[SUMMARY TABLE THAT WILL BE UPDATED AS QUANTIFICATION IS COMPLETED]

Energy Supply Technical Work Group

Quantification of Mitigation Options

#	Policy Name	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	Level of Support
		2010	2020	Total 2007-2020			
ES-1	Renewable Energy Incentives	0.0	0.1	0.8	$39	$46.7	TBD
ES-2	Environmental Portfolio Standard	5.7	37.7	244.6	-$2,352	-$9.6	TBD
ES-3	Removing barriers to CHP and clean DG	0.5	2.1	14.5	$83	$5.7	TBD
ES-4	CO2 tax and/or cap-and-trade	Under preparation					
ES-5	Legislative changes to address environmental & other factors	Under preparation					
ES-6	Incentives for advanced coal	0.0	8.3	66.7	$2,135	$32.0	TBD
ES-7	Public Benefit Charge	0.7	4.5	28.4	-$685	-$24.1	TBD
ES-8	Waste to Energy	0.00	0.01	0.08	-$4	-$49.9	TBD
ES-9	Incentives for CHP and clean DG	Combined with ES-3					
ES-10	NC Greenpower renewable resources program	0.0	0.2	1.0	$12	$11.5	TBD

ES-1 Renewable Energy Incentives (biomass, wind, solar, geothermal, hydro)

A. Quantification Method:

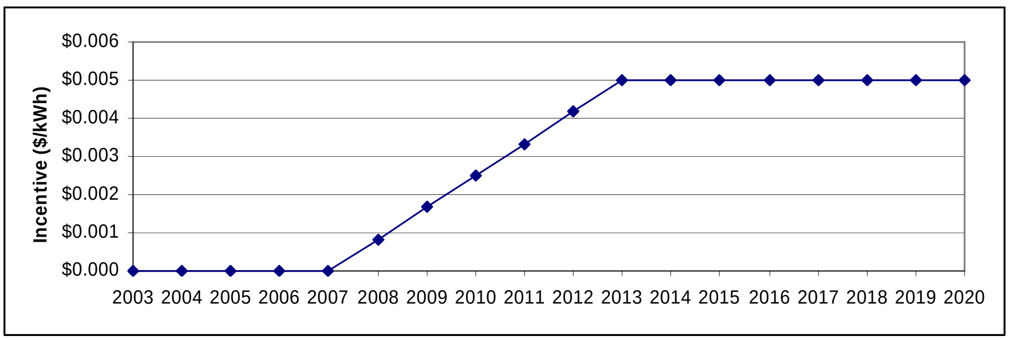
Ideally, one would undertake a full economic modeling exercise to assess the least cost mix/level of renewable energy, relative to NC resource constraints and the incentives proposed. However, such a modeling exercise would be both time-consuming and subject to very large uncertainties. Given time and budget limitations, an alternative analysis strategy is proposed that aims to use previous analysis within a transparent spreadsheet structure. Hence, the proposed analysis will use a simple spreadsheet tool to assess the impact that financial incentives for centralized renewables would have on the penetration of renewable energy. The initial results of the RPS study under preparation in NC will be reviewed for insights into a suitable renewable technology mix, if these results are available within the November-December 2006 time frame. The analysis involves the following steps:

- Identify the type of renewable generation that would most likely be developed as a result of the EPS case combined with the financial incentives using a cost curve approach and taking into account renewable energy resources in NC;
- Estimate the incremental costs associated with each type of renewable technology on a societal costs basis;
- Estimate the incremental renewable generation resulting from the incentive on the basis of a comparison of the net program costs with and without the payments associated with the tax incentives.
- Estimate the amount of CO_2 emissions that are expected to be avoided by the additional renewables resulting from the renewable energy incentives relative to the Reference Case.

B. Key Assumptions and Results:

There are several assumptions that were made in quantifying the GHG reduction benefits and cost effectiveness of this option, as follows:

- *Amount of incentive:* As per guidance from the CAPAG, the maximum level of the incentive was set at \$0.005/kWh (i.e., 0.5 cents/kWh) and was phased in as per the schedule shown on the graph below.



- *Renewable energy mix:* As per guidance from the TWG during the 19 December meeting, the recently completed RPS study[1] for the Public Utilities Commission was reviewed for renewable resource potential in North Carolina and compared with other sources. Resource potential in NC from this study is summarized in the Table below.

	Generation (GWh)		Share (%)	
Resource	Maximum	Practical	Maximum	Practical
Conventional Hydropower	2,032	1,700	3%	11%
Geothermal	0	0	0%	0%
Hog waste	748	600	1%	4%
co-firing	12,207	2,500	20%	17%
Dedicated biomass	20,661	6,200	34%	42%
Solar Thermal	0	0	0%	0%
Solar Photovoltaic	0	0	0%	0%
Wind (onshore)	24,960	3,900	41%	26%
Total	60,608	14,900	100%	100%

The resource shares in the Table above are considerably different from Energy Information Agency (EIA) estimates, which show mostly wind (81%) and the rest consisting of municipal waste (19%). Hence, the analysis was set up to consider three sensitivities, as follows:

  - 1 - LaCapra "practical": This corresponds to the practical assumptions in the RPS report. **Note that this was the default assumption**.
  - 2 - LaCapra "technical potential": This corresponds to the maximum assumptions in the RPS report
  - 3 - EIA estimates for SERC: This corresponds to the EIA assumptions.

- *Levelized costs:* Levelized cost assumptions in 2020 are provided in the Table below. These are central values. At this stage of the analysis, there were no sensitivities considered for either capital costs or fuel.

Resource	Levelized Cost (2005$/MWh)
Hydro	128.0
Wind	54.9
Dedicated biomass	65.7
Hog wastes	54.4
Biomass cofiring	3.0
Solar PV	189.2

- *Avoided costs:* The RCI TWG calculated the avoided costs associated with electric sector expansion. Avoided costs were calculated starting with the levelized 15-year avoided costs from Duke Power, Progress Energy, and Dominion Resource Services price schedules for qualifying facilities purchased power, as filed in late 2005 with the NCUC (Docket No. E-100, Sub 100). Weighted average annual avoided costs were developed by application of estimated weighting factors for on-peak and off-peak usage, and for the fraction of North Carolina's electricity supplied by each of the three utilities. The implied utility-weighted average avoided cost was computed to be **$57/MWh**.

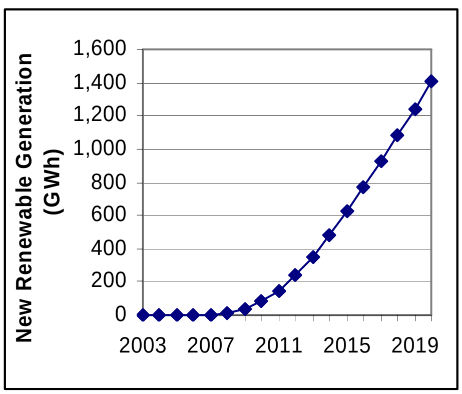
- *Marginal impact of renewable generation:* The introduction of new renewable generation associated with the incentive is assumed to displace generation from existing and/or new

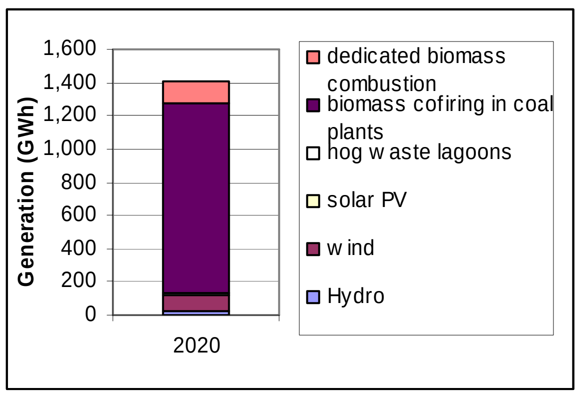
[1] LaCapra Associates, 2006, *Analysis of a Renewable Portfolio Standard for the State of North Carolina*, December

facilities. Since it was unclear was the marginal resource would be, the analysis was set up to consider five sensitivities, as follows:

- 1 - Imports first, then coal/NG/oil generation prorata: This assumes that out-of-state electric power imports are displaced first, followed by fossil resources that are displaced proportional to their share of the overall mix. **Note that this is the default assumption.**
- 2 - Imports first, then coal/NG/oil/nuclear generation prorata: This assumes that out-of-state electric power imports are displaced first, followed by fossil and nuclear resources that are displaced proportional to their share of the overall mix.
- 3 - Imports/coal/NG/oil generation on prorata basis: This assumes that out-of-state electric power imports and fossil resources are displaced proportional to their share of the overall mix.
- 4 - Imports/coal/NG/oil/nuclear generation on prorata basis: This assumes that out-of-state electric power imports, fossil resources, and nuclear resources are displaced proportional to their share of the overall mix.
- 5 - All fossil and hydro in prorata basis: This assumes that all resources except for non-hydro renewables are displaced proportional to their share of the overall mix.

- *New renewable generation:* It was assumed that the level of new renewable generation would be constrained, given the low level of the incentive. It was further assumed that the level of new generation would be less than the renewable generation levels in the Reference Case. The graphs below show the total incremental renewable generation assumed to come on line by the incentives between 2003 and 2020, as well as the new renewable generation mix in 2020.



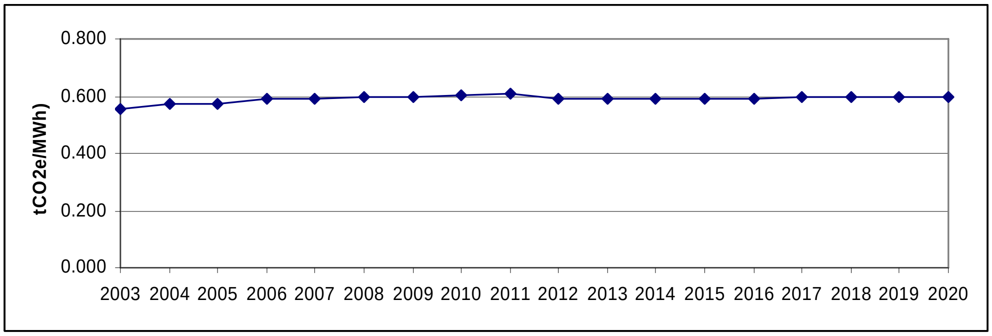


- *System CO2-equivalent emission factor:* The introduction of new renewable generation will lead to different reductions of greenhouse gases (GHG) depending upon whether the full fuel cycle is considered, or whether only GHG emissions are considered at the point of generation. Since it was unclear how the TWG would opt to proceed, the analysis was set up to consider two sensitivities, as follows:

  - 1 – Full fuel cycle emissions associated with electric supply. This assumes that upstream stages of the full fuel cycle (e.g., extraction, transport, beneficiation, etc) are considered the development of CO2e emission factors. **Note that this is the default assumption.**

- 2 –Emissions associated with electric generation only. This assumes that only the generation stage of the fuel cycle is considered the development of CO2e emission factors.

Generation-specific average system emission factors were determined based on information developed in the NC Inventory and Forecast analysis. Full fuel cycle emission factors were determined based on US Department of Energy sources. The graph below shows the average emission factor associated with imported electricity, the sole resource displaced under default assumptions for the renewable incentives options.



- *Results:* The analysis of the assumptions outlined above lead to the results shown in the Table below. These results correspond to default sensitivity assumptions.

		GHG Reductions (E6 tonnes CO2-equiv)				
Option No.	Option Name	2010	2020	Total (2007-2020)	NPV of Costs (E6 2005$)	Cost of Saved
ES-1	Incentives for centralized renewables	0.0	0.1	0.8	$39	$46.7

ES-2 Environmental Portfolio Standard (renewables and energy efficiency) with renewable energy credit trading

A. Quantification Method:

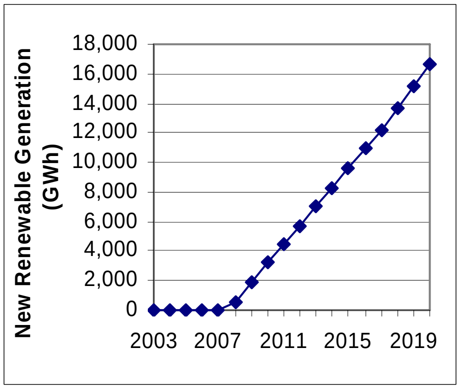
The proposed analysis used a simple spreadsheet tool to compare the aggregated costs and the efficiency and renewable components of the EPS scenario. It will involve the following steps:

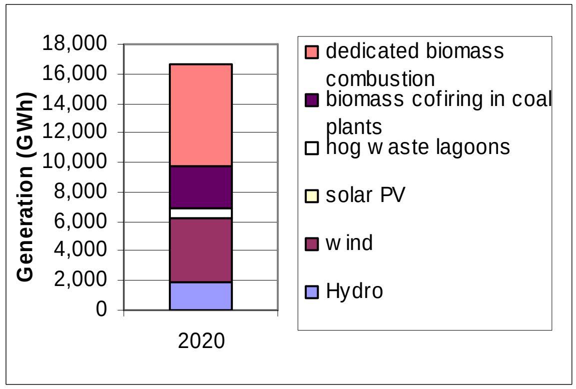
- Identify the type of renewable generation that would most likely be used to meet the EPS' renewable energy targets of 10% by 2017 using a cost curve approach and taking into account the magnitude of renewable energy resources in NC;
- Identify the types of efficiency measures that to meet the EPS' energy efficiency target of 20% by 2020 in coordination with the RCI TWG;
- Estimate the incremental costs of the energy efficiency and renewable generation to meet the targets on a societal costs basis; and
- Estimate the amount of CO_2 emissions that are expected to be avoided by the renewables, relative to the reference case, from the EPS.

B. Key Assumptions and Results:

There are several assumptions that were made in quantifying the GHG reduction benefits and cost effectiveness of this option, as follows. Reference is made to the discussion under ES-1 for assumptions that are common.

- *Energy efficiency target portion of the EPS:* Though the energy efficiency targets indicated above are very similar to the energy efficiency targets analyzed in the RCI TWG, they are not exactly the same (e.g., 19.8% in 2020 for the RCI TWG; 20% in 2020 as per the CAPAG). Hence, the analysis was set up to consider two sensitivities, as follows:
  - 1 – Annual energy efficiency targets as developed by the RCI TWG: **Note that this was the default assumption**.
  - 2 - Annual energy efficiency targets as proposed by the CAPAG: This corresponds to the maximum assumptions in the RPS report
- *Renewable energy mix:* See the discussion under ES-1. The same default assumptions were used.
- *Levelized costs:* See the discussion under ES-1.
- *Avoided costs:* See the discussion under ES-1.
- *Marginal impact of energy efficiency and renewable generation:* See the discussion under ES-1. The same default assumptions were used.
- *New renewable generation:* The graphs below show the total incremental renewable generation assumed to come on line by the incentives between 2003 and 2020, as well as the new renewable generation mix in 2020.

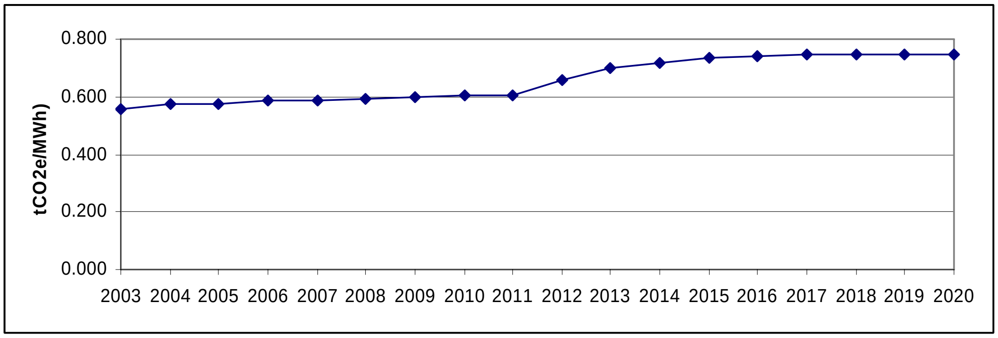


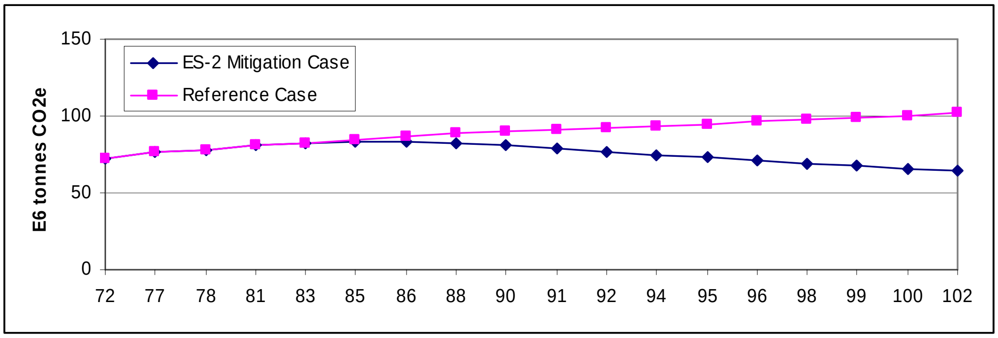


It is important to note that the amount of new renewable generation in 2020 exceeds the "practical" resource potentials identified in the LaCapra report, as summarized in the Table below. However, the levels are well within the maximum resource potentials identified in the LaCapra report.

	Genertion (GWh)		
Resource	ES-2	LaCapra	Difference
hydro	1,895	1,700	11%
wind	4,348	3,900	11%
solar	0	0	NA
hog waste lagoons	669	600	11%
biomass cofiring in coal plants	2,787	2,500	11%
dedicated biomass combustion	6,912	6,200	11%
Total	16,612	14,900	11%

System CO2-equivalent emission factor: See the discussion under ES-1. The same default assumptions were used. The top graph below shows the average emission factor associated with imported electricity and fossil resources displaced under default assumptions for the EPS option. The bottom graph shows annual CO2-equivalent emissions before and after the introduction of the EPS





- *Results:* The analysis of the assumptions outlined above lead to the results shown in the Table below. These results correspond to default sensitivity assumptions.

		GHG Reductions (E6 tonnes CO2-equiv)				
Option No.	Option Name	2010	2020	Total (2007-2020)	NPV of Costs (E6 2005$)	Cost of Saved
ES-2	Environmental performance standard	5.7	37.7	244.6	($2,352)	($9.6)

ES-3 and ES-9 Removing Barriers and Providing Incentives to CHP and Clean DG

A. Quantification Method:

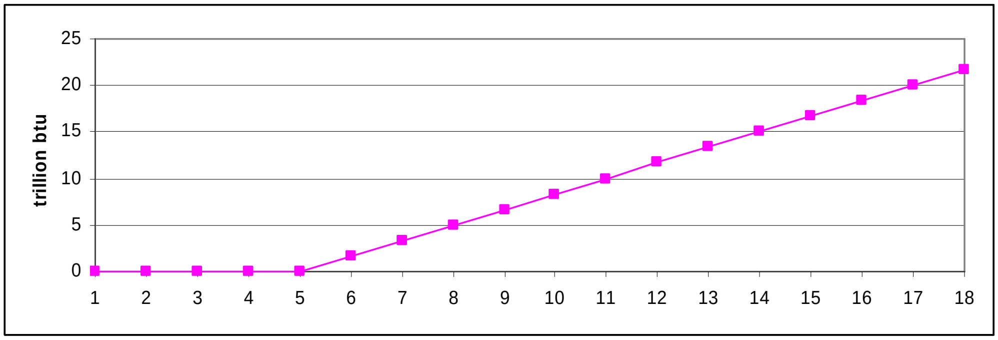
The proposed analysis will use a simple spreadsheet tool to evaluate the costs and benefits associated with introducing 2,000 MW over the study period. It will involve the following steps

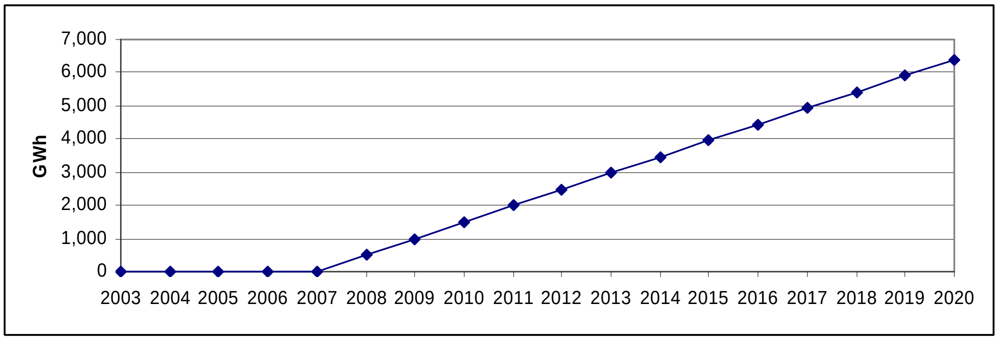
- The starting point for the analysis is to develop a better understanding of the CHP in NC, based on a review of available studies. This will help to confirm a key assumption of the analysis that there exists at least 2,000 MW of CHP potential by 2020, as well as identify a working split between commercial and industrial CHP.
- Integrate assumptions regarding the penetration of and fuel shares for new CHP systems, estimates of future capacity of CHP developed under the policy, and CHP cost and performance for different kinds of systems into a spreadsheet model to estimate the overall net GHG emissions reduction and net cost of the policy. The avoided GHG emissions will be estimated in a manner consistent with the analysis of demand reduction options in RCI.

C. Key Assumptions and Results:

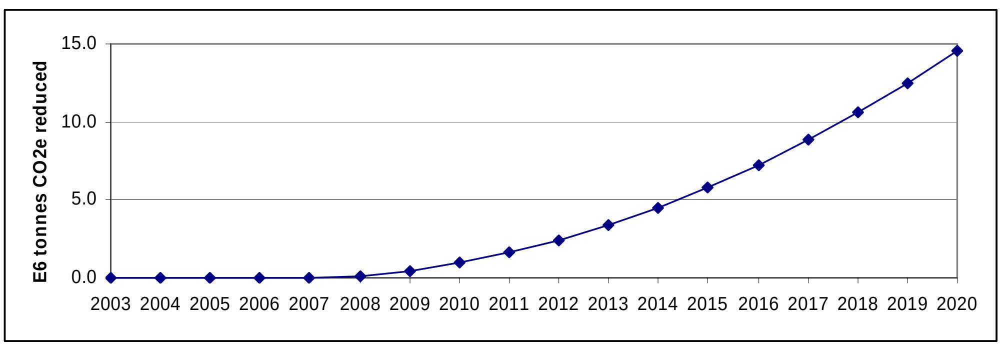
There are several assumptions that were made in quantifying the GHG reduction benefits and cost effectiveness of this option, as follows. Reference is made to the discussion under ES-1 for assumptions that are common.

- *CHP targets:* The CAPAG indicated that a sensitivity analysis should be conducted regarding the level of penetration of CHP systems. Hence, the analysis was set up to consider the following sensitivities.
  - 1 – 50% of the target is met: This corresponds to 1,000 MW of new CHP capacity. **Note that this was the default assumption**.
  - 2 - 90% of the target is met: This corresponds to 1,800 MW of new CHP capacity.
- *Fuel mix:* It was assumed that the fraction of new CHP capacity fueled with NG was 90%, with the remaining 10% split evenly between biomass and coal.
- *Energy and system electricity displaced by CHP:* CHP electric production characteristics as well and system transmission and distribution (T&D) losses were accounted for to estimate annual fuel and system electric generation displaced, as shown on the graph below:





- *Marginal impact of CHP:* See the discussion under ES-1. The same default assumptions were used.
- *CO2-equivalent emission factor and cumulative emissions:* See the discussion under ES-1 for electric supply. The same default assumptions were used. For fuel, standard IPCC emission factors were used for natural gas, coal, biomass, and oil. The graph below shows cumulative CO2-equivalent emission reductions associated with CHP systems.



- *Results:* The analysis of the assumptions outlined above lead to the results shown in the Table below. These results correspond to default sensitivity assumptions.

		GHG Reductions (E6 tonnes CO2-equiv)				
Option No.	Option Name	2010	2020	Total (2007-2020)	NPV of Costs (E6 2005$)	Cost of Saved
ES-3 & ES-9	CHP incentives and barrier removal	0.5	2.1	14.5	$83	$5.7

ES-4: CO_2 tax and/or cap-and-trade (including covering sources including fossil, renewable, and nuclear on life-cycle basis)

A. Quantification Method:

A parameterization approach will be used to assess this policy. This is due to the fact that the modeling of a cap and trade system is highly complex. Parameterization will involve the assessment of the results the cap and trade study done by the Energy Information Administration in a Congressional Service Report from March 2006 entitled "Energy Market Impacts of Alternative Greenhouse Gas Intensity Reduction Goals" and scaling the impacts for NC circumstances.

B. Key Assumptions and Results:

In preparation….

ES-5: Aligning Environmental and Profit Incentives through Electric Sector Regulatory/Rate Reform

A. Quantification Method:

In preparation….

B. Key Assumptions and Results:

In preparation….

ES-6: Incentives for Advanced Coal

A. Quantification Method:

We propose to estimate the incremental cost of IGCC (with and without carbon capture and storage) relative to pulverized coal, and the difference in emissions using a simple spreadsheet analysis which accounts for the additional energy needed for the capture and storage processes. We propose to estimate the costs from the following perspectives:

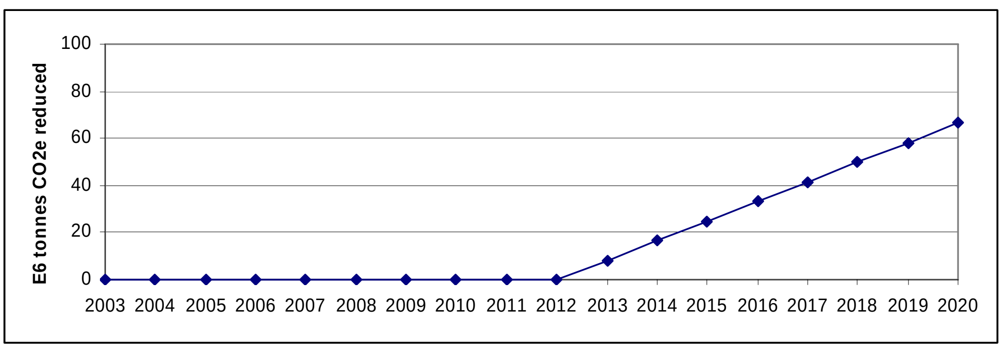
- IGCC only (no carbon capture/storage)
- IGCC with carbon capture and transmission via pipeline, storage and monitoring costs, assuming sequestration in deep saline aquifers near NC.
- IGCC with carbon capture and transmission via truck to depleted natural gas fields in the Southwest.

B. Key Assumptions and Results:

- *IGCC targets:* It was assumed that 1,718 MW of coal capacity would be displaced.
- *Levelized costs:* Levelized cost assumptions in 2020 are provided in the Table below. Sensitivities were considered regarding cost and performance characteristics of IGCC units with carbon capture and storage. The default assumption is the central value.

Facility type	Levelized Cost (2005$/MWh)
Pulverized coal	40.7
IGCC	53.4
IGCC w/CCS - low	43.5
IGCC w/CCS - high	102.1
IGCC w/CCS - central	71.7

- *CO2-equivalent emission factor and cumulative emissions:* An emission factor of 0.843 tCO2e/MWh was used for pulverized coal. An emission factor of 0.405 tCO2e/MWh was used for IGCC with carbon capture and storage. The graph below shows cumulative CO2-equivalent emission reductions associated with the introduction of a large IGCC unit.



- *Results:* The analysis of the assumptions outlined above lead to the results shown in the Table below. These results correspond to default sensitivity assumptions.

		GHG Reductions (E6 tonnes CO2-equiv)				
Option No.	Option Name	2010	2020	Total (2007-2020)	NPV of Costs (E6 2005$)	Cost of Saved
ES-6	Integrated gasification combined cycle with/without carbon capture and storage	0.0	8.3	66.7	$2,135	$32.0

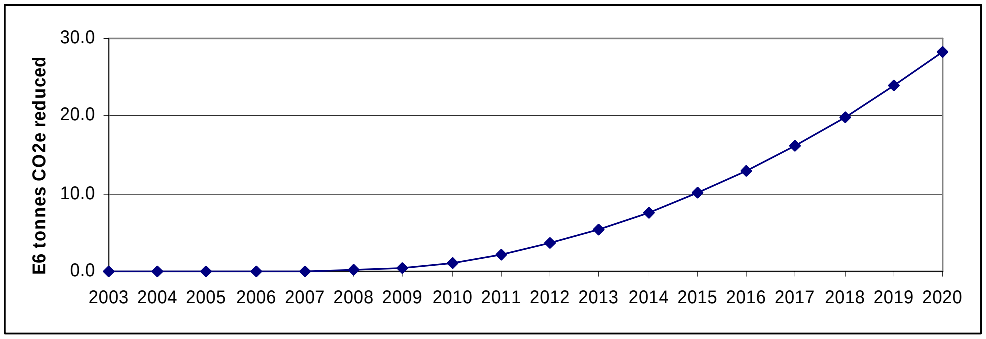
ES-7: Public Benefits Charge on Electric Bills To Support Energy Efficiency Programs

A. Quantification Method:

The analysis of this option was conducted in close collaboration with the RCI who took the initial analytical steps in the quantification of the energy savings.

B. Key Assumptions and Results:

- *Targets:* The targets for the PBF can be structured in various ways. Hence, the analysis was set up to consider the following sensitivities.
  - 1 – RCI TWG analysis: This corresponds to the total generation savings achieved by the PBF as analyzed by the RCI TWG. **Note that this was the default assumption**.
  - 2 - $72 million funding target by 2020. This corresponds to a specific funding level.
  - 3 - 4,760 GWh in reductions by 2020. This corresponds to a specific generation reduction target as advanced by the CAPAG for ES analysis.
- *Marginal impact of energy efficiency:* See the discussion under ES-1. The same default assumptions were used.
- *System CO2-equivalent emission factor:* See the discussion under ES-1. The same default assumptions were used to establish the average system emission factor. The graph below shows the cumulative CO2-equivalent emission reductions due to the PBF.



- *Results:* The analysis of the assumptions outlined above lead to the results shown in the Table below. These results correspond to default sensitivity assumptions.

		GHG Reductions (E6 tonnes CO2-equiv)				
Option No.	Option Name	2010	2020	Total (2007-2020)	NPV of Costs (E6 2005$)	Cost of Saved
ES-7	Public benefits charge	0.7	4.5	28.4	($685)	($24.1)

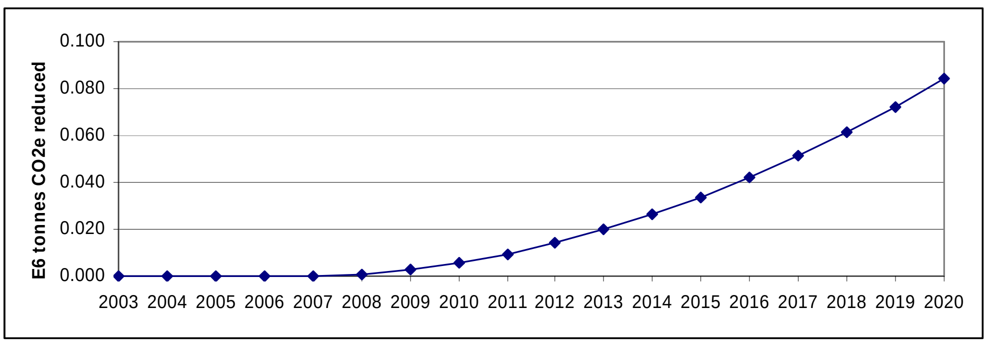
ES-8: Waste to Energy

A. Quantification Method:

We estimated the incremental cost of municipal waste to energy systems relative to the most likely capacity they would displace on the system.

B. Key Assumptions and Results:

- *Technical Capacity:* Technical capacity associated with municipal waste was estimated at 12.8 MW based on the USGS[2] estimate of 546 wastewater treatment public facilities in NC; a net public return flow of 562 million gallons per day (also from USGS); and an assumption of 22.7 MW per million gallon/day from Bailey and Worrel.[3]
- *Targets:* A sensitivity analysis was set up to consider the following:
  - 1 – Mid capacity target of 50% of the technical capacity by 2020. **Note that this was the default assumption**.
  - 2 – Low capacity target of 20% of the technical capacity by 2020.
  - 3 – High capacity target of 100% of the technical capacity by 2020.
- *Marginal impact of energy efficiency and renewable generation:* See the discussion under ES-1. The same default assumptions were used.
- *System CO2-equivalent emission factor:* See the discussion under ES-1. The same default assumptions were used. The graph below shows cumulative CO2-equivalent emission reductions after the introduction of the waste to energy systems. The emission reductions account for the methane emissions that would otherwise be emitted to the atmosphere through anaerobic digestion.



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[2] Table 30 of "Estimated use of water in the United States in 1990 Wastewater Treatment Water Use" by the USGS

[3] "Clean Energy Technologies: A Preliminary Inventory of the Potential for Electricity Generation" by Owen Bailey and Ernst Worrell, LBNL-57451, April 2005

- *Results:* The analysis of the assumptions outlined above lead to the results shown in the Table below. These results correspond to default sensitivity assumptions.

		GHG Reductions (E6 tonnes CO2-equiv)				
Option No.	Option Name	2010	2020	Total (2007-2020)	NPV of Costs (E6 2005$)	Cost of Saved
ES-8	waste-to-energy	0.00	0.01	0.08	($4)	($49.87)

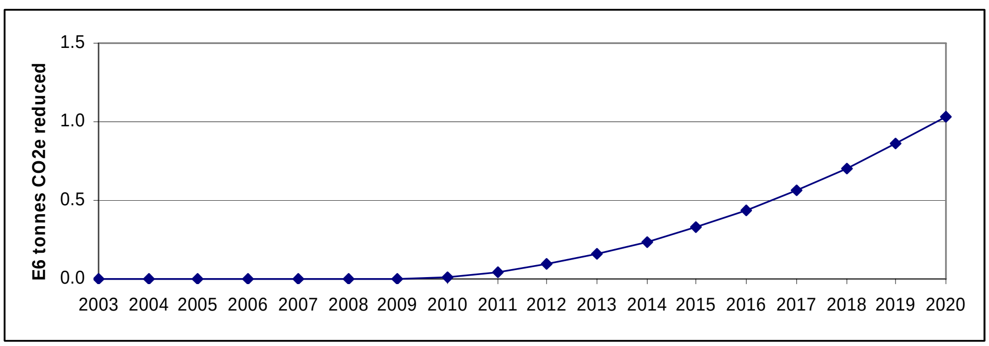
ES-10: GreenPower Renewable Resources Program

A. Quantification Method:

The analysis of this option was conducted in close collaboration with the RCI who took the initial analytical steps in the quantification of the energy savings.

B. Key Assumptions and Results:

- *Targets:* The targets were defined relative to the total generation needed to meet state demand for electricity (i.e., 2,890 GWh in 2020). It was assumed that the target is achieved entirely with renewable energy. The analysis was set up to consider two sensitivities, as follows:
  - 1 – RCI TWG analysis: This corresponds to a 10% target (relative to projected state demand for electricity) achieved by 2017 and remaining constant thereafter. **Note that this was the default assumption**.
  - 2 - This corresponds to 10% target (relative to projected state demand for electricity) achieved by 2020.
- *Marginal impact of energy efficiency:* See the discussion under ES-1. The same default assumptions were used.
- *Renewable energy mix:* See the discussion under ES-1. The same default assumptions were used.
- *System CO2-equivalent emission factor:* See the discussion under ES-1. The same default assumptions were used to establish the average system emission factor. The graph below shows the cumulative CO2-equivalent emission reductions due to the strengthened GreenPower program.



- *Results:* The analysis of the assumptions outlined above lead to the results shown in the Table below. These results correspond to default sensitivity assumptions.

		GHG Reductions (E6 tonnes CO2-equiv)				
Option No.	Option Name	2010	2020	Total (2007-2020)	NPV of Costs (E6 2005$)	Cost of Saved
ES-10	strengthening the NC Greenpower program	0.0	0.2	1.0	$12	$11.5