Appendix D – Development of Renewable Energy Portfolios

TVA's Current Renewable Energy Landscape

In addition to nuclear energy and energy efficiency, expansion of TVA's long history as a renewable energy provider can help achieve TVA's renewed vision for a cleaner and more secure energy future, with less reliance on carbon intensive sources of generation. In addition, a federal renewable energy standard (RES) or, alternatively, a clean energy standard, is expected to be adopted within the next few years, prior to enactment of any additional state-level Renewable Portfolio Standards (RPS) requirements in the Tennessee Valley region.

TVA defines renewable energy as energy production that is sustainable and often naturally replenished (e.g., solar, wind, methane, biomass, geothermal and hydro). There is currently no federal statutory definition of renewable energy resources, but recent federal renewable energy legislative proposals would exclude most of TVA's extensive 3,300 MW conventional hydropower installations. Therefore, TVA has been taking significant strides to increase the non-conventional hydro renewable energy portfolio.

These actions are being taken in part to reduce the risk associated with potential renewable energy requirements, and more importantly, to align with the approved TVA Board of Directors renewed vision, policies and other strategic aspirations (e.g., Strategic Plan, Environmental Policy, Renewable and Clean Energy Guiding Principles, Federal Renewable Portfolio Standard Compliance for Customers, State RPS Compliance for Customers). Actions to date that support these policies are described below:

- Since 1992, TVA has increased generating capacity at its conventional hydropower plants by 565 MW through the Hydro Modernization Program (HMOD). Generation associated with these HMOD improvements could be eligible to meet federal RPS
- Green Power Switch® (GPS) was launched in 2000 to offer Tennessee Valley residents the choice to support renewable energy. 100 percent of the renewable energy produced from GPS is from Tennessee Valley resources, including 14 solar sites, 18 wind turbines, two methane gas sites and nearly 400 Generation Partners solar and wind installations. The GPS program was the first green power pricing program in the Southeast and currently has approximately 12,000 participants. GPS is sold to residential and business consumers in 150 KWh blocks. Each block is $4, which is added to the consumers' power bill each month
- Generation Partners℠ (GP) was launched as a pilot program in 2003 and provides technical support, incentives and premium rates to purchase energy from small-scale (<200 kW) renewable generation systems from eligible resources such as solar photovoltaics, wind, biomass and small hydro. The renewable power generated from GP currently goes towards GPS supply. In the winter of 2009, GP capacity was close to 9 MW, made up of approximately 1 MW of biomass, 7 MW of solar and a little less than 1 MW in wind
- The TVA Board of Directors authorized the purchase of up to 2,000 MW of renewable and clean energy. By February 2011, more than 1,600 MW of solar, wind and methane contracts had been signed. Other proposals are being evaluated
- TVA developed a renewable power purchase plan, known as the Renewable Standard Offer, to further encourage small renewable energy projects in the service territory. This initiative offers a set price for renewable energy projects from 201 kW to 20 MW. The first agreement was signed under this program in January 2011 with Waste Management Renewable Energy LLC for a 4.8 MW landfill gas (i.e., methane) facility

Considering all of these efforts, TVA's current 2012 estimated non-conventional hydro renewable energy portfolio, including commitments for renewable resources not yet online, is approximately 1,800 MW.

Further, TVA is taking initiatives that will advance development of renewable energy efforts, including:

- Completing a biomass conversion feasibility, fuel supply and cost assessment study
- Collaborating with the Tennessee Valley and Eastern Kentucky Wind Working Group to update Tennessee Valley wind energy resource assessments and transmission capabilities using newer wind turbine technology and taller towers
- Partnering with the State of Kentucky to evaluate Kentucky renewable energy resources
- Reviewing waste heat recovery capabilities
- Collaborating with Tennessee Solar Institute to host a solar forum in late 2011
- Partnering to explore a variety of smart grid technologies designed to increase energy efficiency
- Involvement in a multi-partner initiative, called the Electric Vehicle Project, which is the largest deployment of electric vehicles and charging infrastructure in history

Renewable Energy Needs

In 2007, North Carolina became the first state in the Southeast to adopt a RES and energy efficiency standard. Investor-owned utilities operating in North Carolina will be required to meet up to 12.5 percent of their retail sales through renewable energy resources or energy efficiency measures by 2021.

The combination of TVA's renewed vision, the growth in customer demand for renewable energy, the increasing regulatory stringency related to coal burning sources of generation and the anticipation of future federal and state mandates is prompting TVA to move towards generation that reduces or eliminates emissions altogether. Renewable energy is a generation resource that meets many of these challenges. Renewables aid in the reduction of air emissions from electric generation activities and use readily available "fuel" sources that are easily replenished.

IRP Renewable Additions

Two renewable energy portfolios were developed for use in the IRP modeling process in summer and fall 2010. This appendix provides background on information needed by modelers, development of estimates and assumptions common to all portfolios, preparation of 2,500 MW and 3,500 MW portfolios and recent/ongoing events.

Modeling Process

IRP scenarios were developed using two different fixed and given schedules for the introduction of new renewable capacity at TVA, including both self-builds and long-term PPAs. One renewables portfolio was developed to achieve a target of 2,500 MW of new renewable generating capacity (busbar) by 2020. The other portfolio was developed to achieve a target of 3,500 MW of new renewable capacity by that same year.

These portfolio development schedules were designed to be feasible and reasonable in terms of achievability, current and future cost, resource availability and diversity, and federal renewable energy and tax policies. They were intended to be treated in expansion planning models as "must-take" capacity for the Draft IRP (i.e., the capacity additions specified in a schedule were incorporated into the system irrespective of any other alternatives or their costs). This ensures that the scheduled quantities are included in a modeling output no matter the other features of the scenario. The approach was initially applied so the schedule also represented the maximum limit of renewable capacity additions. Subsequent tests were run allowing the model to choose between four different portfolios for the final IRP.

Model Inputs

Inputs provided to model renewable capacity included:

- New renewable capacity at the busbar, by type, by year, in MW (either self-build or PPA)
- Equipment lifetime or PPA term (years)
- Annual capacity factor by year, for intermittent resources (wind and solar) and an assumed hourly profile
- Energy delivered to busbar by year in MWh
- Real "all-in" cost per kilowatt for constructing and operating (including fuel, where applicable) generating equipment over the lifetime and for self-builds (constant 2010 dollars per kW)
- Real "all-in" cost per kW for energy delivery under a PPA over its term (constant 2010 dollars per kW)
- Nominal annual expenditures for use in estimating budget impacts ($ million as spent)

Assumptions for Developing Renewable Portfolios

A number of common assumptions were applied in the development of both the 2,500 MW and 3,500 MW renewable energy portfolios, either across the board or specific to a given resource type. These include:

- Real discount rate (5.5 percent) applied for discounting purposes to all resource types
- Equipment lifetimes or PPA terms by resource type
- Federal investment tax credits, grants and production incentives (except if TVA-owned)
- Capacity factors by resource type
- Per kW all-in cost or cost range by resource type
- A wind generation profile and a solar generation profile representative of Tennessee Valley resources
- Existing or planned capacity already included in power planning models in summer 2010
- Existing or planned capacity not included in power planning models in summer 2010
- Capacity excluded (e.g., existing hydro)

Renewable Resource Types and Components

Figure D-1 shows the resource types, assumed lifetimes, capacity factors, all-in costs and resulting levelized cost.

Resource	Lifetime	Capacity Factor	All-in Cost[1] 2010$/KW	LCOE 2010$/ MWh[2]	Simplifying Assumptions
Hydro modernization	30 years	12%-17%	$454	$30	All cost loaded into first year, including lifetime fuel & O&M
Landfill gas	20 years	85%	$3,851	$38	All cost loaded into first year, including lifetime fuel & O&M. LCOE net of Production Tax Credit
Additional hydro	30 years	33%-45%	$1,688	$40	All cost loaded into first year, including lifetime fuel & O&M
Co-firing (Biomass)	25 years	78%	$3,977-$4,048	$45-$47	All cost loaded into first year, including lifetime fuel & O&M. Revised nominal expenditures
Wind – out-of-Valley (market)	20 years	35%	$4,500	$82	Cost spread over lifetime, one payment per year (revised)
Wind – in Valley	25 years	20%	$4,618	$207	All cost loaded into first year, including lifetime fuel & O&M. Revised nominal expenditures
Dedicated bio-mass (market)	25 years	89%	$7,038	$40	Cost spread over lifetime, one payment per year (revised)
Dedicated biomass (conversion)	25 years	70%	$4,634	$59	All cost loaded into first year, including lifetime fuel & O&M. Revised nominal expenditures
Solar PV	25 years	15%	$5,217	$219	All cost loaded into first year, including lifetime fuel & O&M. LCOE net of tax credits/grants

1 – All-in cost estimates in real 2010$ (including all capital and expense), but excluding any tax incentives.

2 – Levelized Cost of Electricity, real 2010$. Includes relevant tax incentives.

Figure D-1 – Renewable Resource Types and Components

The cost estimates were developed or adapted from a variety of sources, including consultant and industry estimates, internal TVA project estimates and existing PPA price quotes.

Existing and planned renewable capacity already incorporated into power planning by summer 2010 included 580-618 MW of hydro unit modernization and 2 MW of wind in the Tennessee Valley region at Buffalo Mountain (TVA-owned). Existing or planned capacity not already incorporated into power planning in the summer of 2010 included approximately 5 MW of landfill gas (Chestnut Ridge and Middle Point), approximately 3 MW of biomass co-firing at Colbert and Allen coal plants, 27 MW of in-valley wind at Buffalo Mountain (lease agreement with Invenergy) and approximately 2 MW of solar through Generation Partners℠ or other resources.

"New" capacity was set for renewables over and above the amounts listed in Figure D-1. A reasonable deployment schedule was developed for each of the two requested portfolios (2,500 MW and 3,500 MW), with consideration given to the following:

- Cost
- Technology maturity and future advances
- Regional renewable resource availability
- A diversified renewable portfolio strategy
- Anticipated federal legislation/regulation and tax policy

In the Draft IRP, the new renewables were scheduled into the model to meet anticipated renewable energy mandates by 2020. Because of the generally higher cost of renewables and given the use of a model whose objective is minimizing cost of service, the more costly alternatives would not have been picked over more traditional capacity. The modeled portfolio growth in renewables capacity mostly tapers off after 2020 due to higher cost and/or regulatory uncertainty.

The modest post 2020 growth range for renewable energy modeled in the portfolios does not preclude further investments in these resources during the decade. TVA has committed to begin the next IRP effort by 2015. With the development of new data and knowledge the renewable portfolios will be developed further.

An effective improvement of 0.5 percent per year in solar photovoltaic energy output per unit cost was incorporated into the IRP portfolios associated with anticipated technology advancements and declining module cost over time. No other performance or real cost improvements were assumed through 2029 for any of the other resource types. Future market demand and innovation for these resources was dependent on unknown technology-by-technology treatment under future energy and environmental regulation or legislation, as well as future tax policy.

Additional Sensitivities

Sensitivities were explored with targets at 2,000 MW (at a variant of the 2,500 MW portfolio) and at 3,000 MW (at a variant of the 3,500 MW portfolio). These capacity values were targeted for the year 2020. TVA evaluated a model-portfolio selection approach that employed the two core renewable portfolios and the two sensitivities, where the selection of a single portfolio in a model run was driven by a cost criterion that includes costs for emissions and carbon, in addition to traditional cost elements.

Figures D-2 and D-3 contain the capacity values for the 2,500 MW and 3,500 MW renewables portfolios, respectively, prepared for this IRP in summer and fall 2010. These reflect target MW values for the year 2020.

	Net Capacity (MW Cumulative)																	
FY:	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
HMOD						9.6	20.2	31.6	42.9	53.9	64.5	74.7	82.8	88.8	88.8	88.8	88.8	88.8
Landfill gas	1.8	3.7	12.0	15.6	18.4	21.4	25.2	27.9	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3
Addl hydro		24.3	24.3	48.6	48.6	75.6	75.6	107.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6
Co-firing		60.0	118.0	118.0	118.0	118.0	146.0	146.0	146.0	146.0	146.0	146.0	146.0	146.0	146.0	146.0	146.0	146.0
Wind – out-of-Valley (PPA)	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0	1,380.0
Wind – in Valley			50.0	100.0	150.0	200.0	250.0	300.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0
Ded Biomass – PPA		35.0	35.0	67.0	67.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0
Ded Biomass – Conv			80.0	80.0	80.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0
Solar	20.0	25.0	40.0	45.0	60.0	65.0	80.0	85.0	100.0	105.0	120.0	125.0	140.0	145.0	160.0	165.0	180.0	185.0
Total	**1,401.8**	**1,528.0**	**1,739.3**	**1,854.2**	**1,922.0**	**2,156.6**	**2,264.0**	**2,365.1**	**2,489.8**	**2,505.8**	**2,531.4**	**2,546.6**	**2,569.7**	**2,580.7**	**2,595.7**	**2,600.7**	**2,615.7**	**2,620.7**

Figure D-2 – New Renewable Capacity at 2,500 MW

	Net Capacity (MW Cumulative)																	
FY:	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
HMOD						9.6	20.2	31.6	42.9	53.9	64.5	74.7	82.8	88.8	88.8	88.8	88.8	88.8
Landfill gas	1.8	3.7	12.0	15.6	18.4	21.4	25.2	27.9	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3	30.3
Addl hydro	0.0	24.3	24.3	48.6	48.6	75.6	75.6	107.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6	143.6
Co-firing	0.0	60.0	118.0	118.0	118.0	118.0	141.0	169.0	169.0	169.0	169.0	169.0	169.0	169.0	169.0	169.0	169.0	169.0
Wind – out-of-Valley (PPA)	1,380.0	1,480.0	1,630.0	1,780.0	1,930.0	2,080.0	2,230.0	2,380.0	2,380.0	2,380.0	2,380.0	2,380.0	2,380.0	2,380.0	2,380.0	2,380.0	2,380.0	2,380.0
Wind – in Valley			50.0	100.0	150.0	200.0	250.0	300.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0	360.0
Ded Biomass – PPA	0.0	35.0	35.0	67.0	67.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0
Ded Biomass – Conv	0.0	0.0	80.0	80.0	80.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0
Solar	35.0	45.0	75.0	85.0	115.0	125.0	155.0	165.0	195.0	205.0	235.0	245.0	275.0	285.0	315.0	325.0	355.0	365.0
Total	**1,416.8**	**1,648.0**	**2,024.3**	**2,294.2**	**2,527.0**	**2,939.6**	**3,212.0**	**3,468.1**	**3,607.8**	**3,628.8**	**3,669.4**	**3,689.6**	**3,727.7**	**3,747.7**	**3,773.7**	**3,783.7**	**3,813.7**	**3,823.7**

Figure D-3 – New Renewable Capacity at 3,500 MW