Renewable Resources and Clean Energy

Their role in South Carolina's Electric Generation Portfolio

What is a renewable resource?

An energy resource that is naturally replenished in a relatively short period of time.

<u>These include:</u>

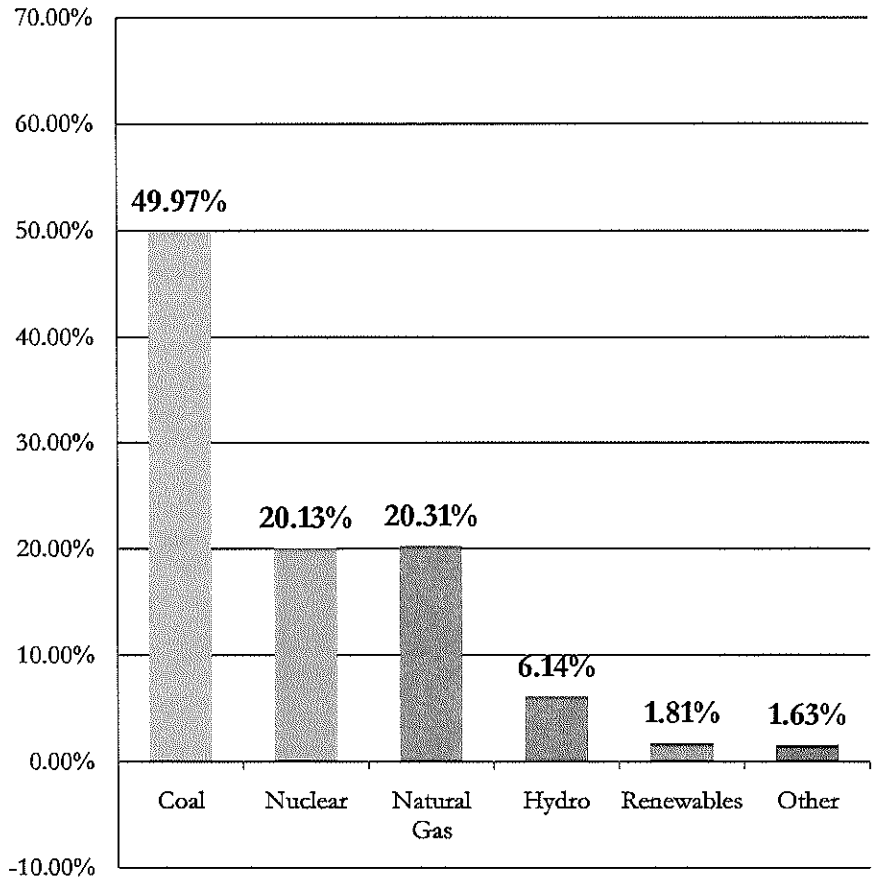
- Solar Energy
- Wind Energy
- Biomass
- Geothermal Energy
- Hydropower

Why Renewable Resources?

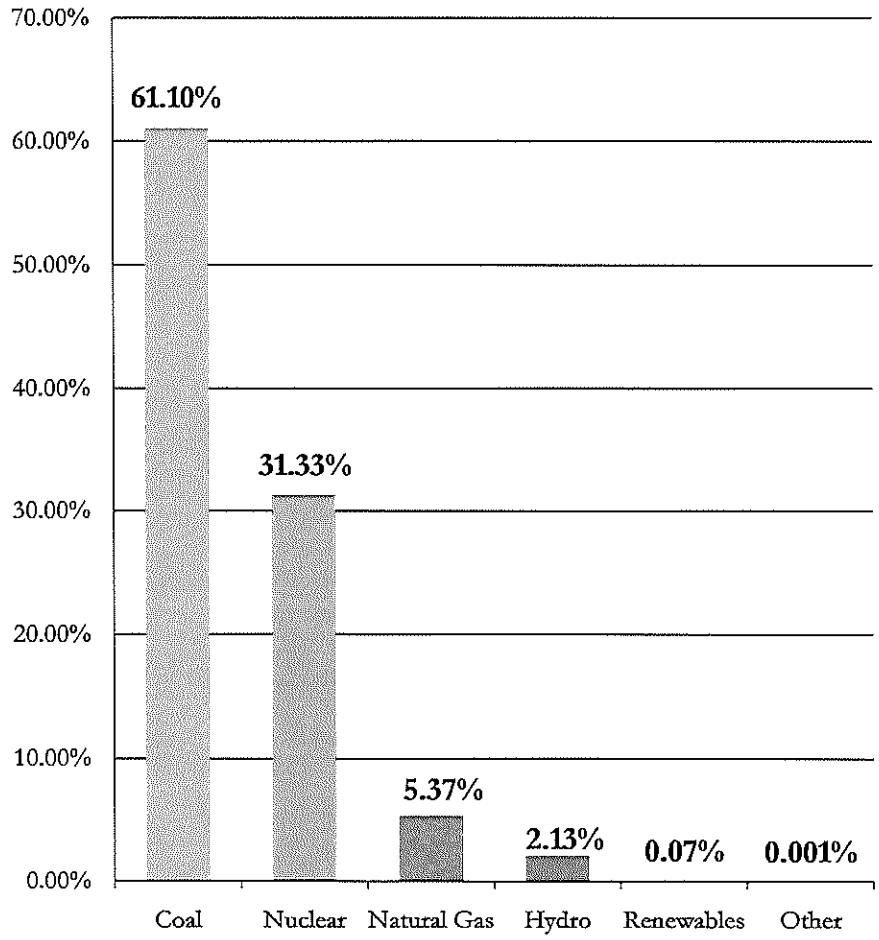
- Demand for electricity continues to increase
- Fossil fuel-fired plants are responsible for: [+]
  - 67% of nation's sulfur dioxide emissions
  - 23% of nitrogen oxide emissions
  - 40% of man-made carbon dioxide emissions
- Technology is making fossil fuels cleaner but there is demand for lower emissions
- Fossil fuel supplies are depleted faster than they can be generated

[+]Source: **U.S. Environmental Protection Agency** (2007) http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html

U.S. Electricity Generation*



S.C. Electricity Generation+



*Source: **Energy Information Administration** (2007 data) http://www.eia.doe.gov/emeu/aer/txt/ptb0802b.html

+Source: **ORS Energy Policy Report** (2007 data) http://www.regulatorystaff.sc.gov/Energy%20Policy%20Report%20website.pdf

Capacity Factor

A way to measure the productivity of power plants

$$\text{Capacity Factor} = \frac{\text{Actual Power Produced}}{\text{Power that would have been produced if plant operated at 100\% all the time}}$$

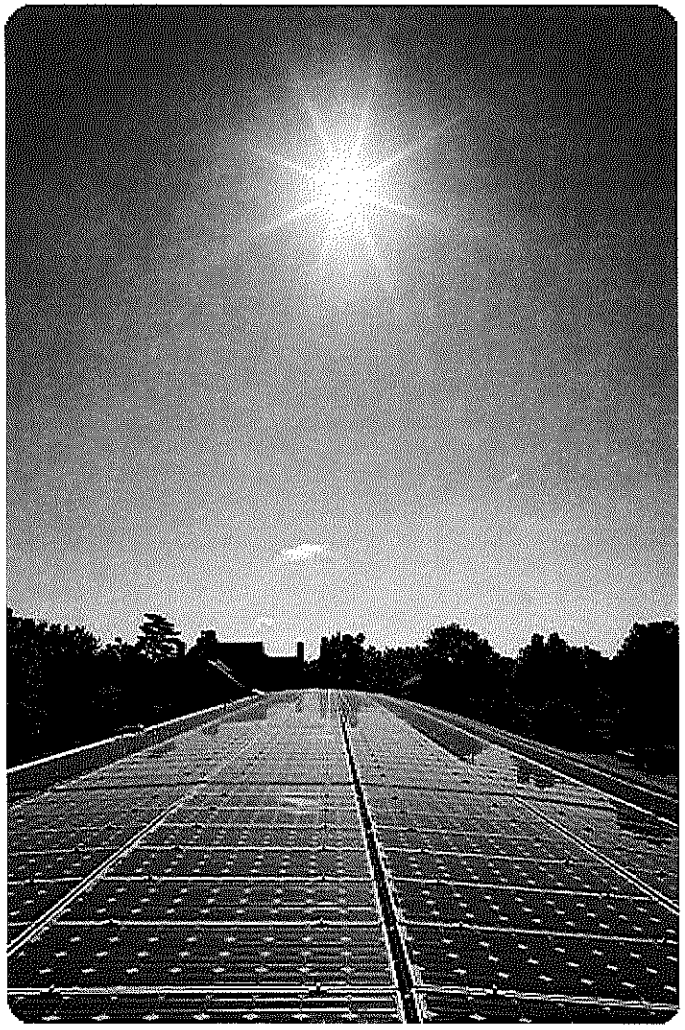
Capacity Factor

Generation Type	Capacity Factor
Nudear+	92%
Coal+	74%
Wind*	25 - 35%
Solar*	19 - 21%
Landfill Gas*	80 - 85%
Wood Biomass*	70 - 75%
Poultry & Swine*	70 - 85%

+Source: **Energy Information Administration** (2007 data) http://www.eia.doe.gov/cneaf/electricity/epa/epata6.html

*Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

Solar Energy



Converting the Sun's energy into electricity

Advantages of Solar Energy[+]

- Air emissions are insignificant because no fuels are combusted
  - No sulfur dioxide emissions
  - No nitrogen oxide emissions
  - No carbon dioxide emissions
- Photovoltaic (PV) systems do not require the use of water to generate electricity
  - Not affected by drought or limited water resources
  - No concern of environmental impact on rivers and lakes

[+] Source: **U.S. Environmental Protection Agency** (2007) http://www.epa.gov/solar/energy-and-you/index.html

Advantages of Solar Energy[+]

- PV systems can be placed on existing structures, requiring no new land
  - Schools, office buildings, etc. can be utilized
- The Sun's energy is typically available during peak times
- No ash or spent fuel created

[+] Source: **U.S. Environmental Protection Agency** (2007) http://www.epa.gov/cleanenergy/energy-and-you/affect/non-hydro.html

Disadvantage of Solar Energy: Costs

- Installed costs for utility-scale solar panels range from $4,000 to $5,000 per KW+
- Residential costs range from $8,000 to $10,000 per KW+
- Many recent projects are not disclosing their upfront costs
- Silicone, a main component in panels, is expensive and in short supply
- Estimates show cost of electricity ranging from 16.5 to 50 cents per kWh+

+Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

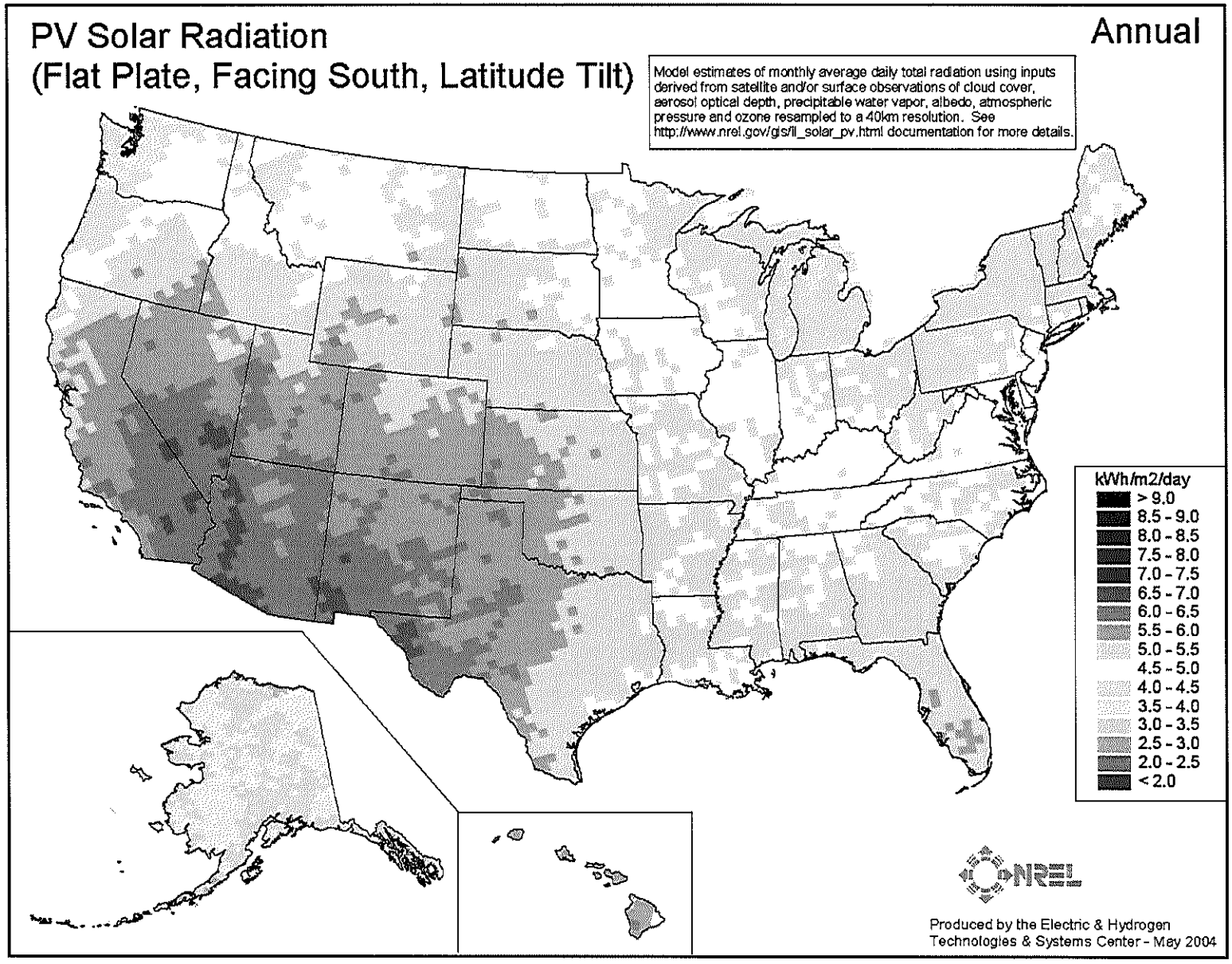
Geographic Limitations

- To efficiently utilize solar power, panels must be located in an area with high solar radiation
- South Carolina receives 4.5 – 5.5 kWh/meter^2/day*
  - This varies during the winter
  - These levels are less than the recommended 6.75 kWh/meter^2/day+

* Source: **U.S. Department of Energy** (2008) http://apps1.eere.energy.gov/states/alternatives/csp.cfm

+ Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

US Solar Potential



Source: **U.S. Department of Energy** (2008) http://apps1.eere.energy.gov/states/alternatives/csp.cfm

Availability of Power

- Sunlight is not constant
  - Must have supplemental system for evening usage
- Capacity Factor: 19% – 21%[+]
- Weather conditions impact power
  - Less solar radiation in the winter
  - Cloudy, overcast days and fog
- Potential damage to panels from storms
- Dust, pollen, and debris can interfere with panels
  - Cleaning may be necessary

[+]Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

Land Usage Considerations

- If panels are not placed on existing structures, land use must be considered
- Land required is difficult to determine because of variances in solar panel sizes and location
- The largest solar facility located in California's Mojave Desert occupies more than 1,500 acres[+]

[+]Source: **NextEra Energy Resources** www.nexteraenergyresources.com

Solar Electric Generating Systems

California's Mojave Desert

- 354 MW capacity
- Nine solar plants
- 900,000 mirrors
- 1,550 acres
- Includes natural gas "back-up"
- Location receives more than 7 kWh/meter^2/day

Solar Electric Generating Systems IV

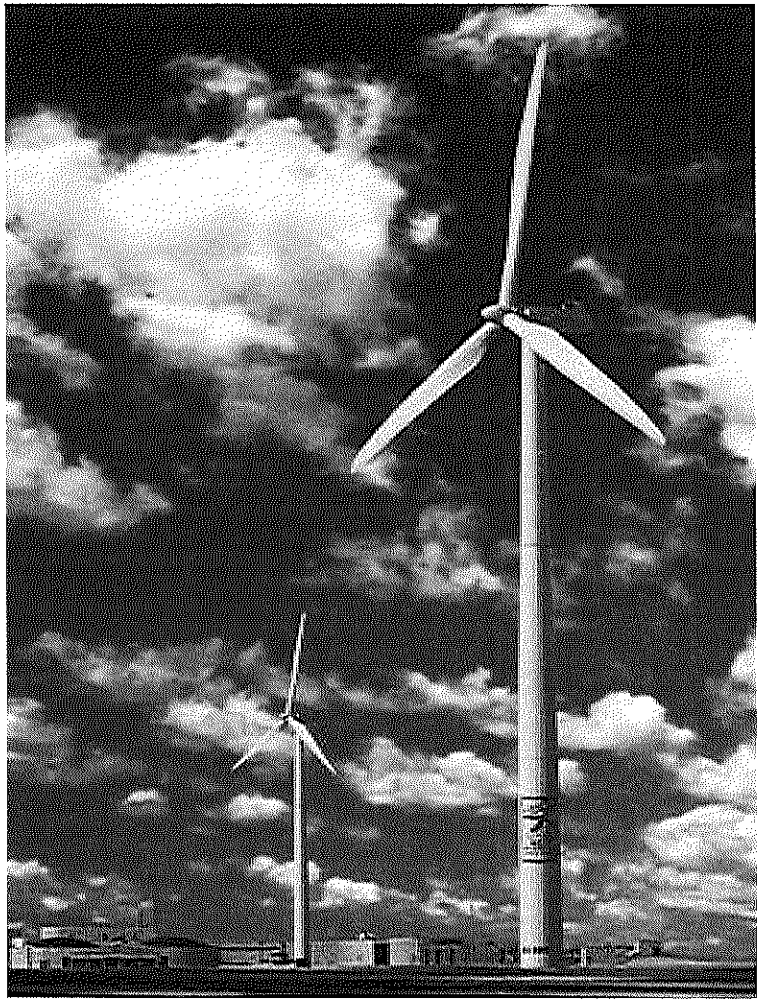
Source: **NextEra Energy Resources** www.nexteraenergyresources.com

How large is 1,550 acres?

- **Riverbanks Zoo:** 170 acres
- **University of South Carolina campus:** 384 acres
- **Central Park:** 843 acres
- **Sesqui State Park:** 1,440 acres
- **1,550 acres** = 1,174 football fields

Half of Central Park's 843 acres

Wind Energy



Converting the Earth's wind into electricity

Advantages of Wind Power[+]

- Air emissions are insignificant because no fuels are combusted
  - No sulfur dioxide emissions
  - No nitrogen oxide emissions
  - No carbon dioxide emissions

- Wind turbines do not require the use of water to generate electricity
  - Not affected by drought or limited water resources
  - No concern of environmental impact on rivers and lakes
  - Minimal water may be needed to clean blades if there is not sufficient rainfall

[+] Source: **U.S. Environmental Protection Agency** (2007) http://www.epa.gov/cleanenergy/energy-and-you/affect/non-hydro.html

Advantages of Wind Power[+]

- Supplies are unlimited when the wind blows
- No ash or spent fuel created
- When turbines are removed from land, there are no solid wastes or fuel residues left behind

[+] Source: **U.S. Environmental Protection Agency** (2007) http://www.epa.gov/cleanenergy/energy-and-you/affect/non-hydro.html

Disadvantage of Wind Power: Costs

- Average installed costs of onshore wind power: $1,800 to $2,000 per KW [+]
- Average installed costs of offshore wind power: $2,800 to $3,300 per KW [+]
- Costs of producing energy vary based on location
- Estimated cost of electricity ranges from 12 to 15.5 cents per kWh[+]

[+] Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

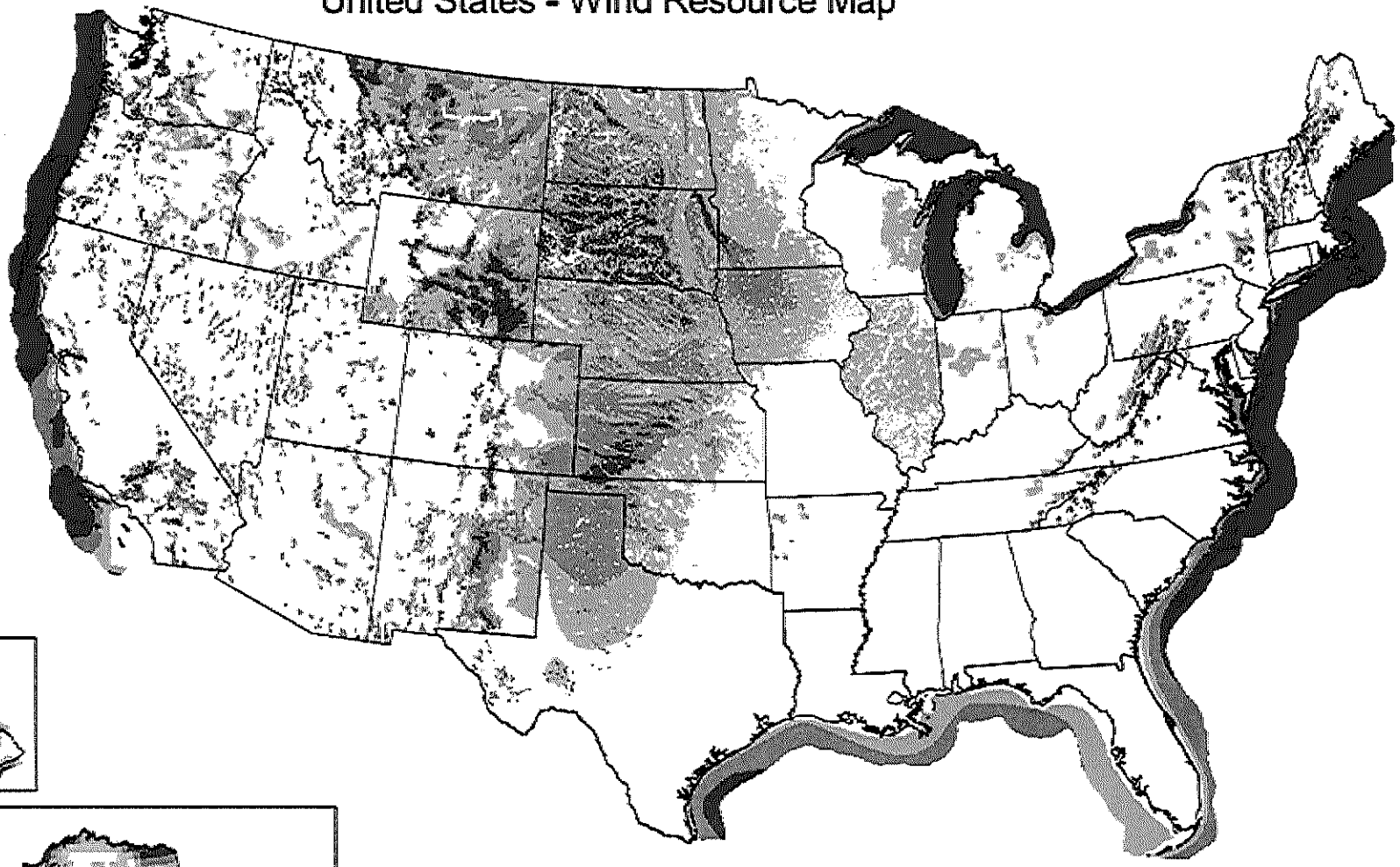
Geographic Limitations

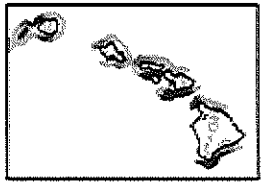
- Grid-connected turbines are typically rated for wind speeds of 14 meters per second (31 mph) +
- South Carolina does not have sufficient on-shore wind speeds to support this form of energy
  - Mean Annual wind speed:
    - 70 meters (230 ft): 6.5 – 7.0 m/s (14.5 – 15.7 mph)*
- Some offshore wind power might be available

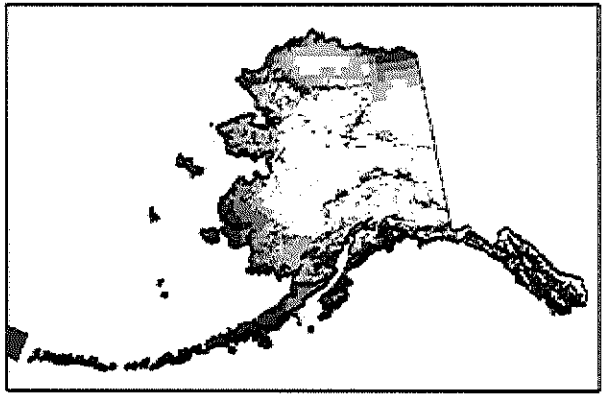
+ Source: **GE Energy** (2005) http://www.gepower.com/prod_serv/products/wind_turbines/en/36mw/36mw_specs.htm

* Source: **S.C. Energy Office** (2003) http://www.energy.sc.gov/publications/SC_spd70m_8April2005.pdf

United States - Wind Resource Map







Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

U.S. Department of Energy
National Renewable Energy Laboratory

* Source: **U.S. Department of Energy** (2009) http://www.windpoweringamerica.gov/wind_maps.asp

Offshore Limitations+

- Underwater transmission lines are very costly so project within 10 miles of the shore would be ideal
- The northern part of SC has some potential for offshore projects
- Offshore permitting is more complicated in federal waters (>3 miles offshore)
- Potential damage from hurricanes
  - GE Wind: Turbines can sustain up to 130 mph winds (Category 3 hurricane)
  - S.C., N.C., and Georgia experienced 21 Category 3 hurricanes or greater since 1851.

+ Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

Availability Limitations

- Wind is intermittent meaning it does not constantly blow
- Must have backup for non-windy times
- Capacity Factor: 25% – 35%[+]
- Wind is not dispatchable, meaning it can not be turned on or off based on demand

[+] Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

Wind Turbine Sizes

GE 3.6 MW Model [+]

- Blades: approx 160 ft each (half of a football field)
- Tower: 295 ft
- Total Height: 455 ft (38 stories – Columbia's Capital Center: 25 stories)
- Vertical Airspace: 364 ft
- Weight: 164 Tons (69 Ford F-150 trucks or 112 Toyota Prius cars)
- Platform:
  - 1,000 tons cement/steel rebar
  - 30-50 feet across
  - 6-30 feet deep

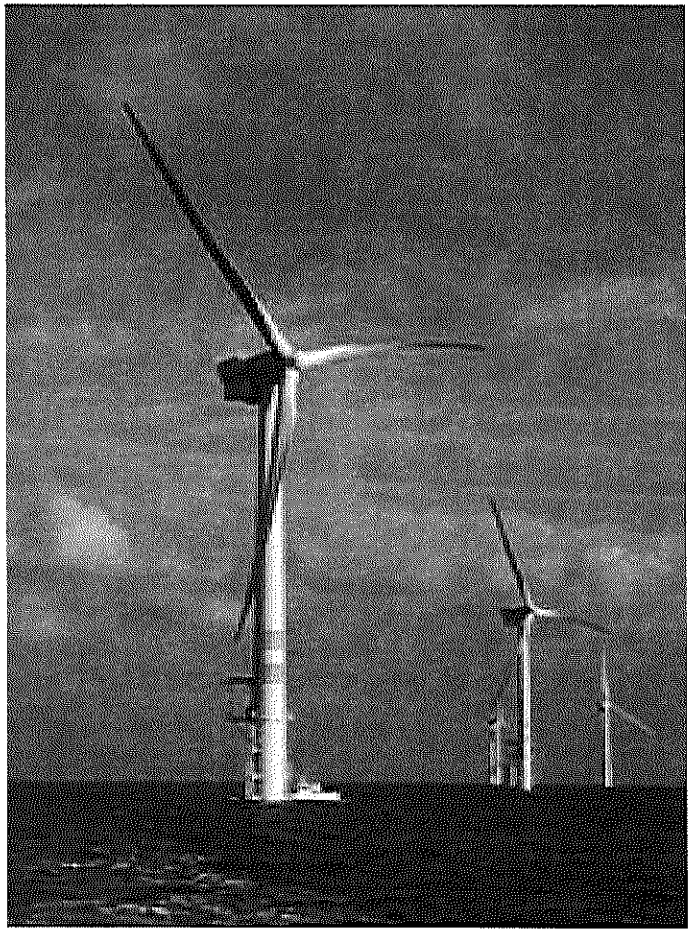
[+] Source: **GE Energy** (2005) http://www.gepower.com/prod_serv/products/wind_turbines/en/36mw/36mw_specs.htm

Cape Wind

Nantucket Sound, MA

Proposed Project:

- Capacity: 420 MW
- Acres: 16,000 (Larger than Myrtle Beach, SC)
- Wind Turbines: 130
- Cost: Undisclosed
- 34 acres per MW



+ Source: **Cape Wind** (2009) www.capewind.org

Biomass: Landfill Gas

Landfills contain methane which can be captured and combusted for energy

Landfill Gas (LFG)

Advantages:

- Methane is captured to produce electricity
- Prevents the emission of methane, a greenhouse gas which is a harmful GHG that is prevalent in landfills
- Capacity factor is 80 – 85% which is higher than other renewable resources[+]

[+] Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

Landfill Gas (LFG)

- Resources are limited – there are only so many landfills able to provide this power
- Btu Content: 9,500
- Costs: 5.9 - 9 cents per kWh[+]

Current Projects:

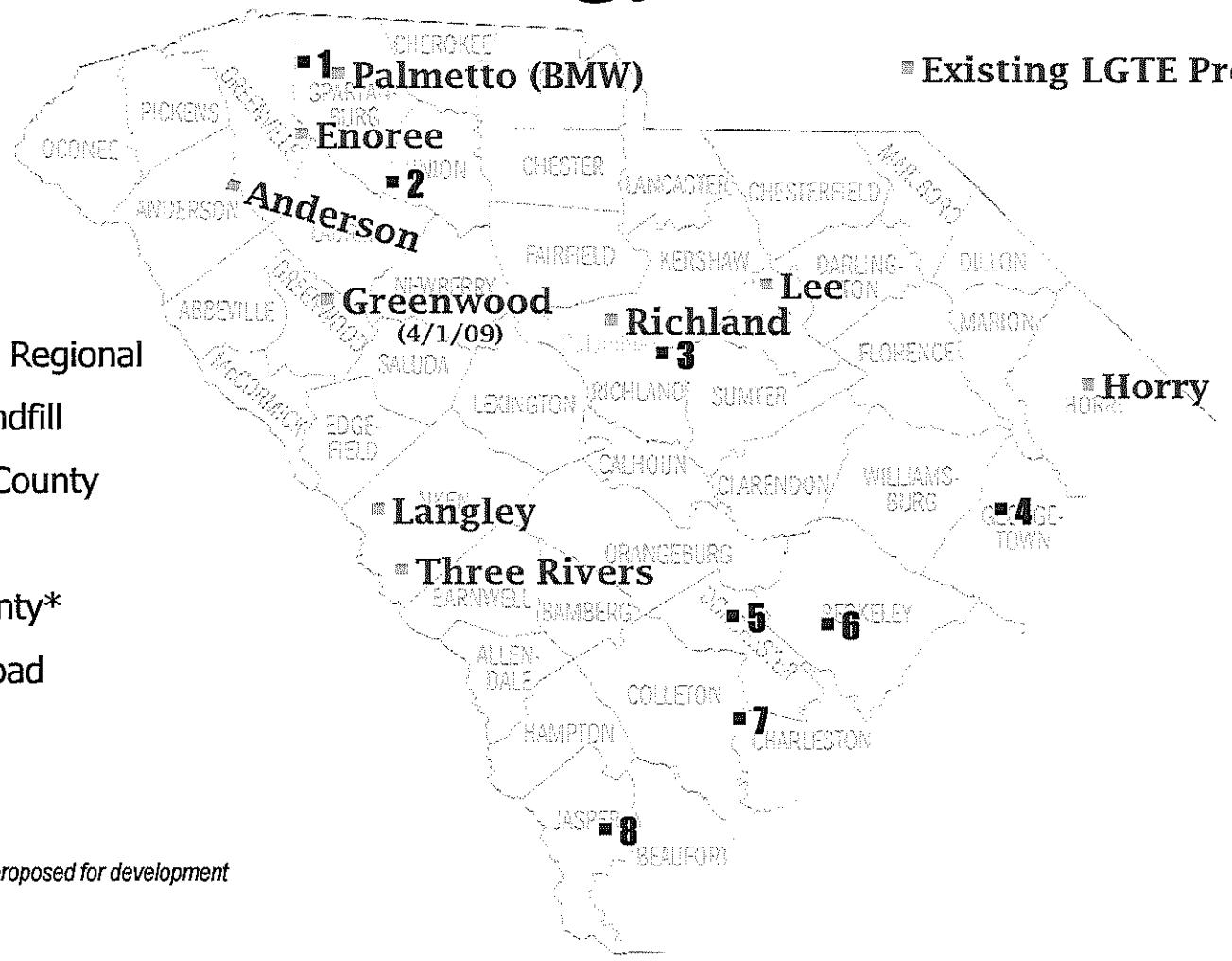
- Ten LFG projects are online in SC – more planned[*]
- Almost 70% of BMW's paint shop energy consumption is generated from LFG[*]

[*] Source: **U.S. Environmental Protection Agency** (2009) http://www.epa.gov/landfill/proj/prof/profile/bmwmanufacturinglandfillg.htm

[+] Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

Existing and Potential Landfill Gas to Energy Sites

1. Wellford
2. Union County Regional
3. Northeast Landfill
4. Georgetown County
5. Oakridge*
6. Berkeley County*
7. Bees Ferry Road
8. Hickory Hill*



* *Under development or proposed for development*

Source: **U.S. Environmental Protection Agency** (2009 data) http://www.epa.gov/lmop/proj/index.htm

Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

Biomass: Wood and Wood Waste

Burning wood and wood waste to create power

Wood and Wood Waste+

- Wood waste, logging residue and commercial thinning can be used in:
  - Direct fire generation (Biomass burned to produce steam to drive turbine engine)
  - Co-Fired Generation (Biomass mixed with fossil fuels, such as coal, to generate power)
- Emissions (CO_2) exist but carbon footprint is reduced
- Reliability is greater than solar or wind
  - Capacity Factor: 70% – 75%

+ Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

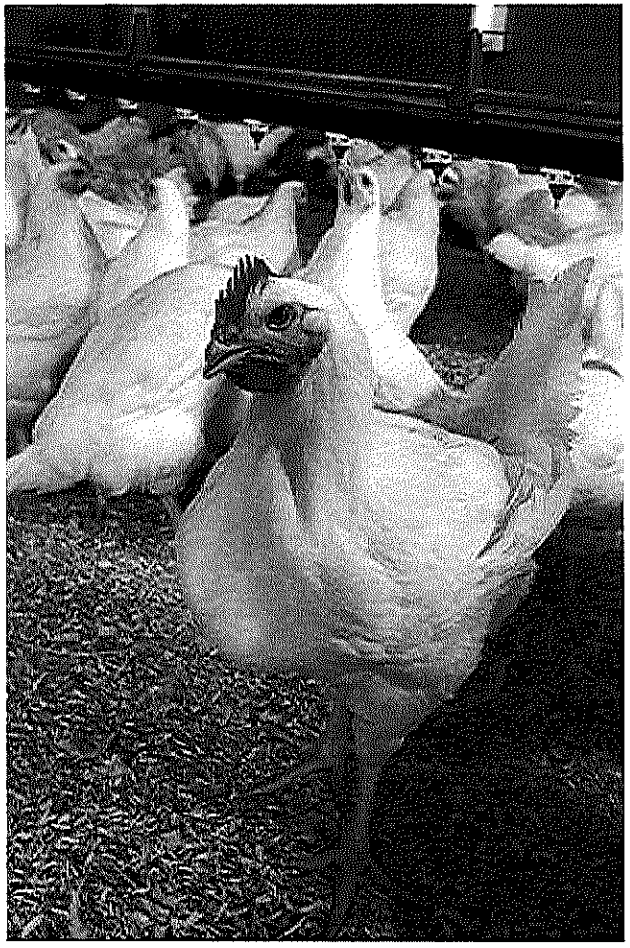
Wood and Wood Waste+

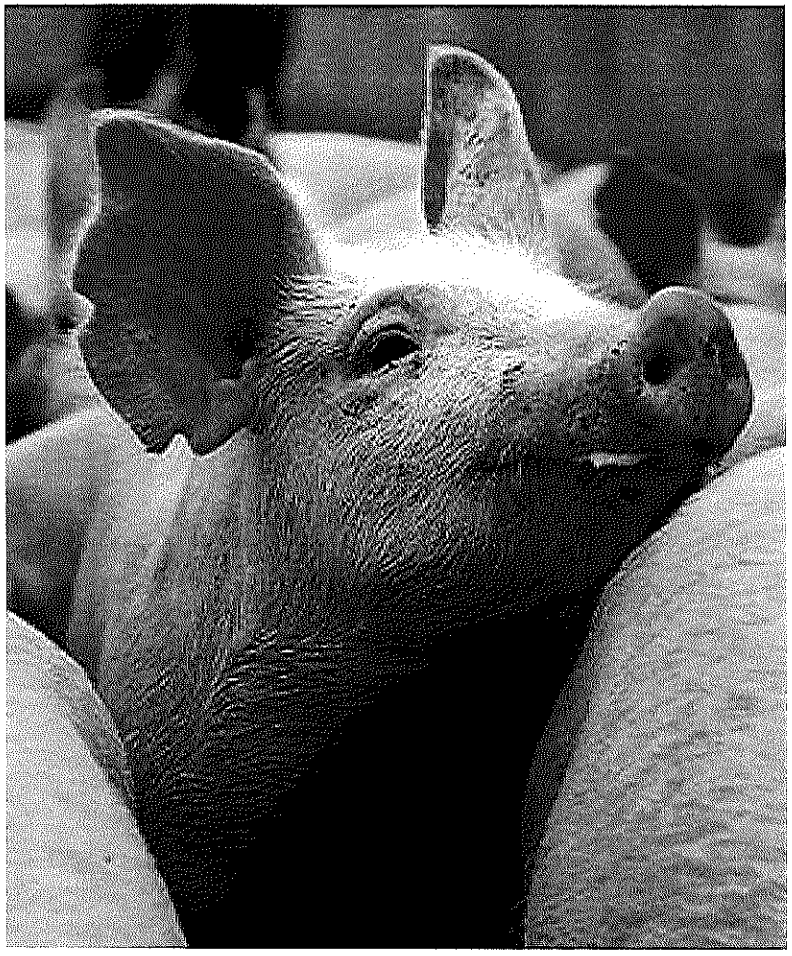
Considerations:

- Limited by the availability of fuel
- Long-distance transportation not ideal
- Btu content: 12,000
- Costs are approximately 9 to 13.5 cents per kWh

+ Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

Biomass: Poultry Litter & Swine Waste





Poultry Litter & Swine Waste[+]

Historically used as fertilizer but there are concerns about groundwater contamination

Advantages:

- Waste is combusted with no new carbon emissions
- Reliability is much greater than solar or wind
  - Capacity Factor: 70% – 85%
- Assists farmers in eliminating waste
- Ash can be used as fertilizer
- Btu content: 12,000 – 14,000

[+] Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

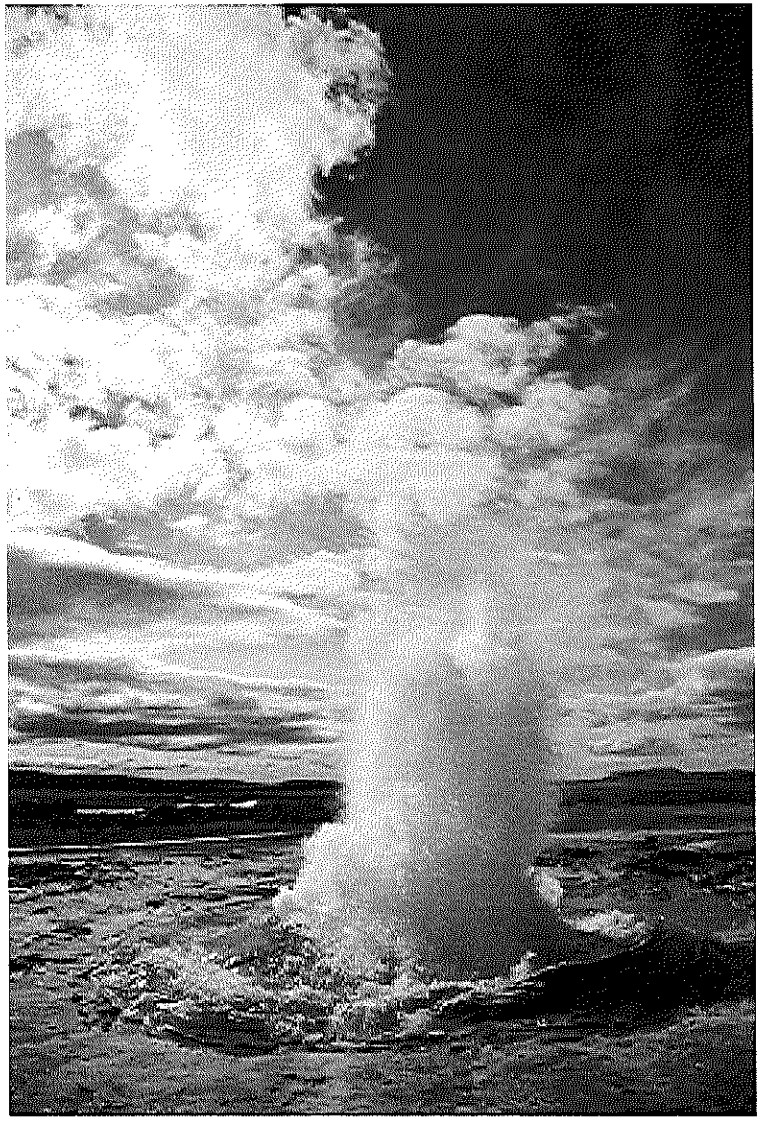
Poultry Litter & Swine Waste+

Considerations:

- Limited by the availability of fuel and cost
  - Poultry Litter is more prevalent in South Carolina
  - Swine Waste is limited and requires greater transportation
- Most likely use is co-firing due to limited resources
- Costs are approximately 9 to 13.5 cents per kWh

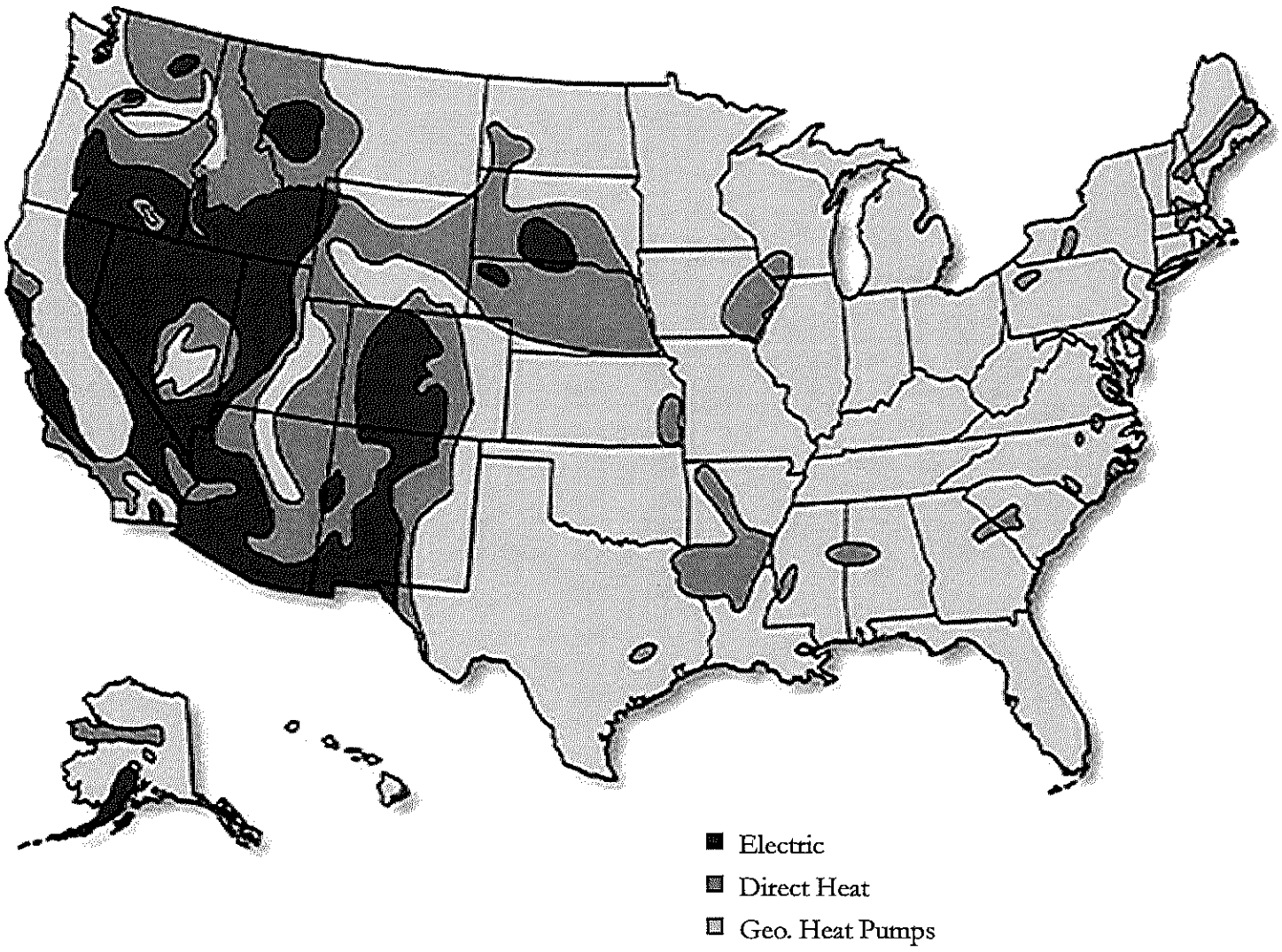
+ Source: **La Capra study** (2007 data) http://www.energy.sc.gov/publications/Renewables%20Potential%20Final%20Report%20-09-12-2007-B.ppt

Geothermal Energy



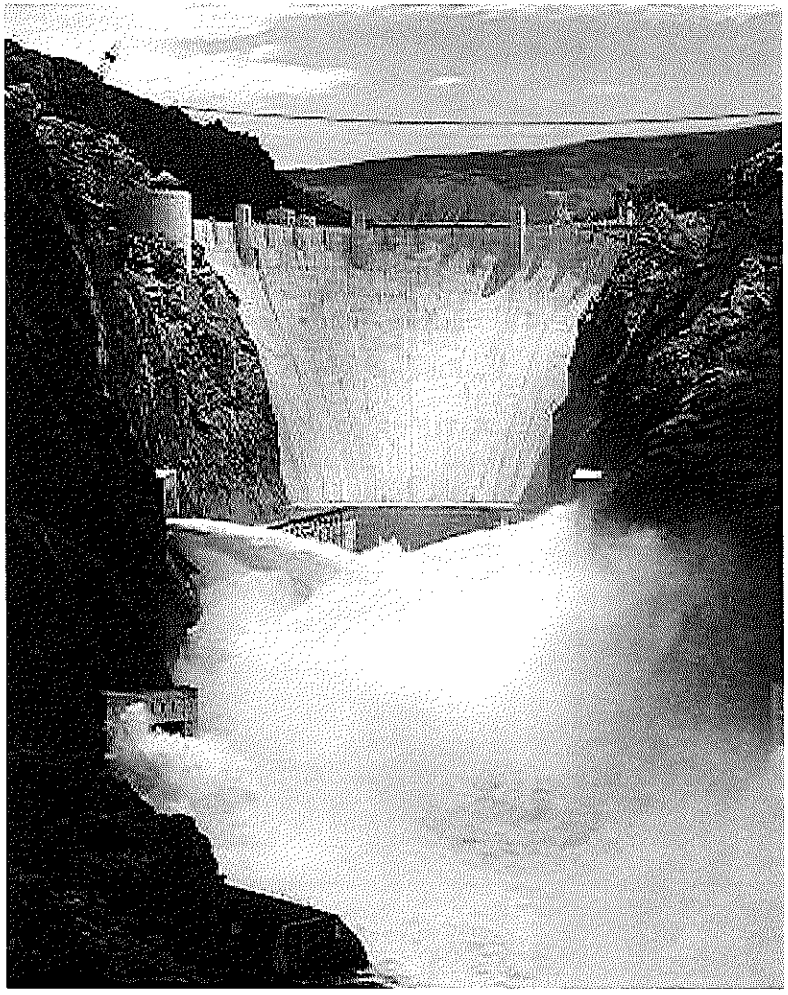
Converting the Earth's heat into energy

Geothermal Potential



Source: **U.S. Department of Energy** (2008) http://www1.eere.energy.gov/tribalenergy/guide/geothermal_resources.html

Hydroelectric Energy



Converting the movement of the Earth's water into energy

What is Clean Energy

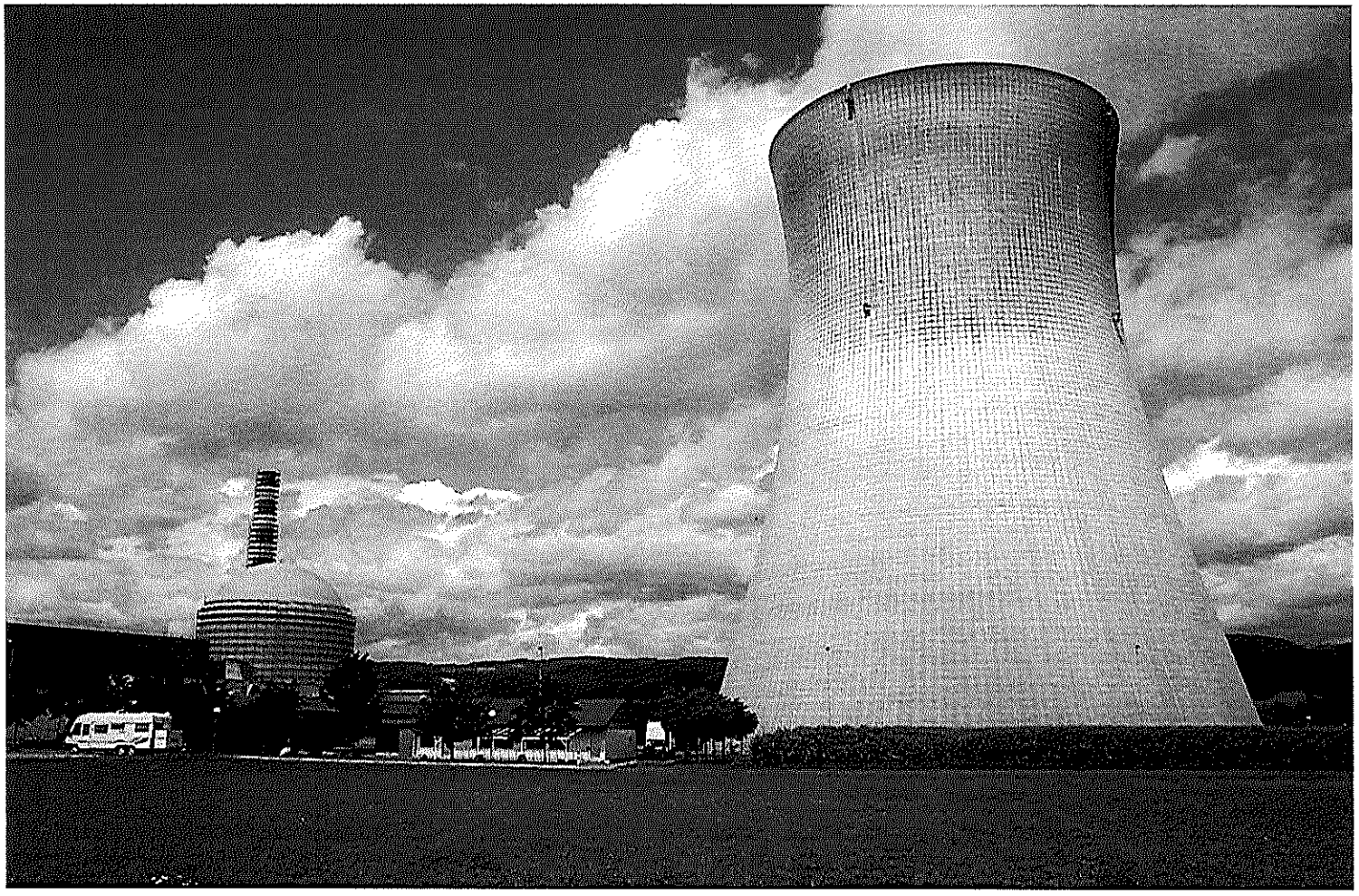
Electricity that when generated, does not produce pollution[+]

<u>This includes:</u>

- Renewables
- Nuclear

[+]Source: **Stirling Energy** http://www.stirlingenergy.com/news-media/glossary.asp

Nuclear Energy



Nuclear Energy

- Advantages:
  - Does not produce air pollution
  - Low fuel and operating costs
  - High capacity factor – 92%
- Disadvantages
  - Water is required for electricity production
  - Spent Fuel
    - On-site Storage
    - Off-site Storage
  - High capital costs

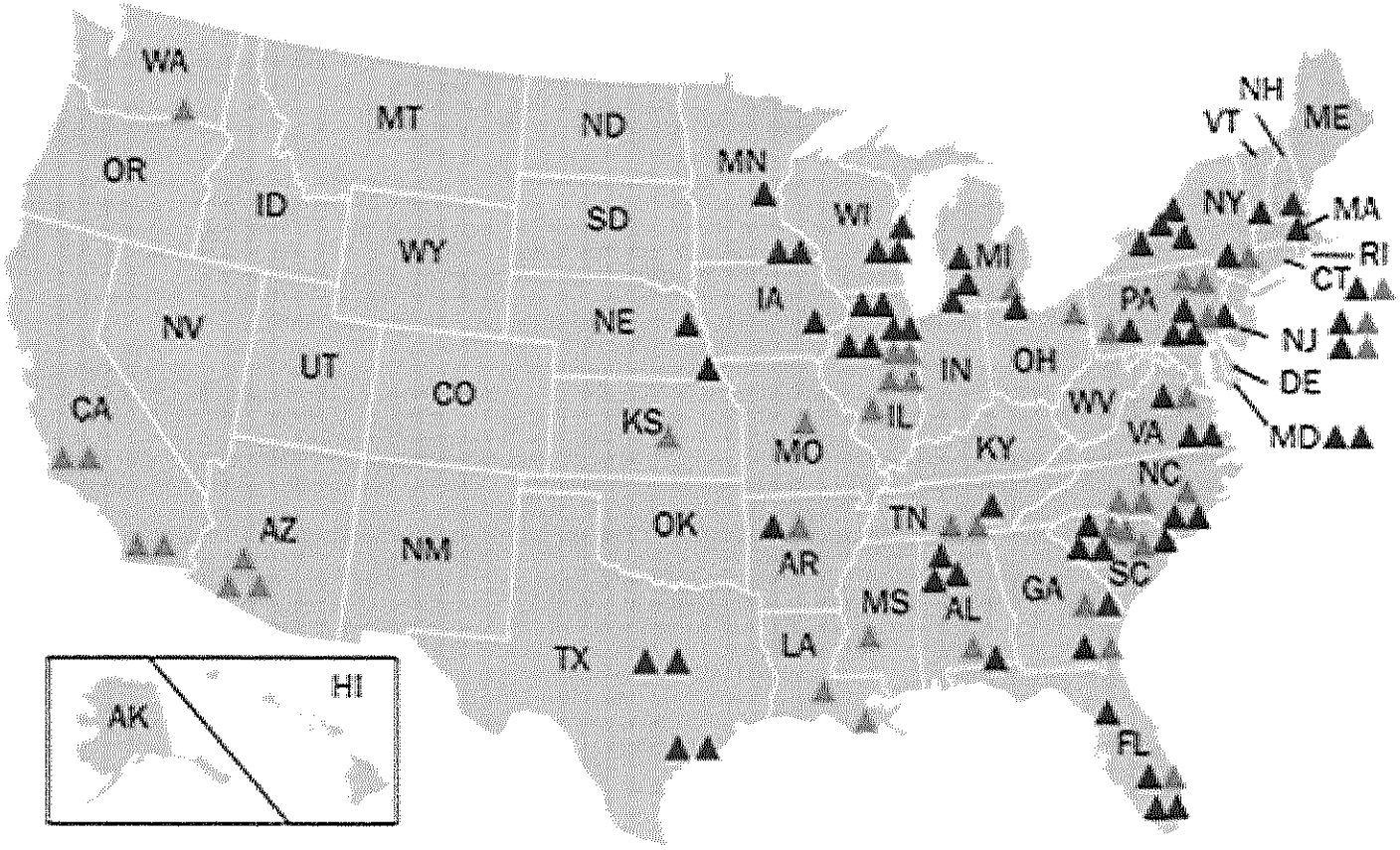
+Source: **Energy Information Administration** (2007 data) http://www.eia.doe.gov/cneaf/electricity/epa/epata6.html

Nuclear Energy+

- 104 reactors in the US
- South Carolina: 3rd in US for nuclear energy
- 7 Reactors in SC
  - Catawba 1 & 2 – 6 miles from Rock Hill, SC
  - Oconee 1, 2 & 3 – 30 miles west of Greenville
  - Robinson 2 – 26 miles from Florence
  - V.C. Summer – Jenkinsville – 26 miles from Columbia

+Source: **Nuclear Regulatory Commission** (2008) http://www.nrc.gov/reactors/operating/map-power-reactors.html

U.S. Commercial Nuclear Power Reactors



Years in Commercial Operation

- 0-9
- 10-19
- 20-29
- 30-39

+Source: **Nuclear Regulatory Commission** (2008)

http://www.nrc.gov/reactors/operating/map-power-reactors.html

Conclusions

- While renewable resources are a part of the solution, they are not *the* solution
- Solar and wind are not economically feasible in South Carolina at this time
- Biomass is an option for South Carolina
- Geothermal and new hydroelectric are not available for utility-scale generation
- Nuclear is an appropriate part of the generation mix for a GHG-constrained society

Questions?