (2006)

Figure 7-4 Location of Permitted Turkey Facilities in South Carolina

[49] Joseph R.V. Flora and Cyrus Riahi-Nezhad, "Availability of Poultry Manure as a Potential Bio-fuel Feedstock for Energy Production," Prepared for the South Carolina Energy Office, 2006.



Source: Flora and Riahi-Nezhad (2006)

Figure 7-5 Location of Permitted Chicken Facilities in South Carolina

Energy crops, at present, are not widely cultivated in South Carolina. Research is ongoing at Clemson University and the University of South Carolina to develop various energy crops that may be well-suited for cultivation in South Carolina. A significant amount of idle agricultural lands have been identified within the state. If these agricultural lands were utilized to cultivate energy crops, there would be a moderate potential for energy crop production in the state. However, the cultivation of energy crops in South Carolina is currently limited to relatively small research plots. In the US, there is growing interest in the use of energy crops, and certain utilities (e.g., Alliant Energy and Southern Company) have conducted test burns of energy crops such as switchgrass for power generation.

Agricultural biomass resources included in this study are as follows:

- Crop residues, including:
  - Corn stover.
  - Cotton residues.
  - Soybean residues.
  - Wheat straw.
- Poultry litter.
- Energy crops, including:
  - Switchgrass.
  - Miscanthus or cellulosic sorghum.

7.2.1 Assessment Methodology and Assumptions

To estimate the technical potential of crop residues and poultry litter in South Carolina, Black & Veatch reviewed data compiled by the USDA National Agricultural Statistical Service (NASS) that quantified annual crop production and annual poultry production in South Carolina.[50]

To estimate the potential production of crop residues, Black & Veatch averaged production of each of the four crops under consideration from 2006 to 2010 based on the USDA NASS data. Then, the annual generation of crop residues was calculated using the average production and residue production factors from NREL.[51] Similarly, to calculate the annual poultry litter production in the state, the average populations of both turkeys and chicken broilers from 2006 to 2010 USDA NASS data were multiplied by the respective poultry litter generation factors from a South Carolina Energy Office (SCEO) study on the potential of poultry litter as a biofuel feedstock.[52]

For energy crops, potential production was estimated based on the potentially available acres on idle farm lands and the expected yields for these energy crops.

The next step was to convert the quantities of agricultural biomass to generation capacity (in terms of MW) and electricity production (in terms of GWh). This conversion required a set of assumptions that reflect a representative standalone biomass plant utilizing agricultural biomass. The assumptions are as follows:

- The generation capacity of each standalone biomass power plant is in the range of 15 MW to 50 MW.
- The average NPHR for biomass power plants across the anticipated size range of 15 MW to 50 MW is assumed to be 13,500 Btu/kWh.
- The average capacity factor for a biomass power plant is assumed to be 85 percent.
- The heating value of crop residues and energy crops is assumed to be 8,500 Btu/lb (dry basis). The moisture content of the crop residues is assumed to be in the range of 12 to 15 percent, depending on the type of residue or energy crop. Therefore, the as-received heating value of crop residues and energy crops is 7,200 to 7,500 Btu/lb (as-received), or 14.4 to 15.0 MBtu/ton (as-received).
- The heating value of poultry litter is assumed to be 4,600 Btu/lb (as-received), or 9.2 MBtu/ton (as-received).

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[50] "South Carolina State and County Crop Data," United States Department of Agriculture – National Agricultural Statistics Service (USDA NASS), 2006-2010.
[51] Milbrandt, Anelia, "A Geographic Perspective on the Current Biomass Resource Availability in the United States," National Renewable Energy Laboratory (NREL) Technical Report NREL/TP-560-39181, 2005.
[52] Flora, Joseph R.V. and Cyrus Riahi-Nezhad, "Availability of Poultry Manure as a Potential Bio-fuel Feedstock for Energy Production," Prepared for the South Carolina Energy Office (SCEO), 2006.

7.2.2 Technical Potential of Agricultural Resources

Using the USDA NASS reported average crop production from 2006 to 2010 and NREL's residue production factors, crop residues total 2.28 million tons per year, as shown in Table 7-5.

Table 7-5 Quantities of Crop Residues in South Carolina

CROP/CROP RESIDUE TYPE	AVERAGE CROP PRODUCTION[a,b] (TONS/YEAR)	CROP RESIDUE FACTOR[c] (TON RESIDUE/ TON PRODUCTION)	AVERAGE QUANTITY OF RESIDUES[a] (GREEN TONS/YEAR)
Corn Stover	899,600	1.0	899,600
Cotton Residues	77,900	4.5	350,800
Soybeans Residues	368,600	2.1	774,100
Wheat Straw	226,200	1.3	254,300
Total	**1,572,300**		**2,278,800**

[a]Crop production and quantities of residues available presented in terms of as-received tons per year. Moisture content of these crop residues is anticipated to range from 13% to 15%, depending upon the crop from which the residue is generated.

[b] USDA National Agricultural Statistical Service. Average annual crop production data for a 5-year period from 2006 to 2010.

[c] Anelia Milbrandt Anelia, "A Geographic Perspective on the Current Biomass Resource Availability in the United States," National Renewable Energy Laboratory (NREL) Technical Report NREL/TP-560-39181, 2005.

Using the average poultry population and poultry litter generation factors from SCEO (2006), the amount of poultry litter totals 421,000 tons per year, as shown in Table 7-6.

Table 7-6 Quantities of Poultry Litter in South Carolina

POULTRY TYPE	AVERAGE ANNUAL PRODUCTION[a] (BIRDS/YEAR)	DRY LITTER FACTOR[b] (TONS LITTER/1000 BIRDS PER YEAR)	AVERAGE POULTRY LITTER GENERATION[a,b] (TONS/YEAR)
Chickens (Broilers)	235,540,000	1.2	282,600
Turkeys	11,260,000	12.3	138,500
Total			**421,100**

[a] USDA National Agricultural Statistical Service. Average annual production is based on annual bird production data for a 5-year period from 2006 to 2010.

[b] Flora, Joseph R.V. and Cyrus Riahi-Nezhad, "Availability of Poultry Manure as a Potential Bio-fuel Feedstock for Energy Production," Prepared for the South Carolina Energy Office (SCEO), 2006.

The technical potential from crop residues and poultry litter resources are listed in Table 7-7 and total 372 MW of generation capacity or 2,770 GWh per year of electricity generation.

Table 7-7 Technical Potential of Agricultural Residues in South Carolina

AGRICULTURAL BIOMASS RESOURCE	QUANTITIES AVAILABLE (TONS/YEAR)	ESTIMATED FUEL POTENTIAL[(a)] (MBTU/YEAR)	TECHNICAL POTENTIAL CAPACITY [(c)] (MW)	TECHNICAL POTENTIAL GENERATION[(b)] (GWH/YEAR)
Crop Residues				
Corn Stover	899,600	12,920,000	129	960
Cotton Residues	350,800	5,250,000	52	390
Soybeans Residues	774,100	11,450,000	114	850
Wheat Straw	254,300	3,740,000	38	280
Poultry Litter	421,100	3,870,000	39	290
Total	**2,699,900**	**37,230,000**	**372**	**2,770**

[(a)]Assumed crop residues have a heating value of 8,500 Btu/lb (on a dry basis) and an average moisture content in the range of 12 to 16 percent, corresponding to an as-received heating value of 14.4 to 15.0 MBtu/ton (as-received). For poultry litter, a heating value (on an as-received basis) of 4,600 Btu/lb, or 9.2 MBtu/ton is assumed.

[(b)]NPHR of a biomass fired generation facility is assumed to be 13,500 Btu/kWh.

[(c)]Capacity factor of the biomass fired generation facility is assumed to be 85 percent.

The technical potential of energy crops in South Carolina is based on the use of agricultural lands that are currently idle. Estimates of idle crop land in South Carolina range from 223,000 acres[53] to 450,000 acres.[54] The total production of energy crops would depend upon the average yield of these crops grown on the presently idle acres. According to a researcher at the University of South Carolina, switchgrass has an estimated average yield of 6 dry tons per acre when cultivated on typical agricultural lands in South Carolina, while the average yield of miscanthus or cellulosic sorghum is estimated to be 15 dry tons per acre in South Carolina.[55]

Using the low end of the range of idle crop land in South Carolina (223,000 acres), annual production of switchgrass may be as high as 1.3 million dry tons per year. If miscanthus or cellulosic sorghum were cultivated on the same 223,000 acres of presently idle crop ground, annual production may be as high as 3.3 million dry tons per year. The total potential production of energy crops would not be the sum of the potential of the energy crops listed, because the quantity of idle

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[53] "2007 Census of Agriculture, South Carolina State and County Data," Table 8 – Land: 2007 and 2002, USDA National Agricultural Statistical Service, Available online at: http://www.nass.usda.gov/Statistics_by_State/South_Carolina/index.asp.

[54] Connor et al., "South Carolina's Forests, 2006," Table 1 – Total Land and Water Area in South Carolina by Land Use and Survey Year, USDA Forest Service – Southern Research Station, Resource Bulletin SRS-158.

[55] Personal communication with Dr. Stephen Kresovich, University of South Carolina.

crop land is finite. The range of potential production of energy crops is, therefore, 1.3 to 3.3 million dry tons or 22,750,000 to 56,870,000 MBtu per year, depending on the mix of energy crops grown. The estimate of technical potential of energy crops in South Carolina is presented in Table 7-8. The capacity potential is equal to approximately 230 to 570 MW, generating 1,690 to 4,210 GWh of electricity per year.

Table 7-8 Technical Potential of Energy Crops in South Carolina

ENERGY CROP RESOURCE	ESTIMATED POTENTIAL PRODUCTION (DRY TONS/YEAR)	ESTIMATED FUEL POTENTIAL [(a)] (MBTU/YEAR)	TECHNICAL POTENTIAL CAPACITY [(c)] (MW)	TECHNICAL POTENTIAL GENERATION [(b)] (GWH/YEAR)
Switchgrass	1,338,000	22,750,000	227	1,690
Miscanthus or Sorghum[(d)]	3,345,000	56,870,000	565	4,210

[(a)]Switchgrass, miscanthus and sorghum assumed to have an average heating value of 8,500 Btu/lb (on a dry basis), corresponding to a heating value of 17 MBtu/dry ton.

[(b)]NPHR of the biomass fired generation facility assumed to be 13,500 Btu/kWh.

[(c)]The capacity factor of the biomass fired generation facility assumed to be 85 percent.

[(d)]There are several types of sorghum that may be grown as an energy crop. The most promising type of sorghum for boiler fuel applications is cellulosic sorghum, which may have an anticipated annual yield of 15 dry tons per acre. A yield of this magnitude would be similar to that of miscanthus.

7.2.3 Relevant Information Provided by Stakeholders

The comments presented in this section are from individual or multiple stakeholders that Black & Veatch interviewed during this process. These comments are not Black & Veatch conclusions or recommendations but are provided for informational purposes.

Relevant comments provided by representatives and staff of South Carolina utilities, universities, and appropriate energy industry organizations regarding agricultural biomass resources include the following:

- Stakeholders generally agreed that while there are moderate quantities of crop residues available in the state, woody biomass resources appear preferable to crop residues for renewable energy projects. None of the stakeholders were aware of any proposed biomass projects in the state that intended to fire crop residues.
- One stakeholder mentioned that crop residues and energy crops may be more attractive for biofuel applications than for bioenergy applications.
- Multiple stakeholders noted that moderate-scale (20 MW to 50 MW) poultry litter fired projects have been proposed on multiple occasions, but opposition to these projects has been sufficient to discourage further development.
- A researcher at the University of South Carolina stated that energy crops such as switchgrass, miscanthus, and sorghum are suitable for cultivation in South Carolina and no technical barriers exist to their widespread development. However, stakeholders at multiple utilities noted that they are unaware of any commercial growers of energy crops within the state.

7.2.4 Constrained Potential of Agricultural Resources

The technical potential of agricultural biomass resources is limited by certain agronomic and logistical constraints. In addition, the use of agricultural biomass as a feedstock for bio-fuel production may be preferable to power generation. Crop residues are available on a seasonal basis rather than throughout the year and have a relatively low energy density (in terms of Btu/ft^3). In addition, at least a portion of the crop residues must be retained on the crop lands to recycle soil nutrients and provide erosion control. Poultry litter does not have seasonal constraints, but portions of the existing poultry litter supply are currently utilized as fertilizer. Energy crops also have certain seasonality limitations and are not currently widely available in the state.

While significant quantities of crop residues are generated on an annual basis, collection of these residues is not a common agricultural practice in South Carolina. Of the crop residues considered in this study, only the collection of corn stover appears to be practical given today's agricultural practices. Because croplands used to grow wheat are typically replanted with soybeans immediately after the wheat harvest, the collection of wheat straw would delay the planting of soybean and would cause significant reduction in soybean yields.[56] Furthermore, residues of soybeans and cotton are not typically collected in South Carolina or any other region within the US, and Black & Veatch is unaware of any bioenergy projects that have been proposed using these crop residues in the US.

Corn stover is collected in other regions of the country, such as the Midwest. If crop residues were to be used for energy production, the techniques developed in the Midwest for corn stover collection could be applied in South Carolina. However, agronomists recommend that at least one-third of corn stover remain in the field to recycle nutrients and minimize erosion. In addition, corn stover resources are relatively dispersed, making collection and delivery to a central location challenging. For these reasons, Black & Veatch has assumed that 35 percent of the total corn stover generated on an annual basis (as listed in Table 7-7) may be available for electricity production.

A portion of the poultry litter produced in the state is currently applied on fields as fertilizer, so not all of the supply identified in Table 7-7 may be accessible for energy production. Furthermore, similar to corn stover, poultry litter resources are somewhat dispersed, making collection and delivery to a central location challenging. Thus, only 50 percent of the previously identified supplies (as shown in Table 7-7) is assumed to be available for electricity production. The amount may be different depending on the relative value of the resource as a fuel or fertilizer.

[56] Harris et al., "Potential for Biomass Energy Development in South Carolina," Final Report to the South Carolina Forestry Commission, 2004.

The constrained potential for crop residue resources and poultry litter resources are shown in Table 7-9.

Table 7-9 Constrained Potential of Agricultural Residues in South Carolina

AGRICULTURAL RESIDUES RESOURCE	QUANTITIES AVAILABLE (TONS/YEAR)	ESTIMATED FUEL POTENTIAL (a) (MBTU/YEAR)	CONSTRAINED POTENTIAL CAPACITY (c) (MW)	CONSTRAINED POTENTIAL GENERATION (b) (GWH/YEAR)
Crop Residues				
Corn Stover	314,860	4,520,000	44	330
Cotton Residues	0	0	0	0
Soybeans Residues	0	0	0	0
Wheat Straw	0	0	0	0
Poultry Litter	210,550	1,930,000	19	140
Total	**525,410**	**6,450,000**	**63**	**470**

(a) Assumed crop residues have a heating value of 8,500 Btu/lb (on a dry basis) and an average moisture content in the range of 12 to 16 percent, corresponding to an as-received heating value of woody biomass of 14.4 to 15.0 MBtu/ton (as-received). For poultry litter, a heating value (on an as-received basis) of 4,600 Btu/lb, or 9.2 MBtu/ton is assumed.

(b) NPHR of the biomass fired generation facility is assumed to be 13,500 Btu/kWh.

(c) Capacity factor of the biomass fired generation facility is assumed to be 85 percent.

As mentioned previously, energy crops are not currently cultivated by commercial growers in South Carolina. It is feasible that these energy crops could be grown on croplands that are presently idle in the state. However, there are a few challenges to the development of energy crops for electricity production compared to woody and agricultural residues, including the following:

- The production costs of energy crops (on a $/MBtu basis) will likely be higher than those of other biomass fuels for electricity production, so the other biomass fuels would be consumed prior to energy crops.
- An integrated supply chain must be developed in conjunction with a power generation project, so sufficient energy crops are cultivated to meet its need.
- Energy crops may be more suitable for the production of biofuels and/or direct (thermal) heating rather than the production of energy, though the cellulosic biofuel market is still in its early phases as well.

Considering these barriers, it was assumed that the constrained potential of energy crops for the production of electricity may be represented by the growth of energy crops on 10 percent of the idle lands identified by USDA NASS. To estimate the constrained potential of energy crops for the production of electricity, it was assumed that either switchgrass (with an anticipated yield of 6 dry tons per acre) or miscanthus or sorghum (each with an anticipated yield of 15 dry tons per acre) could be cultivated on approximately 23,000 acres or 10 percent of presently idle croplands. Because of the variations in anticipated yield, a range of constrained potential of energy crops was developed, as shown in Table 7-10.

Table 7-10 Constrained Potential of Energy Crops in South Carolina

ENERGY CROP RESOURCE	ESTIMATED POTENTIAL PRODUCTION (DRY TONS/YEAR)	ESTIMATED FUEL POTENTIAL [(a)] (GBTU/YEAR)	CONSTRAINED POTENTIAL CAPACITY [(c)] (MW)	CONSTRAINED POTENTIAL GENERATION [(b)] (GWH/YEAR)
Energy Crops[(d)]	135,600 to 339,000	2,310 to 5,700	23 to 56	170 to 420

[(a)]Assumed that switchgrass, miscanthus and sorghum have an average heating value of 8,500 Btu/lb (on a dry basis), corresponding to a heating value of 17 MBtu/dry ton.

[(b)]It is assumed that the NPHR of the biomass fired generation facility is 13,500 Btu/kWh.

[(c)]Assumed that the capacity factor of the biomass fired generation facility is 85 percent.

[(d)]Assumed that energy crops may be grown on 10 percent of the idle acres identified by USDA. The range represents the potential from switchgrass or miscanthus or cellulosic sorghum.

Additional considerations for the constrained potential for agricultural biomass include the following:

- Due to the seasonality of crop residues and, to a lesser extent, energy crops, labor-intensive collection activities would be required to be completed in a relatively short period of time. Following collection, significant stock piles of these resources would be required, unless the material is co-fired with other fuels, such as coal, woody biomass or poultry litter. Power plants would need to be designed to accept multiple fuel streams. Due to the bulkiness of crop residues, the long-term storage of crop residues presents another logistic challenge.
- Because crop residues and energy crops have the potential to contain relatively high quantities of alkalis, such as sodium [Na] and potassium [K], and chlorine relative to those of woody fuels, combustion systems firing these agricultural fuels may require special design and/or operating considerations.
- Since neither crop residues nor energy crops are currently collected and delivered to existing markets for these resources, the supply chains for these resources must be developed as part of any significant investment in agricultural biomass fired projects.
- While the use of crop residues and energy crops is not prevalent in the United States, there are multiple projects that utilize these types of resources in Europe.

7.2.5 Data Sources and References

- Flora, Joseph R.V. and Cyrus Riahi-Nezhad, "Availability of Poultry Manure as a Potential Bio-fuel Feedstock for Energy Production," Prepared for the South Carolina Energy Office (SCEO), 2006.
- Harris, Robert A. et al., "Potential for Biomass Energy Development in South Carolina," Final Report to the SCFC, 2004.
- United States Department of Agriculture – National Agricultural Statistics Service (USDA NASS), "2007 Census of Agriculture, South Carolina State and County Data," 2007.
- United States Department of Agriculture – National Agricultural Statistics Service (USDA NASS), "South Carolina State and County Crop Data," 2006-2010.

7.3 ORGANIC WASTE RESOURCES

Organic waste resources generally fall into one of two categories: organic human wastes or organic animal wastes. Organic human wastes include sewage sludge and discarded FOG and are generally concentrated in areas with high population densities. Organic animal wastes include animal manures with high moisture content, such as swine or dairy manure and are available within concentrated animal feeding operations (CAFOs). The most practical method of deriving electricity from organic waste resources involves the conversion of these wastes to a methane-rich biogas via anaerobic digestion and then combusting the biogas in a reciprocating engine or gas turbine.

Anaerobic digestion is the decomposition of biological wastes by microorganisms, usually under wet conditions, in the absence of air (specifically oxygen), to produce a gas comprising mostly methane and carbon dioxide. Anaerobic digesters have been used for municipal and agricultural waste treatment for many years. Traditionally, the primary drivers for anaerobic digestion projects have been waste reduction and stabilization, rather than energy generation.

Increasingly stringent agricultural manure and sewage treatment management regulations and growing interest in renewable energy generation has led to heightened interest in the potential for anaerobic digestion of organic wastes. Larger projects benefit from economies of scale and hold the most potential to be viable for the production of renewable energy.

The treatment of municipal wastewater at wastewater treatment facilities (WWTFs) produces sewage sludge. Anaerobic digestion is commonly used in municipal wastewater treatment as a first-stage treatment process for sewage sludge. For WWTFs with digestion systems, utilization of the biogas typically has been a secondary consideration. Generation systems are rarely optimized for energy production, and it is more common for treatment facilities to flare the biogas. Converting the biogas to usable thermal energy or electricity may provide benefits such as offsetting onsite electrical and/or thermal demand or providing a revenue stream through the sale of renewable electricity. Anaerobic digesters are employed at 13 WWTF in South Carolina, but only one appears to be utilizing the gas.[57]

Within many metropolitan areas of the United States, collection of discarded FOGs (primarily yellow grease and brown grease) is increasing. A recent study by Moore and Myers estimated the quantities collected on an annual basis in South Carolina.[58] As defined by Moore and Myers, yellow grease is spent cooking oil and other fats and oils collected from commercial or industrial cooking operations, while brown grease is oil collected from grease traps that are installed in commercial, industrial or municipal sewage facilities to separate grease and oil from waste water. The digestion of these greases can yield significant quantities of biogas, particularly if co-digested with sewage sludge in existing WWTF digestion systems. However, several caveats are noted regarding the digestion of FOGs:

- FOGs must be limited (with FOGs representing less than 30 percent of the volatile solids within the digester) to prevent "foaming" within the digester.
- The type of oil contained in yellow or brown grease may impact digester operation. Polyunsaturated oils are more soluble and more likely to ionize and therefore digest better. Saturated and monounsaturated oils can become toxic to the digestion of microorganisms at high concentrations. Pretreatment at high temperatures and pressures will solubilize the saturated fats, making them more digestible.
- Brown grease must go through an initial pretreatment step to remove debris prior to entering digestion systems.
- FOGs may also be used as a feedstock for the production of biodiesel, which may compete with its use in anaerobic digestion at WWTFs.

Animal manures from CAFO facilities provide another opportunity for the creation of biogas through anaerobic digestion. Farm-based digestion projects are generally less than 400 kW in size and typically rely on relatively simple technologies, such as covered lagoon or horizontal plug flow reactors. The animal type, population, and manure collection/ management system are the largest factors in determining the potential and feasibility of a farm-based digestion project. Technology type and process parameters, such as temperature and residence time, also influence the biogas production potential. In recent years, there has been a trend toward larger, more advanced complete mix digesters. A photo of a dairy manure digester is provided in Figure 7-6.

[57] Revised Database from Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities (WWTFs), EPA CHPP, Updated 2010 (unpublished) by NACWA, CASA, and Black & Veatch.

[58] Travis Moore and Erika H. Myers, "An Assessment of the Restaurant Grease Collection and Rendering Industry in South Carolina," Report for the Southeastern Regional Biomass Energy Program, Revised September 1, 2010, by Tara Copeland and Erika H. Myers.

Figure 7-6 Dairy Manure Digester

7.3.1 Assessment Methodology and Assumptions

In a report for the South Carolina Office of Energy, Hayes Seay Mattern & Mattern, Inc. (HSMM) quantified the sewage sludge (in terms of dry tons per year) based on average daily flow during 2006, for each WWTF in South Carolina.[59] In a separate report for the Southeastern Regional Biomass Energy Program, the annual quantity of FOGs (in terms of gallons per year) available in South Carolina was estimated.[60] Incorporating the quantities of organic human wastes identified in South Carolina by these studies, Black & Veatch calculated the potential for biogas production, generation, and capacity assuming the anaerobic digestion of sewage sludge and FOGs at WWTF. Calculations for anaerobic digestion of sewage sludge assumed the following:

- The digestion of 1 dry ton of sewage sludge yields 11,250 standard cubic feet (scf) of biogas, with a heating value of the biogas of 600 Btu/scf.
- The thermal efficiency of the conversion of biogas to electricity is 35 percent.
- Therefore, the anaerobic digestion of 1 dry ton of sewage sludge can produce enough biogas to generate approximately 690 kWh of electricity.

Calculations for anaerobic digestion of FOGs assumed the following:

- Yellow and pretreated brown grease have a density of 7.5 lb per gallon.
- The total solids (TS) percentage of grease is 98 percent.
- The volatile solids (VS) of grease represent 95 percent of TS.

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[59] Hayes, Seay, Mattern & Mattern, Inc., "Bioenergy from Municipal Sludge Study," Report for the South Carolina Office of Energy, 2006.
[60] Moore, Travis and Erika H. Myers, "An Assessment of the Restaurant Grease Collection and Rendering Industry in South Carolina," Report for the Southeastern Regional Biomass Energy Program, revised September 1, 2010, by Tara Copeland and Erika H. Myers.

- Digestion results in volatile solids reduction (VSR) of 80 percent.
- The biogas production rate associated with the digestion of grease is 19.5 scf per lb of VSR, with a heating value of the biogas of 600 Btu per scf.
- The thermal efficiency of the conversion of biogas to electricity is 35 percent.
- Therefore, the anaerobic digestion of 1 gallon of grease can produce enough biogas to generate approximately 6.7 kWh of electricity.

Black & Veatch received information on the state's dairy and swine CAFO facilities from the South Carolina Department of Health and Environmental Control (SCDHEC). CAFO facilities are permitted through the SCDHEC for a certain number of animals (i.e., head of livestock) within the facility. There were approximately 140 permitted dairy and swine CAFO facilities in the state in 2011.

Black & Veatch used the EPA AgStar methodology for estimating digestion potential.[61] The digestion potential of organic animal wastes is based on the listed parameters below. Values of these parameters are provided in Table 7-11.

- Number of animals
- Volatile solids excretion rate
- Typical animal mass
- Methane (CH_4) production and heating value
- Thermal to electric efficiency
- System capacity factor

[61] U.S. EPA AgStar, "Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities,." December 2010.

Table 7-11 Parameters for Anaerobic Digestion Estimate

LIVESTOCK TYPE	DAIRY CATTLE	SWINE
Number of head	From SCDHEC	From SCDHEC
Volatile Solids Excretion Rate, * lb/1,000 lb animal-day	11.5	5.5
Typical Animal Mass (TAM), lb *	1,200	150
CH_4 Production, ft^3/lb VS *	4.2	6.6
CH_4 Heating Value, Btu/ft^3	923	923
Thermal to Electric Efficiency, %	35%	35%
Capacity Factor, %	90%	90%

Source: U.S. EPA, "Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities," December 2010.
Notes:
*From U.S. EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009," April 2011.

Waste material from CAFO facilities located near each other could potentially be combined to supply a larger, more viable project. Thus, the technical potential assumes that waste material may be transported to a central location, so all facilities are included in the technical potential. For the constrained potential, Black & Veatch's analysis considers only individual farms. The constrained potential includes facilities with at least a minimum head of animals (500 head for dairy cattle and 2,000 head for swine), as recommended by the EPA AgStar program.

7.3.2 Technical Potential of Organic Waste

The technical potential of anaerobic digestion of sewage sludge within the state of South Carolina is based on the total annual amount of sewage sludge generated in the state, as quantified by HSMM. The total biogas potential from sewage sludge is approximately 702,000 MBtu per year or equivalent to 9.7 MW in capacity. Similarly, the technical potential of FOGs is based on the total annual quantities of yellow grease and brown grease, as quantified by Moore and Myers. The biogas potential from yellow grease and brown grease total about 1,254,000 MBtu per year or equivalent to 17.3 MW of capacity, which is almost twice as much as sewage sludge. The total technical potential associated with organic human wastes in South Carolina is shown in Table 7-12.

Table 7-12 Technical Potential of Organic Human Wastes in South Carolina

ORGANIC HUMAN WASTE	ESTIMATED ANNUAL GENERATION[a] (DRY TONS/ YEAR)	ESTIMATED FUEL POTENTIAL (MBTU/YEAR)	TECHNICAL POTENTIAL CAPACITY (MW)	TECHNICAL POTENTIAL GENERATION (GWH/YEAR)
Sewage Sludge	104,000	702,000	9.7	72.0
(FOGs				
Yellow Grease	101,625	1,240,000	17.1	127.1
Brown Grease	820	14,400	0.2	1.5
Total	**206,445**	**1,956,400**	**27.0**	**200.6**

[a]For sewage sludge, quantity as reported by HSMM, Inc. (2006). For FOGs, Moore and Myers reported quantities of 27.1 million gallons of yellow grease and approximately 220,000 gallons of brown grease. It is assumed that these greases have a density of 7.5 lb/gal.

To determine the technical potential of organic animal wastes, Black & Veatch included the potential from all permitted dairy and swine operations in the state. The potential is based on the maximum permitted livestock head at each facility and the other parameters provided in Table 7-11. The maximum number of animals allowed by the facility permit may not be the exact number of animals at each facility.

There are a total of 54 permitted dairy facilities and 85 permitted swine facilities in South Carolina. These facilities range widely in the maximum number of animals permitted, from about 80 to 3,500 for dairy and about 15 to 46,000 for swine.

The results of the digestion technical potential analysis for organic animal waste are summarized in Table 7-13.

Table 7-13 Technical Potential of Organic Animal Wastes in South Carolina

PARAMETER	DAIRY CATTLE	SWINE
Number of Farms	54	85
Total Licensed Head (at all farms)	30,000	490,000
Annual CH_4 Production, MBtu/yr[a]	579,000	877,000
Estimated Generation, GWh/yr[b]	59	90
Estimated Capacity, MW[c]	7.5	11.4

[a]CH_4 Production assumes LHV of 923 Btu/ft^3 CH_4.
[b]Generation assumes 35 percent thermal to electric conversion efficiency.
[c]Capacity estimate based on 90 percent capacity factor.

The technical potential of organic animal waste in South Carolina is about 7.5 MW from dairy facilities and 11 MW from swine facilities, if all facilities in the state are considered. However, there is a threshold for projects to be considered viable and practical.

7.3.3 Relevant Information Provided by Stakeholders

The comments presented in this section are from individual or multiple stakeholders that Black & Veatch interviewed during this process. These comments are not Black & Veatch conclusions or recommendations but are provided for informational purposes.

Relevant comments provided by representatives and staff of South Carolina utilities, universities, and appropriate energy industry organizations regarding organic waste resources include the following:

- Representatives of Santee Cooper noted that the 180 kW project at Burrows Hall hog farm in Williamsburg County is under contract and expected to come online late summer 2011. There are other opportunities from farm-based AD projects in the state, but the projects are small (typically in the kW range) compared to other biomass technologies.
- Similar to solar PV projects, the barriers to the development of additional anaerobic digestion projects are considered to be primarily economic rather than technological. The small scale of these projects is generally less attractive to utilities from an economic standpoint.

7.3.4 Constrained Potential of Organic Waste

For organic human wastes, the constrained potential of these resources is significantly less than the technical potential. Candidate WWTFs for digestion systems should process at least 5 million gallons of water per day (mgd).[62]

For sewage sludge, the number of potential facilities that meet the 5mgd criteria decreases from 321 to 18. These facilities are listed in Table 7-14.

Table 7-14 WWTFs with Constrained Potential for Digestion of Sewage Sludge

WASTEWATER TREATMENT FACILITY	ESTIMATED ANNUAL GENERATION (a) (DRY TONS/ YEAR)	ESTIMATED FUEL POTENTIAL (MBTU/YEAR)	CONSTRAINED POTENTIAL CAPACITY (MW)	CONSTRAINED POTENTIAL GENERATION (GWH/YEAR)
Columbia/Metro	10,120	68,310	0.9	7.0
Charleston CPW/Plum Island	6,530	44,078	0.6	4.5
WCRS/Maudlin Road	5,730	38,678	0.5	4.0
NCSD/Felix C Davis	3,770	25,448	0.4	2.6

[62] Eastern Research Group, Inc. (ERG) and Energy and Environmental Analysis, Inc. (2007). *Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities*. Report prepared for the U.S. Environmental Protection Agency, Combined Heat and Power Partnership. Available online at: http://www.epa.gov/chp/documents/wwtf_opportunities.pdf.

Aiken PSA/Horse Creek	3,600	24,300	0.3	2.5
GSW&SA/Myrtle Beach WRF.	3,140	21,195	0.3	2.2
Sumter/Pocataligo River	2,820	19,035	0.3	2.0
Florence/Pee Dee River	2,750	18,563	0.3	1.9
Rock Hill/Manchester Creek	2,730	18,428	0.3	1.9
East Rich Co PSD/Gills Creek	2,670	18,023	0.3	1.8
BCW&SA/Lower Berkeley	2,640	17,820	0.3	1.8
Greenwood/Wilson Creek	2,530	17,078	0.2	1.8
SSSD/Fairforest	2,320	15,660	0.2	1.6
GSW&SA/Schwartz	2,240	15,120	0.2	1.6
WCRSA/Pelham	1,820	12,285	0.2	1.3
Summerville	1,700	11,475	0.2	1.2
Cayce	1,620	10,935	0.2	1.1
WCRSA/Lower Reedy	1,560	10,530	0.2	1.1
Total	**60,300**	**406,960**	**5.6**	**41.7**

[a]Quantity as reported by HSMM, Inc. (2006).

The constrained potential of sewage sludge resources may increase if these resources were collected and processed at a central location rather than at existing WWTFs. However, this strategy would only marginally increase constrained potential of sewage sludge.

For the constrained potential of FOGs, the collection and anaerobic digestion of greases is considered practical in only metropolitan areas, where the concentrations of facilities generating these greases are the greatest. Moore and Myers estimate that 70 to 95 percent of the yellow grease is collected in metropolitan areas, reducing the practical supply of FOGs from 27.3 million gallons to a range of 19.1 to 25.9 million gallons. FOGs can also be used as a feedstock in the production of biodiesel and No. 6 fuel oil. While there are a number of methods for electricity production from FOGs that have been studied, Black & Veatch anticipates that co-digesting FOGs in existing WWTF digesters is the most practical strategy in the near term.[63] However, as noted above, FOGs would need to be limited to 30 percent of the volatile solids within the digester. Taking these considerations into account, Black & Veatch estimated the quantities of FOGs that may be co-digested at the WWTF identified as practical facilities for anaerobic digesters (i.e., those facilities listed in Table 7-14). The total constrained potential of FOGs for anaerobic digestion applications would be about 25,800 tons per year, or approximately 6.9 million gallons per year; the remainder could potentially be used as a feedstock for biodiesel applications. The constrained potential of organic human wastes for electricity generation is listed in Table 7-15.

Table 7-15 Constrained Potential of Organic Human Wastes in South Carolina

ORGANIC HUMAN WASTE	ESTIMATED PRACTICAL ANNUAL GENERATION (DRY TONS/ YEAR)	ESTIMATED FUEL POTENTIAL (MBTU/YEAR)	CONSTRAINED POTENTIAL CAPACITY (MW)	CONSTRAINED POTENTIAL GENERATION (GWH/YEAR)
Sewage Sludge	60,300	406,960	5.6	41.7
FOGs	25,800	449,650	6.2	46.1
Total	**86,100**	**856,610**	**11.8**	**87.8**

[a]For sewage sludge, quantity as reported by HSMM, Inc. (2006). For FOGs, Moore and Myers reported quantities of 27.1 million gallons of yellow grease and approximately 220,000 gallons of brown grease. It is assumed that these greases have a density of 7.5 lb/gal.

[63] FOG as a single source for digestion is difficult to control due to the lack of buffering capacity, high volatile fatty acids (VFA) production and the lack of appreciable nitrogen (N) and phosphorous (P) in the FOG. FOG can also be incinerated in a waste-to-energy facility or converted to biodiesel or No. 6 fuel oil and then combusted for electricity generation, but both pose greater air emissions concerns.

For the constrained potential of organic animal wastes, Black & Veatch limited the practical projects for development to facilities with a minimum head per facility (500 head for dairy cattle and 2,000 head for swine). EPA AgStar recommends these as the minimum requirements to support AD projects.

According to the SCDHEC information, there are 16 dairy facilities with more than 500 head and 56 swine facilities with more than 2,000 head. Combined, these facilities could provide about 16 MW of capacity. The constrained potential estimate is summarized in Table 7-16.

Table 7-16 Constrained Potential of Organic Animal Wastes in South Carolina

PARAMETER	DAIRY CATTLE	SWINE
Number of Farms (with at least 500 dairy cattle or 2,000 swine)	16	56
Number of Head	20,600	467,000
Annual CH_4 Production, MBtu/yr[(a)]	399,000	834,000
Estimated Generation, GWh/yr[(b)]	41	85
Estimated Capacity, MW[(c)]	5.2	10.8

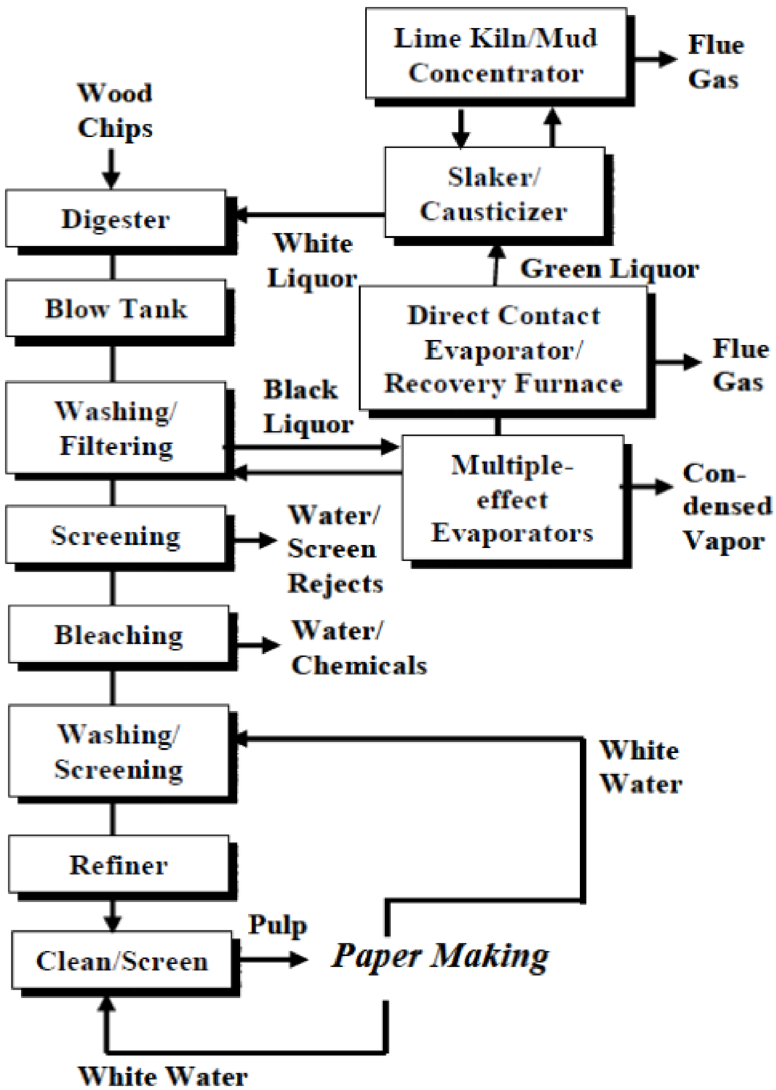
[(a)] CH_4 Production assumes LHV of 923 Btu/ft^3 CH_4.
[(b)] Generation assumes 35 percent thermal to electric conversion efficiency.
[(c)] Capacity estimate based on 90 percent capacity factor.

7.3.5 Data Sources and References

- Eastern Research Group, Inc. (ERG) and Energy and Environmental Analysis, Inc., "Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities," report prepared for the US Environmental Protection Agency, Combined Heat and Power Partnership, http://www.epa.gov/chp/documents/wwtf_opportunities.pdf.
- Hayes, Seay, Mattern & Mattern, Inc., "Bioenergy from Municipal Sludge Study," Report for the South Carolina Office of Energy, 2006.
- Moore, Travis and Erika H. Myers, "An Assessment of the Restaurant Grease Collection and Rendering Industry in South Carolina," Report for the Southeastern Regional Biomass Energy Program, 2006,revised September 1, 2010, by Tara Copeland and Erika H. Myers.
- SCDHEC, Water Permitting, CAFO Regulations.
- US EPA AgStar, "Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities," December 2010.
- US EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009," April 2011.

7.4 PULPING LIQUOR RESOURCES

Pulping liquors are generated as part of the kraft pulping process employed in several pulp and paper mills in operation in South Carolina. These liquors, consisting of black liquor, green liquor, and white liquor, are key intermediary products within the chemical recovery process associated with the kraft process, as shown in Figure 7-7. The chemical recovery process recycles a significant portion of the pulping digestion chemicals used in the initial steps of the kraft process, minimizing the total consumption of these chemicals. For facilities employing kraft pulping process, a significant portion of the mill's energy demands are met by combustion of black liquor.



Source: Energetics Incorporated (2005)

Figure 7-7 Schematic of Kraft Pulping Process

Black liquor contains the portions of the mill feedstocks (i.e., wood) not used for paper making. Two significant organic components of black liquor are lignin and the sap of the tree. Lignin is the component of wood that serves to bind wood fibers together, increasing the rigidity of raw wood. Lignin contains the bulk of the energy content of the wood and provides significant energy through combustion in the recovery furnace.[64] The portion of black liquor derived from tree sap may be separated from the liquor stream during evaporation and may be used as a chemical feedstock.[65]

The combustion of the organic portions of the black liquor produces (1) molten inorganic smelt and (2) superheated steam (which is used as process heat in the paper-making process and/or is used to drive a steam turbine to generate electricity). The inorganic smelt that remains following the combustion of black liquor is reprocessed to produce green liquor and subsequently into white liquor, which is reintroduced into the wood pulp digester to initiate the kraft pulping process.[66] Thus, the combustion of black liquors is part of an essential chemical cycle within the kraft process. The creation and consumption of black liquor are integral to both the chemical and energy processes of a mill and cannot be separated from these processes.

There are six pulp and paper mills currently in operation in South Carolina that employ kraft pulping processes,[67] and the quantities of the black liquor generated at these facilities are listed in Table 7-17. These facilities have a combined steam turbine capacity of 508 MW. Almost all of the black liquor generated at pulp and paper mills in South Carolina is currently utilized for the cogeneration of process heat and electricity to satisfy mill demands. Cogeneration is considered to be the most efficient and practical use of the resource, so there is little to no excess black liquor to use for any other purpose.

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[64] American Forest & Paper Association, "What is Black Liquor?"

[65] The sap from softwood pines is also a component of black liquor (approximately 3 to 5 percent of the solid portion of black liquor stream) at mills processing these woods. This portion of the black liquor is known as black liquor soap skimmings (BLSS), and in some facilities, BLSS is extracted prior to the recovery furnace and used for the production of bio-based chemicals. Following extraction, BLSS is mixed with acid to form Crude Tall Oil (CTO). CTO is a sustainable and renewable chemical raw material used in the production of a wide range of bio-based chemicals, including adhesives, printing inks, hand cleaners, paints, lubricants, emulsifiers, and other products.

[66] Energetics Incorporated, "Energy and Environmental Profile of the U.S. Pulp and Paper Industry," Report to the US Department of Energy, Office of Energy Efficiency and Renewable Energy – Industrial Technologies Program, 2005.

[67] Lockwood-Post Online Directory of Pulp & Paper Mills, last modified March 2011.

Table 7-17 Estimated Black Liquor Generated at SC Pulp Mills

PULP AND PAPER MILL	RECOVERY BOILER SOLIDS CAPACITY[a,b] (TONS/DAY)	ESTIMATED ANNUAL GENERATION OF BLACK LIQUOR SOLIDS[c] (TONS/YEAR)	TOTAL STEAM TURBINE CAPACITY (MW)
Abitibi Bowater – Catawba	2,475	767,900	55
Domtar – Marlboro (Bennettsville)	2,200	682,600	50
International Paper – Eastover	3,650	1,132,400	110
International Paper – Georgetown	2,820	874,900	96
KapStone – North Charleston	3,725	1,155,700	99
RockTenn – Florence	1,500	465,400	98
Total	**16,370**	**5,078,900**	**508**

Source: Lockwood-Post Online Directory of Pulp & Paper Mills (Updated March 2011).

[a]For pulp mills, the mill typically operates with the recovery boiler at full load. Therefore, it is assumed that on a typical day, the mill generates a quantity of black liquor equivalent to its recovery boiler capacity.
[b]For facilities with multiple recovery boilers, the capacity listed is the sum of the capacities of all recovery boilers onsite.
[c]Annual generation of black liquor solids is calculated by Black & Veatch. It is assumed that the recovery boilers typically operate at full load with an annual capacity factor of 85 percent.

Therefore, there is no incremental resource potential derived from black liquor. While there is little to no unutilized pulping liquors available for incremental renewable electricity generation, it is plausible that specific pulp and paper mills may be able to identify efficiency improvements that would result in additional electrical or thermal energy production (e.g., the installation of an upgraded boiler or turbine-generator) that would be in excess of onsite demand. It is recommended that operators of such facilities be engaged to determine (1) if such opportunities exist and (2) if opportunities exist, what conditions would be required to encourage the execution of energy efficiency upgrades at the facility.

7.4.1 Data Sources and References

- American Forest & Paper Association, "What is Black Liquor?"
- Energetics Incorporated, "Energy and Environmental Profile of the U.S. Pulp and Paper Industry," Report prepared for the US Department of Energy, Office of Energy Efficiency and Renewable Energy – Industrial Technologies Program, 2005.
- Lockwood Post Online Directory of Pulp & Paper Mills, last modified March 2011.

8.0 Waste Oil Resources

Waste oil is defined in this section as used oil refined from crude oil or made from synthetic materials (i.e., derived from coal, shale or polymers), per the US EPA. The oil must have been “used as a lubricant, coolant, heat (non-contact) transfer fluid, hydraulic fluid (e.g., transmission fluid), heat transfer fluid, or for a similar use.” The waste oil must be contaminated by physical or chemical impurities due to its use.[68]

In 1991, South Carolina enacted the S. C. Solid Waste Policy and Management Act of 1991, which prohibits the disposal of used oil in landfills, sewers, drainage systems, septic tanks, surface water or groundwater and on the ground. This legislation also prohibits the use of oil for road oiling, dust control, weed abatement and other uses that have the potential to harm the environment.

A factsheet prepared by the South Carolina Department of Health and Environmental Control (DHEC) notes the following:[69]

- Motor oil recycling programs for “do-it-yourselfers” (“DIYers”) collected more than 995,000 gallons of used motor oil in 2009, and these programs have collected more than 16 million gallons of used motor oil since 1990.
- Used motor oil collected in South Carolina is processed for use in asphalt plants, industrial and utility boilers, steel mills and other facilities. A portion of the used oil collected is re-processed for the production of additional motor oil or fuel oils. Another portion is used for space heating (employing specially designed space heaters) of automotive bays and municipal garages.
- Most of the oil collected from DIYers in South Carolina is burned for energy recovery to generate electricity by Santee Cooper, the state-owned utility. According to Santee Cooper, the utility has collected more than 25 million gallons of used motor oil since 1990 and has fired this used oil in its generation units to produce electricity.
- One gallon of used motor oil contains sufficient fuel value to generate 18 kWh of electricity.

[68] “Materials Characterization Paper in Support of the Final Rulemaking: Identification of Nonhazardous Secondary Materials That Are Solid Waste Used Oil,” US EPA, 2011, http://www.epa.gov/osw/nonhaz/define/pdfs/used-oil-final.pdf.

[69] “Used Motor Oil Recycling,” South Carolina Department of Health and Environmental Control – Office of Solid Waste Reduction and Recycling, www.scdhec.gov/environment/lwm/recycle/pubs/used_oil_recycling.pdf.

Additionally, according to the US DOE, approximately 1.37 billion gallons of used oil were available for recovery in the United States, based on 1995 statistics. Of this quantity, 945 million gallons (69%) were recovered, with 780 million gallons combusted as a fuel and 165 million gallons re-refined and re-used as oil.[70] Figure 8-1 shows the different industries that combust used oil. The remaining used oil created in the US in 1995, 426 million gallons, was improperly disposed.

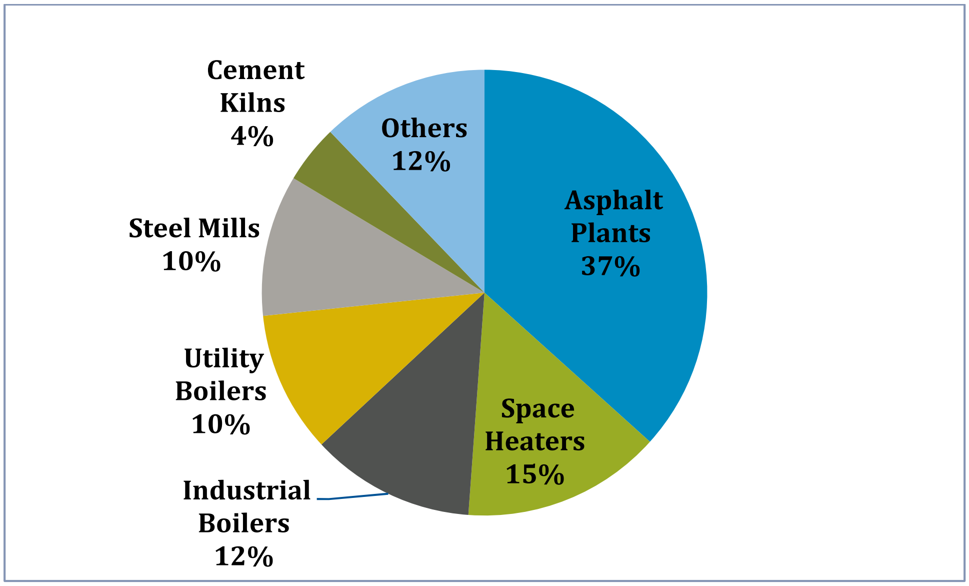

Figure 8-1 Combustion Methods of Recovered Used Oil

8.1 ASSESSMENT METHODOLOGY AND ASSUMPTIONS

After reviewing available literature and data for South Carolina, there was no adequate source of information for the total waste oil generated annually in the state. Therefore, Black & Veatch has assumed that the total used oil recovered in South Carolina is directly proportional to its population, based on the average used oil recovered per capita in the United States from the DOE study.

Black & Veatch calculated the potential generation (in terms of GWh) and capacity (in terms of MW) from waste oil assuming the following:

- One gallon of used motor oil fired in existing utility-scale electrical generation units provides 18 kWh of generation.
- To be consistent with other solid- and oil-fueled units considered in this study, the capacity factor of the utility-scale generation units is assumed to be 85 percent.

[70] "Used Oil Re-refining Study to Address Energy Policy Act of 2005 Section 1838," US DOE Office of Fossil Energy, 2006, Available online at: http://fossil.energy.gov/epact/used_oil_report.pdf.

8.2 TECHNICAL POTENTIAL OF WASTE OIL

The per capita used oil recovery, based on the national data from the US DOE is equal to 3.06 gallons per capita.[71] Multiplying by the population of South Carolina (relative to the population of the United States),[72] the estimated annual oil recovery is approximately 14.1 million gallons of used oil per year. If the entirety of this used oil recovered in South Carolina is fired in utility-scale electric generation units, the electricity generated could total 254 GWh/year, as shown in Table 8-1. While the technical potential generation capacity of waste oil resources is estimated to be 38 MW, the used oil would likely be co-fired in existing utility coal boilers and would not provide incremental new capacity to the state.

Table 8-1 Technical Potential of Waste Oil Resources in South Carolina

	ESTIMATED QUANTITY OF USED OIL[a] (GAL/YEAR)	FUEL VALUE[b] (MBTU/YEAR)	TECHNICAL POTENTIAL CAPACITY[c] (MW)	TECHNICAL POTENTIAL GENERATION[d] (GWH/YEAR)
Used Oil	14,100,000	1,974,000	38	254

[a]To estimate technical potential, it is assumed that all of the estimated motor oil recovered in South Carolina on annual basis is fired in utility-scale generation units.
[b]Consistent with information presented by the US EPA, used motor is assumed to have a heating value of 140,000 Btu/gallon.
[c]Capacity factor of the biomass fired generation facility assumed to be 85 percent.
[d]Firing of 1 gallon of waste oil yields 18 kWh of electricity.

8.3 CONSTRAINED POTENTIAL OF WASTE OIL

Of the used oil recovered on an annual basis in the United States, approximately 80 percent is combusted to provide space heating, industrial process heat or electricity. The largest portion of this used oil is combusted in asphalt plants, while significant portions are also fired at steel mills, cement kilns and other industrial boilers. Approximately 10 percent of the used oil combusted (or 8 percent of the total used oil recovered) is fired in utility scale boilers.[73] Eight percent of the total estimated used oil recovered in South Carolina (1.1 million gallons) is close to Santee Cooper's annual average usage of 1.25 million gallons of used oil collected from DIYers. The remaining used oil currently being consumed in other industries could potentially be made available for utility electricity production, but environmental emissions must be considered. Also, since the other industries use waste oil in thermal applications, which are more efficient processes, the likelihood of diverting the waste oil to utility boilers is probably low. Therefore, the constrained potential for additional waste oil combusted in utility boilers is likely minimal. The one caveat is that there may

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[71] According to U.S. Census Bureau statistics (available online at: http://quickfacts.census.gov/qfd/states/45000.html), the population of the United States in 2010 was 308.7 million.
[72] According to U.S. Census Bureau statistics for the state of South Carolina (available online at: http://quickfacts.census.gov/qfd/states/45000.html), the 2010 population of South Carolina was 4.6 million
[73] US DOE Office of Fossil Energy (2006).

be opportunities for increased recovery if used oil programs continue to expand, since it is estimated that over 30% of used oil is not recovered. However, it is not possible to estimate what the incremental recovery might be, since it would be highly dependent on the program.

8.4 DATA SOURCES AND REFERENCES

- South Carolina Department of Health and Environmental Control – Office of Solid Waste Reduction and Recycling, "Used Motor Oil Recycling."
- US DOE Office of Fossil Energy. "Used Oil Re-refining Study to Address Energy Policy Act of 2005 Section 1838," 2006.
- US Census Bureau, http://quickfacts.census.gov/qfd/states/.
- US EPA, "Materials Characterization Paper in Support of the Final Rulemaking: Identification of Nonhazardous Secondary Materials That Are Solid Waste Used Oil 2011."

9.0 Capital Cost Estimates for Select Technologies

To characterize the capital costs associated with select thermal technologies (as specified by the South Carolina Energy Advisory Council), Black & Veatch has developed representative estimates of capital costs that are not site specific for the following technologies:

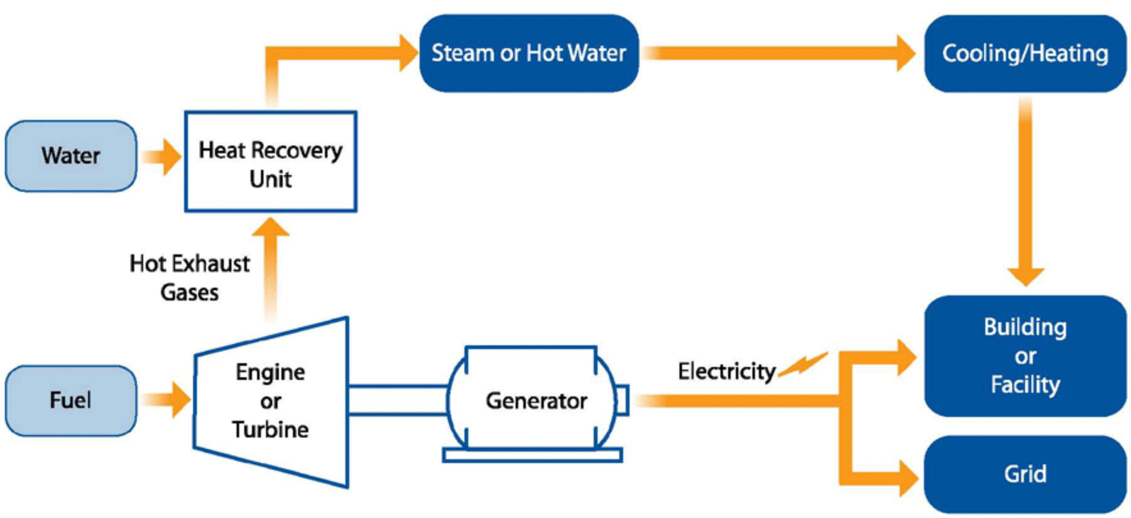
- CHP
- Geothermal Heating/Cooling (i.e., ground source heat pump technologies)
- Solar (Thermal) Water Heating (e.g., domestic and commercial technologies)

These technologies offer the potential to increase energy efficiency of both industrial processes (in the case of CHP technologies) and residential/commercial heating and cooling processes (in the case of geothermal heat pumps and solar water heating technologies).

9.1 COMBINED HEAT AND POWER

CHP is the sequential or simultaneous generation of multiple forms of useful energy (usually mechanical and thermal) in a single, integrated system. CHP systems, as illustrated in Figure 9-1, typically include the following components:

- Prime mover (heat engine)
- Generator
- Heat recovery
- Electrical interconnection

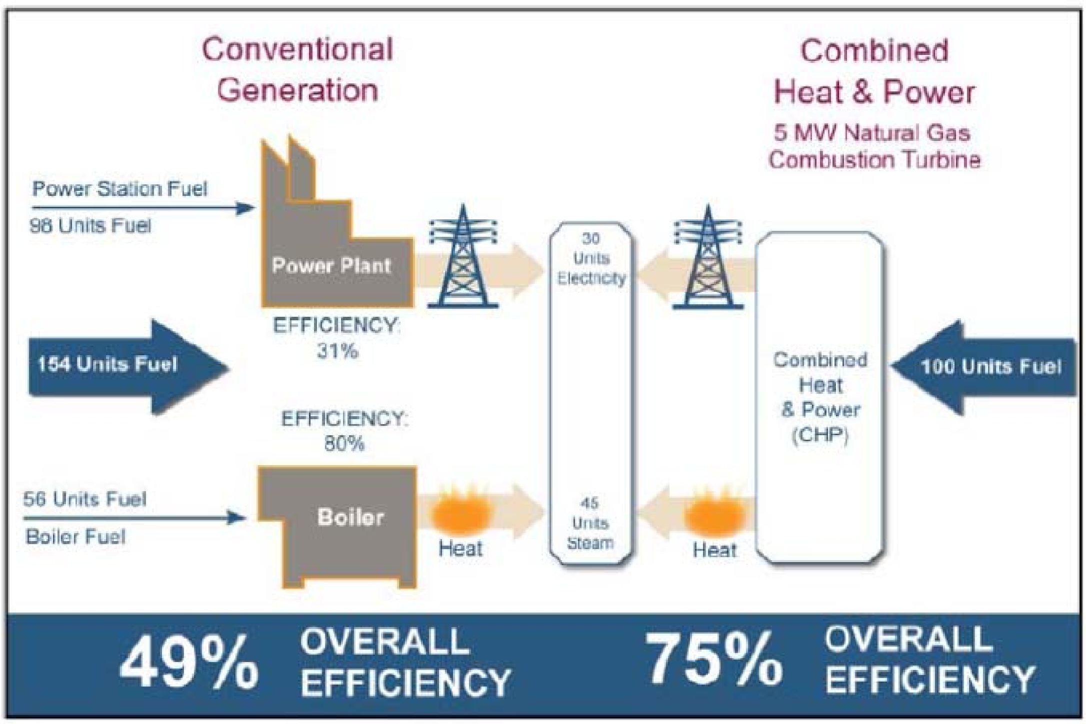


Source: http://www.epa.gov/chp/basic/index.html.

Figure 9-1 Gas Turbine or Engine with Heat Recovery Unit

Several types of equipment may serve as the prime mover of a CHP system, including reciprocating engines, combustion or gas turbines, and steam turbines. These systems may utilize a variety of fuels, including natural gas, coal, or biomass. Mechanical energy generated by the CHP system may be used to produce electricity or drive rotating equipment such as compressors, pumps, and fans. Thermal energy (i.e., process heat) generated by the CHP system may be used directly in a industrial process or indirectly to produce steam, hot water, hot air for drying, or chilled water for process cooling.[74]

The primary advantage of CHP systems is the increased efficiency of the combined processes, as illustrated in Figure 9-2. In this example, by integrating the power production and thermal energy processes, the overall thermal efficiency of the generation of the required power and heat increases from 49 percent to 75 percent.



Source: US EPA CHP Partnership - Catalog of CHP Technologies.

Figure 9-2 Comparison of CHP versus Separate Heat and Power Production

[74] "Catalog of CHP Technologies," US Environmental Protection Agency – Combined Heat and Power Partnership, 2008, http://www.epa.gov/chp/documents/catalog_chptech_intro.pdf.

Characterization of the capital costs associated with CHP systems firing natural gas and biomass are provided in the following subsections. Due to the multiple combinations of fuel input, size, and selected conversion technology, the capital cost information is presented for natural gas fired CHP and biomass fired CHP.

9.1.1 Estimates of Capital Costs for Natural Gas Fired CHP

Natural gas fired CHP systems typically employ combustion turbines as the prime mover, with a complete CHP system arrangement similar to that illustrated in Figure 9-1. These gas fired systems may range in size (in terms of net electrical generation) from less than 5 MW to greater than 200 MW. The output of the CHP systems will depend upon the output of the combustion turbine that serves as the prime mover of the system. The order-of-magnitude capital costs for gas fired CHP systems (including the combustion turbine, heat recovery unit and electrical generator) for the following combustion turbine options are provided:

- Solar Mercury 50
- GE LM2500
- GE LM6000
- GE 7FA.05

The performance characteristics and range of EPC capital costs for these natural gas fired CHP systems are listed in Table 9-1. The unit cost per MW is greatly reduced with larger installations (above 20 MW), though the difference between the LM2500 and the 7FA.05 systems is not as significant.

Table 9-1 Performance and Capital Costs for Natural Gas Fired CHP Systems

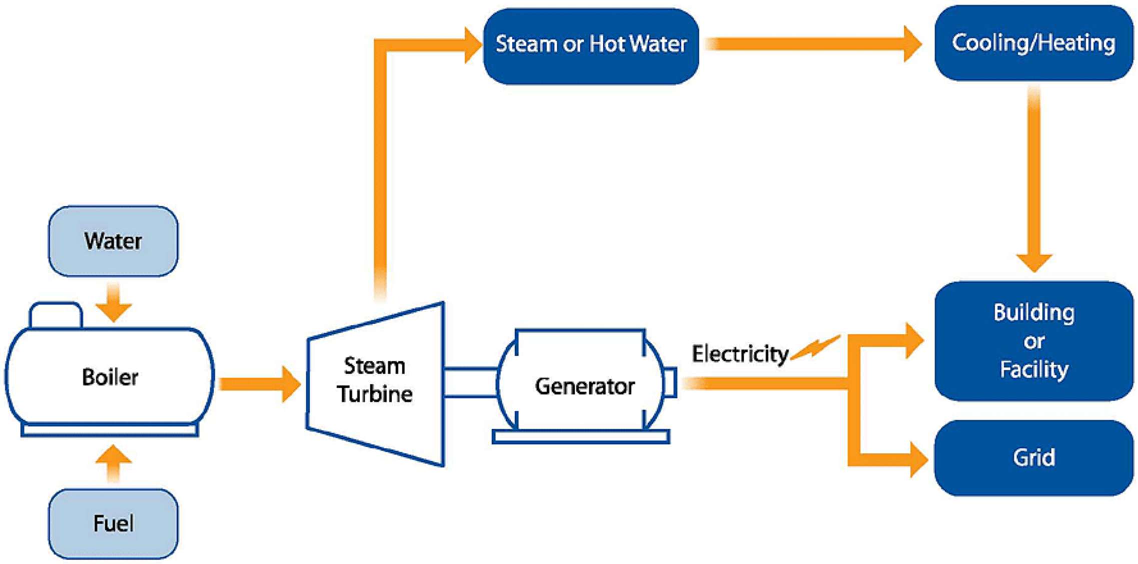
	SOLAR MERCURY 50 CHP SYSTEM	GE LM2500 CHP SYSTEM	GE LM6000 CHP SYSTEM	GE 7FA.05 CHP SYSTEM
System Parameters				
Net Electrical Output, MW	4.2	22.2	38.6	203.5
Net Useful Thermal Output, MBtu/h	16 to 18	95 to 110	110 to 125	740 to 950
Fuel Input, MBtu/h	43	245	345	2,050
CHP Plant Total Efficiency,[a] % (HHV)	70 - 75	70 - 75	70 - 75	70 - 80
EPC Capital Cost,[b] $000 (2011$)	9,880	31,680	53,590	275,100

[a]The total efficiency of the CHP plant is calculated as the sum of the estimated net electrical power and net useful thermal output divided by the total fuel input. Black & Veatch notes that net electrical power is converted from units of net MW to MBtu/h (1 MW = 3.413 MBtu/h).

[b]EPC capital costs are order-of-magnitude, overnight EPC costs for the turnkey construction of the CHP facility. The EPC capital costs exclude Owner's costs (i.e., outside-the-fence costs and project development costs), escalation and allowance for funds used during construction (AFUDC).

9.1.2 Estimates of Capital Costs for Biomass Fired CHP

Biomass fired CHP systems typically employ a solid-fuel boiler and a steam turbine generator as a prime mover, as illustrated in Figure 9-3.



Source: http://www.epa.gov/chp/basic/index.html

Figure 9-3 Solid-Fuel Boiler with Steam Turbine

Biomass fired CHP systems can be characterized by the total quantity of steam flow (at specified temperature and pressure) generated in the biomass fired boiler. The electrical output of these systems will depend upon the pressure and mass flow rate of the process steam streams. Black & Veatch has estimated order-of-magnitude capital costs for biomass fired CHP systems at the following steam generation rates (at the specified steam conditions at the boiler outlet):

- 60,000 lb/h (at a pressure and temperature TBD)
- 150,000 lb/h (at 1500 psig and 950° F)
- 300,000 lb/h (at 1500 psig and 950° F)
- 450,000 lb/h (at 1500 psig and 950° F)

The performance characteristics and estimated capital costs associated with these biomass fired CHP systems are listed in Table 9-2. The unit cost per MW for these systems declines significantly with larger systems, taking advantage of economies of scale.

Table 9-2 Performance and Capital Costs for Biomass Fired CHP Systems

	60,000 LB/HR BIOMASS CHP SYSTEM	150,000 LB/HR BIOMASS CHP SYSTEM	300,000 LB/HR BIOMASS CHP SYSTEM	450,000 LB/HR BIOMASS CHP SYSTEM
System Parameters				
Steam flow at boiler outlet, lb/hr	60,000	150,000	300,000	450,000
Steam pressure at boiler outlet, psig	TBD	1500	1500	1500
Steam temperature at boiler outlet, ° F	TBD	950	950	950
Net Electrical Output, MW	1.5	6.5	16.2	29.0
Net Useful Thermal Output, MBtu/h	TBD	110	220	330
Fuel Input, MBtu/h	TBD	220	440	660
CHP Plant Total Efficiency,[a] % (HHV)	TBD	60	62.5	65
EPC Capital Cost,[b] $000 (2011$)	22,950	95,000	130,000	170,000

[a]The total efficiency of the CHP plant is calculated as the sum of the estimated net electrical power and net useful thermal output divided by the total fuel input. Black & Veatch notes that net electrical power is converted from units of net MW to MBtu/h (1 MW = 3.413 MBtu/h).

[b]EPC capital costs are order-of-magnitude, overnight EPC costs for the turnkey construction of the CHP facility. The EPC capital costs exclude Owner's costs (i.e., outside-the-fence costs and project development costs), escalation and AFUDC.

9.2 GEOTHERMAL — GROUND SOURCE HEAT PUMPS

Ground source heat pumps (GSHP) take advantage of the difference between the relatively stable temperatures of subsurface soils (at depths as shallow as 4 to 6 feet) and the relatively variable temperatures of aboveground, ambient air. In winter, temperatures underground are warmer than the ambient air temperature, and the soil acts as a heat source for domestic heating. In summer, temperatures underground are cooler, and the soil acts as a heat sink for domestic cooling. GSHP systems operate on the premise that it is often more efficient to move heat than to use fuels to generate heat or do work (to actively cool a home). In many cases, domestic water heating can be incorporated as part of the GSHP system, which can provide a significant portion of domestic water heating for a relatively limited additional capital cost.

GSHP systems pump water or another heat transfer through a loop of piping to gather heat from or deposit heat into and out of the ground. The piping, in contact with the ground, allows for the exchange of heat either from the ground to the refrigerant fluid or from the fluid to the ground. This piping loop may be oriented either horizontally or vertically. For horizontal loop systems, a field of horizontal trenches is typically dug to allow flexible pipe to be buried. Alternatively, vertical wells may be drilled to provide a similar amount of ground contact. Approximately 200 feet of piping is needed for each ton of heating/cooling load. A typical home requires approximately three tons of heating or cooling; therefore, a typical residential GSHP system requires approximately 600 feet of piping.

GSHP systems can be scaled up to provide heating and cooling for apartment complexes and office buildings. These larger systems require a corresponding increase in the piping loop field that is in contact with the ground and additional heat pump equipment. Furman University is currently installing GSHP systems on 11 apartment-style dormitories on its campus.[75] The GSHP systems being employed at Furman will employ vertical wells rather than horizontal trenches to reduce the required footprint of the loops. Each building contains 24 residential units, and each apartment has a dedicated 2.5 ton heat pump; therefore, the total heating/cooling capacity of each building's GSHP system is 60 tons. Each building is connected to a common loop system of 20 vertical wells. The installation of these systems will occur over the summers in 2011 through 2013. A total installed cost of $4.92 million is expected for the project.[76]

Based on the discussions with installers of GSHP systems, Black & Veatch has estimated the capital costs associated with the installation of residential-scale GSHP systems and commercial-scale (e.g., apartment building) systems, as shown in Table 9-3. The capital costs shown in Table 9-3 are the total capital costs required for turnkey installation of these systems.

[75] "DOE Awards Furman $2.5 Million Grant for Geothermal System on Campus," Furman University press release, November 2, 2009.
[76] Personal communication with Jeff Redderson of Furman University.

Table 9-3 Capital Costs for Ground Source Heat Pump Systems

	3-TON (RESIDENTIAL) SYSTEM	60-TON (COMMERCIAL) SYSTEM[a]
System Parameters		
System Type	Horizontal Trench	Vertical Well
Maximum Heating/Cooling Load, tons	3	60
Number of Trenches/Wells[b]	1	20
Length of Trench/Depth of Well[b], ft.	600	500
Capital Cost,[c,d] 2011$	17,000	450,000

[a]Estimates for the 60 ton commercial system are based on capital costs associated with the installation of GSHP systems currently being installed at Furman University. The Furman project will install 60 ton GSHP systems in each of 11 apartment-style dormitory buildings on campus. Based on personal communication with staff of Furman University, the total installed cost of these 11 GSHP systems is anticipated to be $4.92 million, or approximately $450,000 per 60 ton system.

[b]The number of trenches for the horizontal system was not specified, but the system requires approximately 200 feet of trench per ton of heating/cooling load.

[c]Residential-scale GSHP system includes indoor air handler, piping and required pumps, valves and controls. Commercial-scale GSHP includes water-to-water heat pumps, loop piping within buildings, horizontal piping between building and wells, a 120 ft^2 pump control room, and required pumps, valves and controls.

[d]Costs shown are the total capital costs required for turnkey installation of these systems (including the necessary trenching or drilling of wells).

9.3 SOLAR (THERMAL) WATER HEATING

Solar water heating (SWH) systems convert solar radiation into heat for warming of water (to temperatures significantly less than the boiling point of water) for domestic uses in homes, small businesses or apartments. SWH systems differ from solar PV systems in that the solar module that is exposed to the sun's rays converts the solar radiation to thermal energy rather than electricity. They also differ from utility-scale concentrating solar thermal power plants that use mirrors or lenses to concentrate solar radiation to make high temperature steam to drive a steam turbine and generate electricity.

Solar collectors, typically mounted on rooftops, are employed to receive sunlight, and the collected thermal energy is transferred to a fluid piped through the collector. The fluid may be the water that is to be heated, or it may be a heat transfer fluid (HTF) which then passes through a heat exchanger to warm the domestic water. In addition to the solar collector, heat exchanger and storage tank, SWH systems include the required pumps, valves and control systems.

SWH systems typically use a flat-plate glazed collector to receive sunlight. SWH systems using flat-plate glazed collectors can be scaled up to commercial scales to handle larger volumes of water (e.g., hot water systems for hotels or heating of community pools). Collector designs other than the flat-plate glazed design may be employed for SWH systems (e.g., evacuated tube collectors), although capital costs associated with these alternative designs are typically greater than those of flat-plate glazed collectors.

In many climates, SWH systems must have a means of freeze protection. One method of freeze protection (typical in warmer climates such as South Carolina) is a drain-back system, which drains water out of the collector when the sun is not warming the system. Another method (typical in cooler climates) uses an anti-freeze fluid that circulates and remains in the collector.

Based on the discussions with installers of SWH systems, Black & Veatch has estimated the capital costs associated with the installation of residential-scale SWH systems, as shown in Table 9-4. The capital costs are the total capital costs required for turnkey installation of these systems. Discussions with an existing SWH system installer in South Carolina indicated that this cost would also include a 5-year warranty for parts and service.

Table 9-4 Capital Costs for Residential Solar Water Heating Systems

	ONE-COLLECTOR SYSTEM	TWO-COLLECTOR SYSTEM	THREE-COLLECTOR SYSTEM
System Parameters			
Number of Collectors	1	2	3
Total Collector Area, ft^2	32	64	96
Storage Tank Capacity, gal	80	80	120
Thermal Rating, Btu/day	25,600	51,200	76,800
Size of Household [a]	2 to 3	3 to 5	6 to 8
Capital Cost [b,c], 2011$	6,000	7,000	8,000

(a)A one-collector system is sufficient to provide the hot water requirements of households consisting of 2 to 3 people. Two- and three-collector systems are sufficient to provide the hot water requirements of households consisting of 3 to 5 people and 6 to 8 people, respectively.

(b)SWH system includes solar collector, heat exchanger, storage tank and any required pumps, valves and controls.

(c)Costs shown are the total capital costs required for turnkey installation of these systems and include a 5 year warranty for parts and service.

The capital costs associated with the installation of SWH system suitable for hotel applications are shown in Table 9-5, based on the discussions with installers of SWH systems. The capital costs are the total capital costs required for turnkey installation of these systems.

Table 9-5 Capital Costs for Commercial Solar Water Heating Systems

	HOTEL-BASED SOLAR HOT WATER SYSTEM
System Parameters	
Number of Collectors	10
Total Collector Area, ft^2	320
Storage Tank Capacity,[a] gal.	480
Thermal Rating, Btu/day	256,000
Capital Cost,[b,c] 2011$	28,000 to 30,000

[a]It is anticipated that four 120 gallon tanks would be employed to provide a total of 480 gallons of hot water storage capacity.
[b]SWH system includes solar collector, heat exchanger, storage tanks and any required pumps, valves and controls.
[c]Costs shown are the total capital costs required for turnkey installation of these systems and include a 5 year warranty for parts and service.

9.4 DATA SOURCES AND REFERENCES

- "DOE Awards Furman $2.5 Million Grant for Geothermal System on Campus," Furman University press release, November 2, 2009.
- US Environmental Protection Agency – Combined Heat and Power Partnership, 2008, "Catalog of CHP Technologies," http://www.epa.gov/chp/documents/catalog_chptech_intro.pdf.
- US Environmental Protection Agency, "Combined Heat and Power Partnership," http://www.epa.gov/chp/basic/index.html.

Appendix A.

Table A-1 Announced Renewable Energy Projects in South Carolina

	PROJECT OWNER/ DEVELOPER	LOCATION	GENERATING CAPACITY (MW)	ESTIMATED ONLINE DATE
Solar (PV) Projects				
Boeing Facility[a]	SCE&G	Charleston	2.6 MW	Not specified
Biomass Projects				
Burrows Hall (anaerobic digestion)[b]	Environmental Fabrics Inc.	Williamsburg County	180 kW	2011
Berkeley (biogas)[b]	BioEnergy Technologies	Berkeley County	1.6 MW	2012
Columbia Biomass (biogas)[b]	W2E-Organic Power	Columbia	1.6 MW	2012
Allendale (woody biomass)[b]	Southeast Renewable Energy	Allendale County	15 MW	2012
Dorchester (woody biomass)[b]	Southeast Renewable Energy	Dorchester County	15 MW	2012
Hartsville (woody biomass)[c]	Peregrine Energy	Hartsville, SC	50 MW	2012
Kershaw (woody biomass)[b]b	Southeast Renewable Energy	Kershaw County	15 MW	2012
Loblolly (woody biomass)[d]	Rollcast Energy	Newberry County	50 MW	Not specified
Northstar Renewable Energy (woody biomass)[b]	Northstar Renewable	Williamsburg County	21 MW	Not specified
Orangeburg County (woody biomass)[e]	Orangeburg County Biomass	Orangeburg County	35 MW	Not specified
Savannah River (woody biomass)[f]	Ameresco	Aiken	18 MW	2011
Landfill Gas Projects				
Wellford Landfill (LMOP)[g]	Spartanburg County	Spartanburg	1.6 MW	Not specified

[a]SCG&E Press Release, April 2011. Available: http://www.sceg.com/en/news-room/current-news/boeing-and-sceg-announce-renewable-energy-partnership.htm.
[b]Santee Cooper Green Power.
[c]Peregrine Energy Press Release. Available: http://www.peregrinecorp.net/UserFiles/CaseStudies/64/FullCaseStudy.pdf
[d]Rollcast Energy.
[e]South Carolina Department of Health and Environmental Control, Bureau of Air Quality, October 2009.
[f]South Carolina Energy Office, "South Carolina Biomass Brief." September 2010.
[g]US EPA LMOP database.

Table A-2 NREL Estimated Technical Potential for Offshore Wind (No Exclusions)

WIND SPEED AT 90M M/S	DISTANCE FROM SHORELINE									TOTAL
	0 - 3 NM			3 - 12 NM			12 - 50 NM			
	DEPTH CATEGORY (M)			DEPTH CATEGORY (M)			DEPTH CATEGORY (M)			
	0 - 30	30 - 60	> 60	0 - 30	30 - 60	> 60	0 - 30	30 - 60	> 60	
	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*	AREA (KM²) *(MW)*
7.0-7.5	848	--	--	608	--	--	--	--	--	1,457
	(4,241)	--	--	*(3,042)*	--	--	--	--	--	*(7,283)*
7.5-8.0	594	--	--	3,054	--	--	4,268	287	--	8,202
	(2,968)	--	--	*(15,269)*	--	--	*(21,338)*	*(1,435)*	--	*(41,010)*
>8.0	23	--	--	1,609	--	--	6,178	7,035	1,544	10,384
	(115)	--	--	*(8,047)*	--	--	*(30,892)*	*(35,176)*	*(7,721)*	*(81,952)*

Table A-3 Solar PV Land Use Categories, Definitions and Assumptions

CLASS	CATEGORY	DEFINITION	% INCLUDED	COMMENTS
Non-Developable	Bare Rock/ Sand/Clay	perennially barren areas of bedrock, desert, pavement, scarps, talus, slides, volcanic material, glacial debris and other accumulations of earthen material.	---	N/A
	Deciduous Forest	areas dominated by trees where ≥75 percent of the tree species shed foliage simultaneously in response to seasonal change.	---	N/A
	Evergreen Forest	areas characterized by trees where ≥75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.	---	N/A
	Mixed Forest	areas dominated by trees, neither deciduous nor evergreen species are ≥75 percent of cover.	---	N/A
	Emergent Wetlands	areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated or covered with water.	---	N/A
	Woody Wetlands	areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated or covered with water.	---	N/A
	Transitional	areas of sparse vegetative cover (≤25 percent) changing dynamically from one land cover to another, often because of land use activities.	---	N/A
	Open Water	areas of open water, generally with less than 25 percent or greater cover of water (per pixel).	---	N/A
Urban (Distributed Generation)	Commercial/ Industrial/ Transportation	includes infrastructure (e.g., roads, railroads) and all highways and all developed areas not classified as High Intensity Residential.	30%	Assumes 50% of developed commercial areas available (65% of total area*).
	High Intensity Residential (HIR)	areas of heavily built up urban centers where people reside in high numbers. Examples: apartment complexes, row houses. Vegetation accounts for ≤20 percent of the cover. Constructed material accounts for 80-100 percent of the cover.	20%	Assumes 30% of HIR areas have proper orientation, 70% of which is not heavily shaded. *
	Low Intensity Residential (LIR)	areas with constructed materials and vegetation mixture. Constructed materials account for 30-80 percent. Vegetation may account for 20-70 percent. Commonly include single-family housing units. Population densities are lower than high intensity residential areas.	20%	Assumes 30% of LIR areas have proper orientation, 60% of which is not heavily shaded. *
	Urban/Rec Grasses	vegetation (primarily grasses) planted in developed settings for recreation, erosion control or aesthetic purposes. Examples: parks, lawns golf courses, airport grasses, industrial site grasses.	2%	Assumes only airport and urban grass areas available for PV development.
Utility-Scale	Pasture/Hay	areas of grasses, legumes or grass-legumes mixtures planted for livestock grazing or the production of seed or hay crops.	5%	Assumes limited development to avoid significant impact on ag industry.
	Row Crops	areas used for the production of crops such as corn, soybeans, vegetables, tobacco and cotton.	5%	Avoid significant impact on ag industry.
	Quarries/Mines/ Gravel Pits	areas of extractive mining activities with significant surface expression.	10%	Assumes reclamation of 10% of abandoned mines. **

Source: USGS Land Cover Institute, NLCD Land Cover Class Definitions.

*Maya Chadhuri, et al, "PV Grid Connected Market Potential under a Cost Breakthrough Scenario." September 2004. Online: http://www.ef.org/documents/EF-Final-Final2.pdf
**Mining Association of South Carolina.

Table A-4 Existing Hydroelectric Plants in South Carolina

NO.	PLANT NAME	OWNER/OPERATOR	NAMEPLATE CAPACITY (MW)	TYPE
1	99 Islands	Duke Energy Carolinas, LLC	18	Hydro
2	Boyds Mill Hydro	Northbrook Carolina Hydro LLC	1.4	Hydro
3	Buzzard Roost	Duke Energy Carolinas, LLC	15	Hydro
4	Cedar Creek	Duke Energy Carolinas, LLC	45	Hydro
5	Cherokee Falls	Broad River Electric Coop, Inc	4.3	Hydro
6	Clifton Dam 3 Power Station	Converse Energy Inc	1.2	Hydro
7	Columbia	South Carolina Electric & Gas Co	10.6	Hydro
8	Dearborn	Duke Energy Carolinas, LLC	45	Hydro
9	Fishing Creek	Duke Energy Carolinas, LLC	42.3	Hydro
10	Gaston Shoals	Duke Energy Carolinas, LLC	6.7	Hydro
11	Great Falls	Duke Energy Carolinas, LLC	24	Hydro
12	Hollidays Bridge Hydro	Northbrook Carolina Hydro LLC	4	Hydro
13	J Strom Thurmond	USCE-Savannah District	361.9	Hydro
14	Jefferies	South Carolina Pub Serv Auth	132.6	Hydro
15	Keowee	Duke Energy Carolinas, LLC	157.6	Hydro
16	Lockhart	Lockhart Power Co	18	Hydro
17	Neal Shoals	South Carolina Electric&Gas Co	5.2	Hydro
18	Parr Hydro	South Carolina Electric&Gas Co	14.4	Hydro
19	Pelzer Lower	Pelzer Hydro Co Inc	3.3	Hydro
20	Pelzer Upper	Pelzer Hydro Co Inc	2	Hydro
21	Piedmont Hydro Power Project	Aquenergy Systems Inc	1	Hydro
22	Rocky Creek	Duke Energy Carolinas, LLC	28	Hydro
23	Rocky River	Abbeville City of	2.6	Hydro
24	Saluda	Northbrook Carolina Hydro LLC	2.4	Hydro
25	Saluda	South Carolina Electric&Gas Co	207.3	Hydro
26	Spartanburg Water System	Spartanburg Commissioners PW	1	Hydro
27	Spillway	South Carolina Pub Serv Auth	2	Hydro
28	St. Stephen	US Army Corps of Engineers	84	Hydro
29	Ware Shoals Hydro Project	Aquenergy Systems Inc	6.2	Hydro
30	Wateree	Duke Energy Carolinas, LLC	56	Hydro
31	Wylie	Duke Energy Carolinas, LLC	60	Hydro
32	Bad Creek	Duke Energy Carolinas, LLC	1065.2	PS*
33	Fairfield Pumped Storage	South Carolina Electric & Gas Co	511.2	PS*
34	Jocassee	Duke Energy Carolinas, LLC	612	PS*

Source: EIA http://www.eia.gov/cneaf/electricity/page/capacity/existingunitsbs2008.xls

*Pumped Storage.

Table A-5 IHRED Potential Hydroelectric Plants/Sites in South Carolina

NO.	PLANT NAME/SITE	STREAM NAME	CAPACITY	DAM STATUS*	SITE
1	HOLIDAYS**	SALUDA R	4.84	Without Power	0.90
2	STEVENS CREEK	SAVANNAH R	23.80	Without Power	0.90
3	FORK SHOALS DAM	REEDY R	2.03	Without Power	0.90
4	BOYDS MILL**	REEDY R	3.54	Without Power	0.90
5	THOMPSON RIVER	THOMPSON R	3.40	Without Power	0.90
6	PACOLET SC	PACOLET R	2.79	Without Power	0.90
7	TROUGH	PACOLET R	6.90	Undeveloped	0.90
8	GASTON SHOALS**	BROAD R	7.21	Without Power	0.50
9	GREATER CHEROKEE	BROAD R	14.95	Without Power	0.50
10	GR GASTON SHOALS	BROAD R	115.82	Without Power	0.50
11	NEAL SHOALS	BROAD R	8.32	Without Power	0.50
12	GREATER LOCKHART 3	BROAD R	250.00	Without Power	0.50
13	ROCKY CREEK**	CATAWBA R	20.80	Without Power	0.50
14	BUZZARDS ROOST**	SALUDA R	14.30	Without Power	0.50
15	LAKE WATEREE**	WATEREE R	26.35	Without Power	0.50
16	FISHING CREEK	CATAWBA R	27.70	Without Power	0.50
17	COURTNEY ISLAND	CATAWBA R	50.60	Without Power	0.50
18	VAN PATTON	ENOREE R	3.47	Without Power	0.50
19	PARR SHOALS	BROAD R	4.96	With Power	0.50
20	BLAIR	BROAD R	109.00	Without Power	0.50
21	PRINT CRASH	MIDDLE TYGER R	1.10	Without Power	0.50
22	BLALOCK	PACOLET R	2.09	Without Power	0.50
23	BURNT FACTORY	TYGER R	9.48	Without Power	0.50
24	LOCKHART (GREATER)	BROAD R	150.00	Without Power	0.50
25	UPPER WARE SHOALS	SALUDA R	20.22	Undeveloped	0.10
26	SANTEE COOPER	SANTEE R	68.40	Undeveloped	0.10
27	HOPEWELL	BROAD R	8.68	Undeveloped	0.10
28	LAKE ROBINSON	BLACK CR	1.68	Undeveloped	0.10
29	THE FORKS	SALUDA R	18.30	Undeveloped	0.10
30	LOWER SALUDA RIVER	SALUDA R	20.00	Undeveloped	0.10
31	FROST SHOALS	BROAD R	40.00	Undeveloped	0.10
32	W C BOWEN LAKE	S FK PACOLET R	1.55	Undeveloped	0.10
33	SUGAR CREEK	CATAWBA R	19.50	Undeveloped	0.10

Source: US Hydropower Resource Assessment Final Report, 1998. http://hydropower.inel.gov/resourceassessment/pdfs/doeid-10430.pdf

* Dam Status is status as noted in 1998 report.

- With Power indicates a site with current power generation but the total hydropower potential has not been fully developed (the capacity noted is for the undeveloped portion of total potential).
- Without Power means the site does not currently generate any power though it has some type of developed impoundment or diversion structure.
- Undeveloped sites do not have any power generation or developed impoundment or diversion structure.

** Project has been developed already or is under development.

Table A-6 Current Developed Landfill Sites

LANDFILL	PROJECT CITY	YEAR ONLINE	CAPACITY (MW)*	UTILIZATION TYPE	TECHNOLOGY
Anderson Regional Landfill	Belton	2008	3.2	Electricity	Reciprocating Engine
Berkeley County Subtitle D LF	Moncks Corner	2011	3.2	Electricity	Reciprocating Engine
Croft Landfill	Spartanburg	Before 5/2010	4.4	Electricity and Direct	Reciprocating Engine and Boiler
Enoree LF, Phase II	Greer	2008	3.2	Electricity	Reciprocating Engine
Georgetown County Landfill and Subtitle D LF	Georgetown	2010	1.0	Electricity	Reciprocating Engine
Greenville County	Greenville	Before 5/2010	3.2	Electricity	Reciprocating Engine
Greenwood County Subtitle D LF	Greenwood	2009	-	Direct	Boiler
Greenwood Landfill	Greenwood	2009	-	Direct	Boiler
Horry County LF	Conway	2001	2.0	Electricity	Reciprocating Engine
Horry County LF	Conway	2003	1.0	Electricity	Reciprocating Engine
Langley Landfill	Langley	2007		Direct	Direct Thermal
Lee County LF, LLC	Bishopville	2005	5.4	Electricity	Reciprocating Engine
Lee County LF, LLC	Bishopville	2009	5.5	Electricity	Gas Turbine
Northeast Landfill	Columbia	Before 5/2010	5.5	Electricity	Reciprocating Engine
Palmetto Landfill	Wellford	2006		Direct	Direct Thermal
Palmetto Landfill	Wellford	2009	11.0	Electricity	Cogeneration
Richland County Landfill	Elgin	2006	5.5	Electricity	Gas Turbine
Richland County Landfill	Elgin	2011	3.2	Electricity	Reciprocating Engine
Three Rivers Regional Subtitle D MSWLF	Jackson	2011	-	Direct	Boiler
Wellford LF	Wellford	2011	-	Electricity	Reciprocating Engine
Wellford LF	Wellford	2011		Direct	Boiler
Westinghouse Savannah River Co. Landfill	Aiken	Before 5/2010		Direct	Boiler

Source: LMOP accessed August, 2011
Santee Cooper website accessed July, 2011 and Combustion Renewable Energy Users in South Carolina Database (updated May 2010)

* Capacity data not available for some projects.

Table A-7 Existing Biomass Projects

FACILITY	LOCATION	MW	BIOMASS FUEL	TECHNOLOGY
Domtar Marlboro Mill	Bennettsville	50	Wood residue & pulping liquor	CHP
Bowater Pulping Mill	Catawba	55	Wood residue & pulping liquor	CHP
Kapstone Paper and Packaging Corp.	Charleston	99	Wood residue & pulping liquor	CHP
International Paper – Eastover	Eastover	110	Wood residue & pulping liquor	CHP
International Paper – Georgetown	Georgetown	96	Wood residue & pulping liquor	CHP
RockTenn Co.	Florence	98	Wood residue & pulping liquor	CHP
Cameron Lumber Company	Cameron	N/A	Wood residue	Steam only
Capstone Paper & Packaging	Charleston	N/A	Wood residue	Steam only
Carolina Furniture Works	Sumter	N/A	Wood residue	Steam only
Carter Manufacturing Co	Lake City	N/A	Wood residue	Steam only
Council Energy Co	Orangeburg	N/A	Wood residue	Steam only
Elliott Sawmilling Co.	Estill	N/A	Wood residue	Steam only
Georgia Pacific Prosperity	Prosperity	N/A	Wood residue	Steam only
GTP Greenville	Greenville	N/A	Wood residue	Steam only
Ingram Lumber Co.	Leesville	N/A	Wood residue	Steam only
International Power Johnston Mill	Johnston	N/A	Wood residue	Steam only
Kearse Manufacturing	Olar	N/A	Wood residue	Steam only
Koppers Inc.	Florence	N/A	Wood residue	Steam only
New South Camden Plant	Camden	N/A	Wood residue	Steam only
New South Darlington Plant	Darlington	N/A	Wood residue	Steam only
Norbord South Carolina	Kinards	N/A	Wood residue	Steam only
United Wood Treating Co	Whitmire	N/A	Wood residue	Steam only
Walterboro Veneer	Walterboro	N/A	Wood residue	Steam only
Warren & Griffin Co.	Williams	N/A	Wood residue	Steam only
West Frazier Newberry	Newberry	N/A	Wood residue	Steam only
Weyerhauser Chester Paper Mill	Fort Mill	N/A	Wood residue	Steam only

Table A-8 Potential Woody Biomass in South Carolina, by Resource and Cost

WOODY RESOURCE	DELIVERED COST (2008$)					
	$20/ton	$22/ton	$24/ton	$26/ton	$28/ton	$30/ton
	Green Tons					
Unutilized						
Logging Residues	600,000	1,360,000	1,800,000	3,400,000	4,380,000	4,530,000
Residual Inventory	448,000	1,121,000	1,457,000	2,765,000	3,587,000	3,736,000
Pre-Commercial Thinnings	0	0	0	0	0	540,000
Unutilized Total	1,048,000	2,481,000	3,257,000	6,165,000	7,967,000	8,806,000
Utilized						
Mill Residues	2,571,000	2,931,000	3,291,000	3,651,000	5,610,000	5,610,000
Urban Wood Waste	1,252,000	1,418,000	1,584,000	1,749,000	1,915,000	2,081,000
Utilized Total	3,823,000	4,349,000	4,875,000	5,400,000	7,525,000	7,691,000
Total	**4,871,000**	**6,830,000**	**8,132,000**	**11,565,000**	**15,492,000**	**16,497,000**
Source: Connor, Adams and Johnson (2009).						

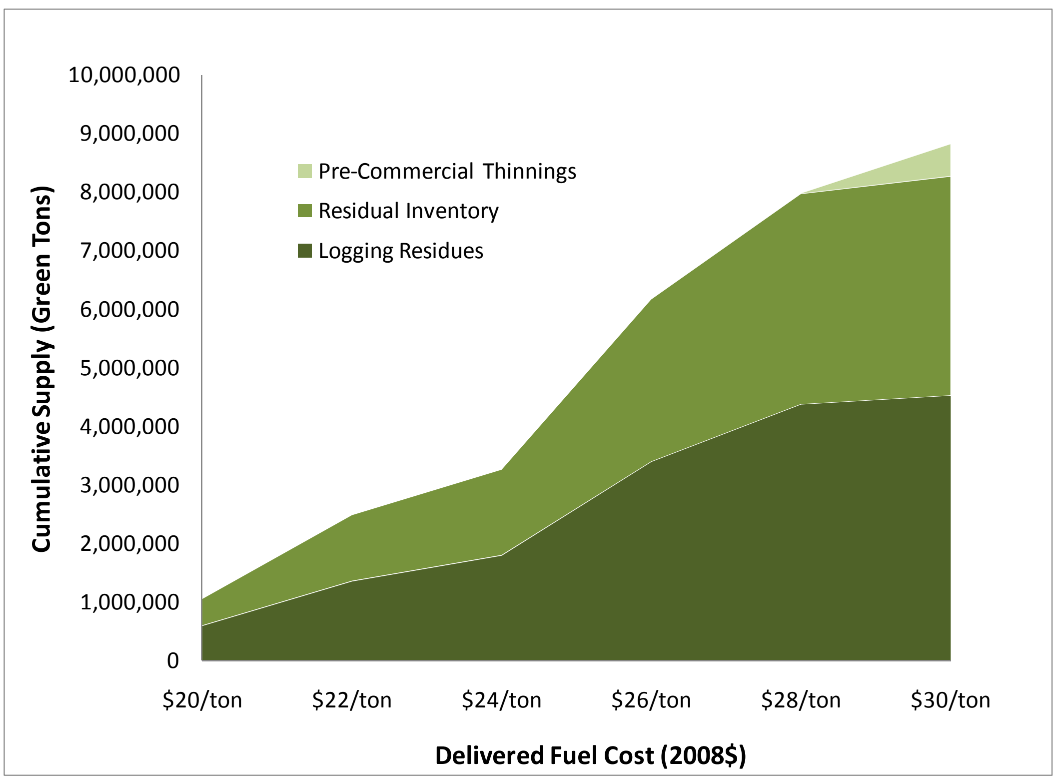


Figure A-1 Supply Curve for Unutilized Woody Biomass Resources in South Carolina