Analysis of a 30 Percent by 2030 National Renewable Electricity Standard

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Technical Appendix: Scenario Descriptions and Modeling Approach

Union of Concerned Scientists

UCS used the National Renewable Energy Laboratory's (NREL) Regional Energy Deployment System (ReEDS) model to examine the implications to the U.S. electricity system of achieving higher levels of renewable electricity spurred by the enactment of a 30 percent by 2030 National Renewable Electricity Standard (RES). This document describes the methodology and assumptions used for our analysis.

ReEDS is a computer-based, long-term capacity-expansion model for the deployment of electric power generation technologies in the United States. ReEDS is designed to analyze the impacts of state and federal energy policies, such as clean energy and renewable energy standards or policies for reducing carbon emissions, in the U.S. electricity sector. ReEDS provides a detailed representation of electricity generation and transmission systems and specifically addresses issues related to renewable energy technologies, such as transmission constraints, regional resource quality, variability, and reliability. UCS used a modified 2014 version of ReEDS for our analysis. The model is mostly the same version that NREL used for the Department of Energy's *Wind Vision Report* (DOE 2015). It does not include the impacts of the U.S. Environmental Protection Agency's (EPA) Clean Power Plan, and the Cross State Air Pollution Rule and Mercury Air Toxics Standard are only captured implicitly through announced coal plant retirements (DOE 2015).

While we rely primarily on NREL's assumptions for renewable energy technologies, we modified some of their assumptions for conventional energy technologies that are based on Energy Information Administration (EIA) projections, using project-specific data and mid-range estimates from recent studies and regulatory filings. We have also updated the existing state RES and Energy Efficiency Resource Standard (EERS) policies to reflect status as of January 1, 2015.

Summary description of two cases

To analyze the impacts of a national RES, we developed two future cases, as described below. We compared the results of the cases to each other to estimate the impacts driven by the proposed national RES.

BUSINESS AS USUAL CASE

The Business As Usual (BAU) or reference case assumes that all state and federal policies enacted as of end of 2014 remain in effect as written. Projected growth in renewable electricity is spurred primarily by state policies and continued cost reductions that improve economic competitiveness of renewables compared to conventional technologies. Federal tax credits for renewable energy technologies are only assumed to be available through the end of 2016, according to current law.

The projected electricity sales in this case are derived from the EIA's Annual Energy Outlook (AEO) 2014 projections, following the approach used in the default assumptions for ReEDS. ReEDS starts with the 2010 electricity sales for each state, then projects future electricity sales using the growth rate for the appropriate census region from the AEO 2014 reference case. We adjusted these projections to account for reductions in electricity sales resulting from currently-enacted state EERS policies that are not included in the AEO 2014. Our adjustments follow the approach used by the EPA in *Projected Impacts of State Energy Efficiency and Renewable Energy Policies* (EPA 2014) with minor updates (for example, we change sales projections to reflect AEO2014 and adjust targets in states that reduced their energy efficiency goals in 2014). In addition, we assume full compliance with existing state RES and EERS policies.

30 PERCENT BY 2030 RES CASE

Our policy case assumes implementation of a national renewable electricity standard requiring obligated utilities to supply a minimum percent of their electricity sales through renewable electricity. The RES is modeled after S. 1264, introduced on May 11, 2015 and sponsored by Senators Tom Udall (NM), Ed Markey (MA), Sheldon Whitehouse (RI), Jeff Merkley (OR), Martin Heinrich (NM), Mazie Hirono (HI), and Michael Bennet (CO). All other state and federal energy policies are assumed to be the same as the BAU scenario.

The annual renewable electricity targets that must be met or exceeded by obligated utilities start at 7.5 percent of covered electricity sales in 2015, and ramp up gradually to 12 percent in 2020, 20 percent in 2025 and 30 percent in 2030, as illustrated under the nominal RES targets column in Table 1. The obligated utilities required to meet these targets include investor-owned utilities with annual electricity sales greater than 1 million megawatt hours (MWh). All municipal utilities and rural electric co-operatives are exempt under the proposal. In addition, existing hydropower and municipal solid waste generation are excluded from baseline electricity sales in calculating the annual minimum renewable generation needed to meet the targets.

Furthermore, the national RES does not preclude state-level RES policies from having stronger targets. Therefore, we assume that the national RES sets a floor for renewable energy generation nationwide, and obligated entities in states with higher annual renewable energy targets than the national targets much achieve the higher state target. The actual RES targets reported in Table 1 reflect UCS estimates of the impact of these exemptions, exclusions, and higher state RES policies on the total amount of renewable generation needed to meet the required targets as a share of total U.S. electricity generation.

Eligible renewable energy resounrce resources include wind, solar photovoltaic, concentrated solar power, distributed solar, landfill gas and biomass. The obligated utilities must demonstrate their compliance with the RES through a national renewable energy credit tracking and trading system.

TABLE 1. **Schedule of requirements for 30 percent by 2030 RES case, nominal and actual RES targets**

Year	Nominal RES target for covered utilities (% of covered electricity sales)	Actual RES target, (renewable generation % of total national electricity sales)
2015	7.5%	7.9%
2016	8%	8.7%
2017	8.5%	9.2%
2018	9.5%	10.0%
2019	10.5%	10.9%
2020	12.0%	12.4%
2021	13.5%	13.3%
2022	15.0%	14.0%
2023	16.5%	14.8%
2024	18.0%	15.5%
2025	20.0%	16.8%
2026	22.0%	17.8%
2027	24.0%	18.9%
2028	26.0%	20.0%
2029	28.0%	21.2%
2030	30.0%	22.4%

UCS Assumptions for NREL ReEDS Model

COST AND PERFORMANCE FOR ELECTRIC GENERATING TECHNOLOGIES

The cost and performance assumptions for electric generating technologies that UCS used in the 2014 version of NREL's ReEDS model are shown in Tables 1-3 below, compared to EIA's AEO 2014 assumptions (EIA 2014). For conventional technologies, NREL uses EIA's AEO 2014 cost and performance assumptions. We did not make any changes to EIA's assumptions for natural gas and coal prices, fixed and variable O&M costs, and heat rates, with a few exceptions noted below (EIA 2014). However, we did make several changes to EIA's capital cost assumptions and wind and solar capacity factors based on project specific data for recently installed and proposed projects, supplemented with mid-range estimates from recent studies, when project data was limited or unavailable. The cost and performance assumptions for renewable energy technologies are mostly consistent with the assumptions that were developed for the DOE Wind Vision Report (DOE 2015). We also describe our assumptions for energy efficiency investments that were not included in the model.

The key assumptions we made include:

- **Learning.** We do not use EIA's learning assumptions that lower the capital costs of different technologies over time as the penetration of these technologies increase in the U.S. (EIA 2014). EIA's approach does not adequately capture growth in international markets and potential technology improvements from research and development (R&D) that are important drivers for cost reductions. Instead, we assume costs for mature technologies stay fixed over time and costs for emerging technologies decline over time at the same levels for all scenarios.

- **Natural gas and coal.** For plants without carbon capture and storage (CCS), we use EIA's initial capital costs, but do not include EIA's projected cost reductions due to learning because we assume they are mature technologies. For new IGCC and supercritical pulverized coal plants, we use EIA's higher costs for a single unit plant (600-650 MW) instead of dual unit plants (1200-1300 MW), which is more consistent with data from proposed and recently built projects (SNL 2013). For plants with CCS, we assume: 1) higher initial capital costs than EIA based on mid-range estimates from recent studies (Black & Veatch 2012, Lazard 2013, NREL 2012, EIA 2014), 2) no cost reductions through 2020 as very few plants will be operating by then, and 3) EIA's projected cost reductions by 2040 will be achieved by 2050 (on a percentage basis).

- **Nuclear.** We assume higher initial capital costs than EIA for new nuclear plants based on mid-range estimates from recent studies and announced cost increases at projects in the U.S. that are proposed or under construction (Black & Veatch 2012, Henry 2013, Lazard 2013, Penn 2012, SNL 2013, Vukmanovic 2012, Wald 2012). We did not include EIA's projected capital cost reductions, given the historical and recent experience of cost increases in the U.S. We also assume existing plants will receive a 20-year license extension, allowing them to operate for 60 years and will then be retired. To date, no existing plant has received an operating license extension beyond 60 years. Consistent with the NREL assumptions in ReEDS, we include 4.7 GW of retirements at five existing plants (Vermont Yankee, Kewaunee, Crystal River, San Onofre, Oyster Creek) based on recent announcements and closures, and 5.5 GW of planned additions (Vogtle, V.C. Summer, and Watts Bar).

- **Onshore Wind.** We assume lower initial capital costs than EIA based on data from a large sample of recent projects from DOE's 2013 Wind Technologies Market Report (Wiser and Bolinger 2014). This report shows that capacity-weighted installed capital costs for U.S. projects declined 13 percent from $2,262/kW (in 2013$) in 2009 to $1,960/kW in 2012. While costs dropped again to $1,630/kW in 2013 and are expected to average $1,750/kW in 2014, these projects are heavily weighted toward lower cost projects in the interior region of the U.S. Thus, we conservatively assume that average U.S. installed costs will stay fixed at 2012 levels over time based on a larger sample of projects, and assuming the wind industry invests in technology improvements that result in increases in capacity factors. Current capacity factors are based on data from recent projects and studies that reflect recent technology advances (Wiser 2014). We assume capacity factors will increase over time based on the DOE Wind Study to achieve a reduction in the overall cost of electricity based on mid-range projections from 13 independent studies and 18 scenarios (DOE 2015, Lantz 2013). We also assume higher fixed O&M costs than EIA based on mid-range estimates from the DOE Wind Vision Report (DOE 2015, EIA 2014).

- **Offshore wind.** Capital costs, O&M costs, and capacity factors for offshore wind are based on mid-range projections from the DOE Wind Vision Study (DOE 2015). Initial capital costs are consistent with data from recent and proposed projects in Europe and the U.S. from NREL's offshore wind database (Schwartz 2010). Capital cost reductions and capacity factors increases over time from the DOE Wind Vision study draw on mid-range projections from several studies (Lantz 2013, EIA 2014, NREL 2012, Black & Veatch 2012, BVG 2012, Prognos 2013).

- **Solar photovoltaics (PV).** Similar to the approach used in the DOE Wind Vision study, we assume lower initial capital costs than EIA based on data from a large sample of recent utility scale and rooftop PV projects installed in the U.S. through the second quarter of 2014 (SEIA 2014, DOE 2015). We also assume future solar PV costs for utility scale, residential, and commercial systems will decline over time based on mid-range projections from the DOE Sunshot Vision Study's 62.5 percent by 2020 and 75 percent by 2040 cost reduction (relative to 2010 levels) scenarios. In addition, we use NREL's projections for residential and commercial PV deployment from their SolarDS model that are based on these assumed cost reductions. These distributed PV deployment projections are used as an input to the ReEDs model. Finally, we use slightly lower capacity factors for solar PV than EIA based on NREL data (NREL 2012).

- **Solar CSP.** We assume concentrating solar plants will include six hours of storage and used the capital and O&M cost projections from the DOE Sunshot Vision Study's 62.5 percent by 2020 and 75 percent by 2040 cost reduction scenarios.

- **Biomass.** We use EIA's initial capital costs for new fluidized bed combustion plants, but do not include EIA's projected cost reductions due to learning because we assume it's a mature technology. For biomass co-firing in coal plants, we assume higher capital costs based on data from Black & Veatch (2012). We also use a slightly different biomass supply curve than EIA and NREL based on a UCS analysis of data from DOE's Updated Billion Ton study that includes additional sustainability criteria, resulting in a potential biomass supply of 680 million tons per year by 2030 (UCS 2012, ORNL 2011).

- **Geothermal and hydro.** We restricted the construction of large hydro dams until after 2019 to reflect the long lead times for planning, permitting and building such facilities. We didn't make any other changes to NREL's assumptions for geothermal and hydro, which are site specific.

- **Recent or planned changes to generating resource or transmission availability.** To ensure the ReEDS model has an accurate accounting of the current and near-term electricity system, we undertook a thorough review of the model's depiction of the electricity system (across the contiguous United States) in 2012 and 2014 and compared that with our understanding, based on SNL data and industry reports/projections, of real-world conditions. Our updates to ReEDS included:
    - Accounting for prescribed builds within the model to accurately reflect newly constructed or under-construction generating resources (including natural gas, nuclear, coal, wind and utility-scale solar facilities);
    - Accounting for recent or recently-announced coal-plant retirements to ensure these resources are not available to the model; and
    - Updating assumptions for transmission projects that are under-construction.

TABLE 2. **Comparison of Assumed Overnight Capital Costs for Electricity Generation Technologies (2013$/kW)**

	UCS					EIA AEO2014			
Technology*	**2010**	**2020**	**2030**	**2040**	**2050**	**2010**	**2020**	**2030**	**2040**
Natural Gas CC	1,036	1,036	1,036	1,036	1,036	1,043	1,036	914	826
Natural Gas-CC-CCS	n/a	3,005	2,724	2,513	2,407	n/a	2,052	1,777	1,559

Natural Gas CT	689	689	689	689	689	689	670	575	515
Coal-Supercritical PC	3,306	3,306	3,306	3,306	3,306	2,988	3,051	2,802	2,562
Coal-IGCC	n/a	4,482	4,482	4,482	4,482	n/a	3,828	3,412	3,067
Coal-PC-CCS	n/a	6,166	5,807	5,548	5,373	n/a	5,272	4,736	4,231
Nuclear	n/a	6,529	6,529	6,529	6,529	n/a	4,905	4,376	3,831
Biomass	4,187	4,187	4,187	4,187	4,187	4,187	3,862	3,492	3,112
Solar PV-Utility	5,215	1,925	1,604	1,283	1,283	3,943	3,334	2,963	2,625
Solar PV-Residential	7,700	2,888	2,406	1,925	1,925	7,636	3,850	2,823	2,823
Solar PV-Commercial	6,417	2,413	2,008	1,604	1,604	6,545	2,951	2,567	2,567
Solar CSP-With Storage	5,493	3,299	2,897	2,496	2,496	n/a	n/a	n/a	n/a
Wind-Onshore	2,280	1,969	1,969	1,969	1,969	2,254	2,301	2,113	1,932
Wind-Offshore	5,309	4,112	3,228	2,968	2,734	6,343	6,330	5,608	4,932

*Abbreviations are as follows: combined cycle (CC), combustion turbine (CT), carbon capture and storage (CCS), pulverized coal (PC), integrated gasification and combined cycle (IGCC), and photovoltaic (PV).

TABLE 3. **Operation and Maintenance (O&M) and Heat Rate Assumptions**

Technology*	Fixed O&M (2013$/kW-yr)	Variable O&M (2013$/MWh)	Heat Rate 2010	Heat Rate 2050
Natural Gas-CC	14.53	3.5	6740	6567
Natural Gas-CC-CCS	32.36	3.3	7525	7493
Natural Gas CT	7.32	13.15	10,300	9500
Coal-Supercritical PC	31.75	4.55	8800	8740
Coal-IGCC	52.32	7.35	8700	7450
Coal-IGCC-CCS	67.68	4.53	12000	9316
Nuclear	94.98	2.18	10452	10452
Biomass	107.56	5.36	13500	13500
Solar PV-Utility	7.61	0.00	n/a	n/a
Solar PV-Residential	10.62	0.00	n/a	n/a
Solar PV-Commercial	8.02	0.00	n/a	n/a
Solar CSP-With Storage	41.30	2.64	n/a	n/a
Wind-Onshore	50.75	0.00	n/a	n/a
Wind-Offshore	132.00	0.00	n/a	n/a

* Abbreviations are as follows: combined cycle (CC), carbon capture and storage (CCS), combustion turbine (CT), pulverized coal (PC), integrated gasification and combined cycle (IGCC), photovoltaic (PV), and concentrating solar plants (CSP).

TABLE 4. **Comparison of Assumed Solar Capacity Factors**

Technology*	UCS	EIA AEO 2014
Solar PV-Utility	17–28%	21–32%
Solar CSP-With Storage	40–65%	n/a

*Abbreviations are as follows: photovoltaic (PV) and concentrating solar plant (CSP).

TABLE 5. **Comparison of Assumed Wind Capacity Factors**

	UCS					EIA AEO2014			
Technology*	**2014**	**2020**	**2030**	**2040**	**2050**	**2010**	**2020**	**2030**	**2040**
Onshore Wind									
Class 3	32%	35%	37%	38%	40%	28%	29%	29%	29%
Class 4	38%	41%	44%	45%	47%	32%	33%	33%	33%
Class 5	44%	47%	49%	51%	53%	39%	39%	39%	39%
Class 6	46%	49%	52%	53%	55%	45%	46%	46%	46%

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