Renewable Portfolio Standard and Acreage Calculator

The Renewable Portfolio Standard (RPS) and Acreage Calculator (calculator) is a spreadsheet-based tool for estimating the renewable energy needed to realize user-specified percentage reductions in greenhouse gas emissions (GHG) from the electricity sector.[1] The user may specify the desired percentage reduction in GHG emissions and the values for the drivers of the resulting renewable energy requirement (for example, load growth) to arrive at a total expressed in both GWh and as a RPS as a percentage of retail sales. The user can then build renewable generation portfolios that satisfy the energy/RPS requirement; the calculator provides an estimate of the acreage required for each portfolio. In constructing renewable portfolios, the user can vary assumptions that determine acreage requirements, including the composition of the portfolio with respect to technology (wind, solar, and so forth.), the acreage requirements for a megawatt (MW) of each technology, the share of renewable energy that can be provided by out-of-state resources, and so forth.

The calculator consists of two columns of user entries and output. The left column contains data related to the renewable energy requirement and its derivation. The user provides estimates of electricity demand, desired GHG reductions and the share of these reductions that can be met with offsets, and the amount of energy that is provided by non-renewable and existing renewable sources. The required amount of renewable energy (and RPS) and new renewable energy (the "renewable net short") are then estimated as residuals. The right column contains data related to a user-specified renewable generation portfolio. The user specifies the MW of each technology in the portfolio, plus the performance characteristics and acreage requirements of each technology. The calculator then indicates the extent to which the portfolio satisfies the new renewable energy requirement (as a percentage of the requirement) and the total acreage needed for the portfolio.

The RPS (expressed as a percentage of retail sales) needed to realize a specific percentage reduction in GHG from 1990 levels in the electricity sector is driven by the assumptions itemized below. It is easiest to think of a cap on carbon emissions being imposed on the sector[2]; a certain amount of electricity can be produced using fossil fuels whose aggregate combustion reaches the cap, some amount of electricity can be generated using non-fossil, non-renewable resources (for example, nuclear, entirely clean coal, large hydro); the remaining generation, a share of which can be out-of-state, must be renewable.

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1 Only CO_2 emissions are considered by the calculator;"GHG emissions" are synonymous with "CO_2 emissions" in this document.

2 This cap is higher to the extent that GHG reductions can be realized with offsets purchased from other sectors of the economy. An 8 percent cap on offsets increases the cap in 2050 from 23 to 30 million metric tons.

Section 1: Calculating Need for New Renewable Energy

This section contains and requires information on energy demand, desired GHG reductions, allowed offsets, existing zero-carbon resources, combined heat and power, and the efficiency of gas-fired resources, all needed to estimate the amount of new renewable energy and the RPS needed to meet electricity demand while reducing GHG emissions by the desired amount.

- **Year Under Analysis.** The user may select any year between 2020 and 2050; entering a value outside of this range or other than a whole number results in an error message. In the reminder of this document, the year under analysis is referred to as the "target year."

Energy Needed to Meet Demand

- **Energy Needed in 2010.** The amount of energy that must be produced or purchased by load-serving entities (for example, utilities) to meet customer demand for electricity in 2010. This amount is also referred to as "net energy for load" and includes transmission and distribution losses, for example, it is the amount of energy that must be generated by power plants in aggregate to satisfy customer demand. This 2010 number is an estimate from the Energy Commission's 2009 forecast; it is fixed and should not be changed by the user.
- **Annual economic/demographic demand growth rate (percent).** An estimate of annual load growth from 2010 forward due to economic and demographic factors; the impacts of energy efficiency expenditures are not considered here. The value for 1990 – 2010 was 1.5 percent.
- **Annual reductions from energy efficiency (percent).** An estimate of the annual change in net energy for load from energy efficiency programs from 2010 forward. The value for 1990 – 2010 was -0.81 percent.
- **GWh savings from EE.** The increase in Net Energy for Load in the target year had the energy efficiency program impacts been set at zero.
- **Net Energy for Load (subtotal).** The Net Energy for Load in the target year after growth due to economic/demographic factors and impacts of energy efficiency are accounted for.
- **Needed energy increases in target year from electrification.** An estimate of the incremental increase in Net Energy for Load in the target year due to electrification of the other sectors of the economy, notably the transportation sector. The calculations that underlie this value can be found in the cells immediately below Section 1.
- **New combined heat and power reductions.** Energy consumed on site by cogenerators is treated as a reduction to net energy for load, and is escalated to account for avoided transmission and distribution losses. The value in this cell is determined by entries in the

Combined Heat and Power section of the calculator (in Section 1; these entries are discussed below), as well as assumed transmission and distribution losses.

- **New customer distributed generation reductions**. Customer distributed generation encompasses customer-side of the meter generation (for example, small rooftop PV) in excess of that already embedded in the Energy Commission's demand forecast. Energy generated and consumed on site is treated as a reduction to energy needed to meet demand (net energy for load) and is escalated to account for avoided transmission and distribution losses. The value in this cell is determined by entries in the Customer Distributed Generation section of the calculator (in Section 1; these entries are discussed below) as well as assumed transmission and distribution losses.
- **Energy needed before storage (subtotal).** Net Energy for Load in the target year considering all factors except incremental energy needed for storage
- **Storage needs.** Incremental energy needed to meet storage requirements. The value in this cell is determined by entries in the Storage Needs section of the calculator (these entries are discussed below).
- **Final energy needed in target year (Net Energy for Load)**. This is the amount of energy needed to meet demand in target year, net of that self-provided by combined heat and power and customer distributed generation.

Carbon Baseline

This section allows the user to specify desired percentage reductions in GHG emissions from the electricity sector and the share of reductions that can be met with offsets from uncapped sectors of the economy.

- **1990 baseline carbon level.** The value of 115.8 million metric tons for the electricity sector in 1990 is from the Air Resource Board's Carbon Inventory. This value is fixed and should not be changed by the user.
- **Desired percentage reduction in GHG.** This user chosen value sets a target for GHG reductions in the target year for the electricity sector. The value input must be between 5 percent and 99.9 percent.
- **Target year carbon cap without offsets.** This is the CO_2 cap for the electricity sector (in million metric tons) given the user-selected percentage reduction in GHG emissions, assuming that no offsets are allowed. All GHG reductions must come from reduced emissions by electric generators.
- **Allowed carbon offsets.** The amount of electricity sector GHG reductions (as a percentage of needed reductions in GHG emissions) that are a result of offsets purchased from uncapped sectors of the economy, expressed as a percentage of total reductions required.

- **Offsets.** The total amount of offsets allowed in million metric tons, equal to the reductions in GHG emissions from the electricity sector required to satisfy the percentage reduction specified by the user, multiplied by the percentage of offsets that are allowed. This value cannot be changed by the user directly, but will change when Allowed Carbon Offsets is changed.
- **Target year carbon cap with offsets.** The 2050 carbon cap without offsets plus the additional emissions allowed as result of purchase of offsets from elsewhere in the economy. This value cannot be changed by the user directly, but will change when Allowed Carbon Offsets is changed.

Zero-Carbon Generation Resources in Target Year

This section contains information about existing renewables and non-renewable zero-carbon resources that are expected to be available in the target year. When combined with the fossil fired generation allowed under the carbon cap, these determine the residual need for energy that must be met by renewable resources.

- **Existing Renewables Operating in Target Year.** By the end of 2011, some 40,000 GWh of renewable energy will be owned by or under contract to California utilities. The share of these still under contract/operating in the target year will contribute to the RPS and reduce the need for the construction of new renewable resources between now and 2050. This value is the sum of the in-state and out-of-state values immediately below; only these latter values can be edited by the user.
    - **In state.** The energy provided in the target year by in-state renewable resources that exist in 2011.
    - **Out-of-state.** The energy provided by out-of-state renewables in the target year that are providing energy in service of California loads in 2011.
- **Large Hydroelectric Energy.** In an average water year, large hydroelectric facilities in California currently provide 33,000 GWh of energy (based on 1995 – 2009 average). The user may adjust this number to reflect new construction, changes in output due to climate change, and so forth.
- **Existing Nuclear Energy.** Diablo Canyon, San Onofre and Palo Verde (California utility share) provide 42,000 GWh of energy annually (Diablo Canyon and san Onofre provide 18,000 GWh each, Palo Verde 6,000 GWh). The user can assume they have been decommissioned or continue to operate in the target year.
- **New nuclear energy.** This allows the user to estimate the renewable energy need/acreage impacts associated with developing additional nuclear resources. The user inputs the nameplate MW and capacity factor; the resulting energy value is a product of these values and should not be directly input by the user.

- **Out-of-state (non-renewable) zero-carbon resources.** At present, the only zero-carbon, non-renewable resources owned by or under contract to California utilities with an RPS obligation are the Palo Verde Nuclear Station and Hoover Dam. The user can enter a value that reflects future contributions of such resources to meeting electricity demand in California, based on assumptions regarding contracts with out-of-state large hydro facilities, the development of clean coal resources out-of-state, and so forth.
- **Total energy from zero-carbon resources in target year.** The sum of the entries in this section, this reflects the energy from all zero-carbon resources except the incremental renewable energy needed to satisfy the GHG emissions constraint.

New Combined Heat and Power

CHP entails the production of electricity using waste heat from an industrial process or the capture of waste heat from electricity generation for use in an industrial process. In both instances it produces electricity for both on-site use and for export to the transmission grid.[3]

- **MW (nameplate capacity).** Total nameplate capacity for new CHP
- **Annual Operating Level (Capacity Factor).** Total annual output for this technology, expressed as a percentage of full output (nameplate capacity multiplied by 8,760 hours)
- **Share of total production-consumed on site; Energy consumed on site.** Energy consumed on-site is assumed to reduce energy needed to meet demand (net energy for load) by an amount equal to energy consumed on-site plus avoid transmission and distribution losses. The GHG emissions associated with the energy consumed on site are attributed to the industrial sector, not the electricity sector.
- **Energy exported to grid.** The amount of energy that is exported to the grid (wholesale energy). The GHG emissions associated with this energy are attributed to the electricity sector.
- **Assumed operating efficiency for exported energy (heat rate).** This value is used to calculate the assumed CO_2 emissions for the energy exported to the grid.
- **Carbon in exported energy.** The carbon content (million metric tons) of the energy exported to the grid by new CHP

Customer Distributed Generation (Small Rooftop PV)

- **MW (nameplate) including original 3,000 MW CSI target.** Total nameplate capacity for customer distributed generation (small rooftop PV).

3 In the event that all electricity is consumed on site, both the electrical load and the generation resource used to provide it are excluded from the Energy Commission's supply/demand balance.

- **Annual operating level (capacity factor).** Annual output from small rooftop PV (GWh), expressed as a percentage of nameplate capacity multiplied by 8,760.
- **Total energy from small rooftop solar.** Annual output from small rooftop solar. This number is derived from the values in the two cells immediately above and should not be changed by the user.
- **Incremental (not embedded in 2009 forecast) customer DG output.** The Energy Commission's demand forecast assumes the development of 3,000 MW of small rooftop PV and reduces net energy for load accordingly; this cell adjusts total small rooftop PV output to account for this fact.

Storage Needs

The electricity system of the future may include a substantial amount of energy storage in order to incorporate variable (intermittent) energy resources: shift output to higher demand hours, manage large amounts of generation on the distribution system, and so forth.

- **Percentage of total energy stored.** Share of net energy for load (for all uses other than storage; see cell D15) that is stored.
- **Efficiency.** The percentage of stored energy that is recovered. For example, 90 percent efficiency indicates that 9 MWh are recovered when 10 MWh are stored.
- **Additional energy needed.** The total amount of energy needed to replace the energy needed for storage, for example, lost due to storage. This value is derived from Percent of total energy stored and Efficiency; it should not be directly changed by the user.

Fossil Performance and Sequestration

The performance of fossil generation and sequestration of resulting GHG emissions influence the GWh of fossil generation that are allowed under the carbon cap.

- **Assumed average operating efficiency for gas-fired generation (Btu/kWh).** The average heat rate for gas-fired power plants. The heat rate for gas-fired generation (the efficiency with which the fuel is converted to electricity) currently varies from 6.800 Btu/kWh for new combined cycles (serving baseload needs) to 12,000 Btu/kWh and more for peaking plants. The average heat rate in future years will depend on technological change and the role that gas plants play in a renewable intensive system and the types of plants that are thus required. A reasonable assumption for the average heat rate in 2050 is somewhere between 7,000 and 8,000 Btu/kWh.
- **Assumed average operating efficiency for coal-fired generation (Btu/kWh).** The average heat rate for coal-fired power plants in California utility portfolios.
- **MW of generation with sequestration.** The MW of capacity that sequester some share of carbon emissions for each technology.

- **Percent carbon sequestered.** The share of carbon emissions (weighted average across MW of generation with sequestration) that is sequestered for gas/coal-fired emissions. For example, if two 500-MW gas-fired power plants sequester 100% and 50% of their carbon emissions, MW generation with sequestration is 1,000; Percent carbon sequestered is 75 percent.
- **Capacity factor.** The weighted average capacity factor (GWh of generation expressed as a share of potential output, MW multiplied by 8,760) of MW generation with sequestration for each technology.
- **Energy from sequestered generation.** The total energy from plants that sequester carbon for each technology. This value is derived from MW of generation with sequestration and Capacity factor; it should not be directly changed by the user.
- **MMT carbon.** The carbon emissions from power plants that sequester some share of their carbon emissions for each technology. This value is derived from MW of generation with sequestration, Capacity factor, and the carbon content of natural gas (0.053 metric tons/million Btu) and coal (0.093 metric tons/million Btu); it should not be directly changed by the user.

Total Fossil Generation

This section compiles the fossil generation that takes place/is allowed under the cap. All values are from other cells or are derived from other values; they should not be directly changed by the user

- **CHP exports.** The energy from CHP facilities that is exported to the grid (wholesale energy). Taken from cell D47.
- **Sequestered gas.** Generation from gas-fired plants that sequester some share of carbon emissions. Taken from cell D69.
- **Sequestered coal.** Generation from coal-fired plants that sequester some share of carbon emissions. Taken from cell D74.
- **Remaining GWh gas allowed under cap.** Estimates the residual carbon emissions allowed under the cap: Target year carbon cap with offsets less emissions from CHP exports, Sequestered gas, and Sequestered coal. Then determines the amount of additional gas-fired generation allowed under the cap based on the Assumed average operating efficiency for gas-fired generation.
- **Total Fossil Generation.** The sum of CHP exports, Sequestered gas. Sequestered coal, and Remaining GHG allowed under cap.

New Renewable Energy Needed (Net Short)

This section compiles the amount of new renewable energy needed in the target year. All of the values are determined by entries/assumptions elsewhere; the user should not directly change any of the cell entries.

- **Renewable energy needed to meet carbon constraint.** Net energy for load in the target year, less energy available from (a) zero-carbon resources, (b) new CHP exports, (c) gas- and coal-fired generation that sequesters a share of its carbon emissions, and (d) residual gas-fired generation allowed under the cap.
- **Existing renewables still operating in target year.** Taken from cell D29
- **New renewable energy needed (Net short).** Renewable energy needed to meet carbon constraint less Existing renewables still operating in target year.

RPS Calculations

This section contains derivations of the RPS needed to satisfy the carbon constraint imposed in the target year. Only Transmission and distribution losses should be changed by the user; all other entries are derived from values elsewhere in the spreadsheet.

- **Final energy needed in target year.** Net energy for load taken from cell D17
- **Transmission and distribution losses.** Losses, expressed as a percentage of generation *cum* net energy for load
- **Retail sales in target year (Net Energy for Load less T&D losses and pumping loads in 2009 forecast).** Net Energy for Load from above, less transmission and distribution losses, less pumping loads of 13,000 GWh (2009 level)
- **Renewable energy needed to meet carbon constraint.** Taken from cell D85
- **RPS percentage.** Renewable energy needed to meet carbon constraint, expressed as a percentage of Retail sales in target year

Electrification in Target Year

This section contains the values needed to derive the net energy for load needed to electrify the transportation sector. Values can be input for two types of light-duty vehicles: full electric and plug-in hybrid.

- **Number of vehicles.** The number of vehicles of each type (full electric, hybrid) in the California fleet in the target year.
- **Average vehicle efficiency (kWh/mile).** Electricity consumed per mile of travel.
- **Annual vehicle miles travelled per vehicle**

- **Fraction of miles on full electric.** For hybrid vehicles, the share of miles traveled on full electric
- **Net energy for load.** Net energy for load (electricity consumption adjusted upward to account for transmission and distribution losses) by vehicle class in aggregate. This value is derived from preceding values and should not be directly changed by the user.
- **Total light-duty vehicle net energy for load.** The sum of Net energy for load for the two classes of vehicles. This value is derived from preceding values and should not be directly changed by the user.
- **Public transportation net energy for load.** Incremental increases in net energy for load due to public transportation use of electricity adjusted upwards to account for transmission and distribution losses.
- **Ship net energy for load.** Incremental increases in net energy for load as a result of ship electrification.
- **High speed rail net energy for load.** Incremental increases in net energy for load as a result of high speed rail.
- **Goods movement efficiency improvements net energy for load.** Incremental increases in net energy for load as a result of goods movement efficiency improvements.
- **Total net energy for load for electrification.** The sum of the increases in net energy for load for each component of the transportation sector. This value is derived from preceding values and should not be directly changed by the user.

Section 2: Renewable Portfolio Development and Acreage

This section allows the user to develop portfolios of renewable resources that will meet the requirements for new renewable energy developed in Section 1. The calculator then provides estimates of acreage needed for four central station technologies - solar thermal, solar PV, wind, biomass and geothermal – and utility-side distributed solar generation (up to 20 MW). It also measures the contribution of these technologies to meeting the Net Short under the user-entered values for nameplate capacity. MW values should be entered for *new*, *in-state* renewable resources only; existing resources and out-of-state resources are accounted for elsewhere.

- **MW Assumed.** The user inputs the installed (nameplate) MW for each technology.
- **Annual Operating Level.** The user inputs the assumed capacity factor for each technology.
- **MW/Acre.** The user inputs the assumed MW/acre for each technology.
- **Output.** The installed MW and Capacity Factor yield total output (GWh). This value is derived from preceding values and should not be directly input by the user.
- **Share of Needed Renewable Generation.** The output from the technology expressed as a share of the incremental renewable energy needed to meet the RPS (net short). This value is derived from other values in the spreadsheet and should not be directly input by the user.
- **Total Acres.** The acreage needed for the MW specified, based on the MW/acre value. This value is derived from other values in the spreadsheet and should not be directly input by the user.
- **Share of acres on disturbed land (for utility-side solar DG only).** The share of MW assumed to be developed in areas that are already zoned for such development (for example, at industrial locations, within urban areas, within the footprint of existing transportation corridors, and so forth.)

Other Zero-Acreage In-State Renewable Technologies

The calculator allows the user to assume that a share of new renewable energy needs are met by technologies other than small rooftop and utility-side DG that doesn't not have new acreage requirements. Four of these are specified, two others may be added by the user.

- **MW:** The user inputs the installed (nameplate) MW for each technology.
- **Capacity factor:** The user inputs the assumed capacity factor for each technology.
- **Energy:** The resulting energy from the technology, given the values for MW and Capacity factor. This value should not be directly changed by the user.

- **Total energy from other zero-acreage in-state renewable technologies:** The sum of energy values for each of the component technologies. This value should not be changed by the user.

In-State Totals

- **Total MW of central-station technologies.** Aggregate nameplate capacity for the five central-station technologies
- **Total MW of distributed generation.** Aggregate nameplate capacity for Customer and Utility-side distributed generation.
- **Total incremental GWh from all renewable technologies.** Aggregate output from new central-station and distributed renewable resources. This value is derived from other values and should not be directly changed by the user.
- **Share of Renewable Net Short.** Total incremental GWh from all new in-state renewable technologies expressed as a share of New renewable energy needed (cell D87).

Total Acreage for Central-station Technologies

This value is the sum of the acreage requirements for the individual technologies. It is derived from other input values and should not be directly changed by the user.

New Out-of-State Renewables

- **Share of renewable energy (RPS) produced out-of-state.** The share of renewable energy (that can be) procured from out of state, expressed as a percentage of the renewable energy needed to meet the RPS. The share of the RPS that can be met with tradable renewable energy credits should be included here.
- **New Out-of-State Renewable Energy.** Total renewable energy (that can be) procured from out-of-state less existing (in 2011) out-of-state renewables still operating in the target year. This value is derived from other input values and should not be directly changed by the user.
- **Share of Renewable Net Short.** The share of the renewable net short that is met with out-of-state renewables. This may be higher or lower than the share of the RPS that can be met with out-of-state renewables, depending on whether existing out-of-state renewables (in 2011) that are still operating in the target year are a large or small share of all existing renewables (in 2011) that are assumed to still be operating in the target year.

Totals

- **Total Energy Including Out-of-State Renewables.** Total new renewable energy generated from in-state and out-of-state sources. In-state renewables include the energy from the supply-side technologies in Section 2 plus the share of customer-side distributed generation not embedded in the Energy Commission's demand forecast.
- **Surplus/Deficit (GWh).** The amount of additional new renewable energy that needs to be developed to meet the Net short beyond that provided by the portfolio.
- **Share of Needed Renewable Generation.** New renewable energy procured given the portfolio specified, expressed as a share of the new renewable energy needed to meet the RPS/GHG constraints. A portfolio of new renewable resources that exactly satisfies the necessary RPS/GHG constraint will result in a value of 100 percent.

The calculator also includes a summary of the portfolio developed by the user (see cell J93, immediately below Section 2). This has been developed to allow the user to easily see the portfolio that he/she has developed.