Committing to Renewables in New Mexico

Boosting the State's Economy, Generating Dividends for All

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Appendix: Technical Document

Union of Concerned Scientists

This document details the methods and data used in the two models supporting the *Committing to Renewables in New Mexico* analysis by the Union of Concerned Scientists (UCS): the Regional Energy Deployment System (ReEDS) and the Jobs and Economic Development Impact (JEDI) models. The report characterizes what a policy commitment to a high-renewables future could look like for the state. It can be found online at *www.ucsusa.org/NewMexicoRenewable.*

Assumptions Underlying the UCS Version of the Regional Energy Deployment System (ReEDS)

UCS uses the National Renewable Energy Laboratory's (NREL) Regional Energy Deployment System (ReEDS) to analyze the technical and economic feasibility of clean energy policies. ReEDS is a long-term, capacity-expansion model for the deployment of electric power generation technologies in the contiguous United States. ReEDS is designed to analyze the impacts of state and federal energy policies, such as clean energy and renewable energy standards or reducing carbon emissions, in the 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, resource quality, variability, and reliability (NREL 2017).

UCS used the 2016.RE.TaxExt.P1 version of ReEDS for our analysis. However, some changes were made to NREL's assumptions for renewable and conventional energy technologies based on project-specific data and estimates from recent studies, as described in more detail below.

CHARACTERIZATION OF ANALYSIS SCENARIOS

This analysis considered two primary scenarios, as well as several input sensitivities. For each case, we ran the model holding a core set of assumptions in place, while modifying specific assumptions to match each analysis scenario.

The baseline scenario, intended to approximate a "business-as-usual" future for New Mexico, includes assumptions that:

- No adjustments are made to the current energy efficiency standard, which plateaus at 8 percent in 2020 and then continues at that level into the future, as under existing law.
- No adjustments are made to the current renewable portfolio standard, which plateaus at 20 percent for public utilities and 10 percent for rural electric cooperatives in 2020 and then continues at that level into the future, as under existing law.
- All in-state, coal-fired generation is retired by 2030, according to the following schedule:
    - San Juan Generating Station, Units 2 and 3: 2017/2018
    - San Juan Generating Station, Units 1 and 4: 2023/2024
    - Four Corners Generating Station, Unit 5: 2025/2026
    - Four Corners Generating Station, Unit 4: 2027/2028
    - Escalante Generating Station, Unit 1: 2029/2030

For the strengthened renewable portfolio standard (RPS) scenario, energy efficiency and coal retirement assumptions were held in line with the baseline scenario, while the RPS policy was adjusted such that:

- The escalation and supply requirements were held steady through 2020, as under existing law.
- Following, the RPS was steadily increased for public utilities as follows:
    - ≥35 percent by 1/1/2025, with an interim average increase of 3 percent per year
    - ≥50 percent by 1/1/2030, with an interim average increase of 3 percent per year

    - ≥65 percent by 1/1/2035, with an interim average increase of 3 percent per year
    - ≥80 percent by 1/1/2040, with an interim average increase of 3 percent per year
- For rural electric cooperatives, the RPS was increased as follows:
    - ≥25 percent by 1/1/2025, with an interim average increase of 3 percent per year
    - ≥40 percent by 1/1/2030, with an interim average increase of 3 percent per year
    - ≥55 percent by 1/1/2035, with an interim average increase of 3 percent per year
    - ≥70 percent by 1/1/2040, with an interim average increase of 3 percent per year
- To account for several large-scale wind and solar projects currently being constructed in New Mexico but contracted to serve out-of-state load, the above renewables requirements were adjusted upwards to ensure such resources are not incorrectly considered to be contributing to renewable portfolio standard requirements.
- No changes were made to modeling inputs for any other components of the current Renewably Energy Act and associated Rule 572 including:
    - The definition of "fully diversified energy portfolio" in Rule 572, which presently requires:
        - ≥30 percent wind
        - ≥20 percent solar
        - ≥3 percent distributed generation from 2015 onward
        - The model's omission of the specific portfolio requirement of "≥5 percent one or more of other RE technologies" due to modeling limitations
    - NREL's translation of New Mexico's reasonable cost threshold to a representative alternative compliance payment value due to modeling limitations
    - The omission of the early solar credit multiplier due to model limitations

CHARACTERIZATION OF BASELINE ASSUMPTIONS

UCS regularly reviews data and research on the technologies and systems that are simulated in ReEDs. Information on the assumptions and methodology in ReEDs is available on the NREL website (NREL 2017). We have updated assumptions in ReEDS that were inconsistent with this latest research and note the main changes in the following section.

Cost and performance for electric generating technologies. The cost and performance assumptions for electric generating technologies that UCS used in ReEDS are shown in Tables 1–4 below. We compare our key assumptions to the Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2016 assumptions (EIA 2016), since the AEO assumptions are widely used for energy policy analysis and provide a well-recognized industry benchmark.

We made several changes to NREL's capital cost assumptions. NREL uses EIA's AEO 2016 cost assumptions for conventional plants; our revisions are based on project-specific data for recently installed and proposed projects, supplemented with mid-range estimates from recent studies. We did not make any changes to the assumptions for operating and maintenance (O&M) costs and heat rates.

NREL provides a set of projections for future cost and performance assumptions for renewable energy technologies that users can easily select. Our choices for these projections are mostly consistent with the assumptions that were developed for the DOE Wind Vision report (DOE 2014).

The changes we made include:

- **Learning**. Unlike NREL, 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 United States (EIA 2016). EIA's approach does not adequately capture growth in international markets and potential technology improvements from research and development 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 using a trajectory that is independent of technology penetration in a particular scenario.

- **Coal**. For new integrated gasification and combined cycle (IGCC) and supercritical pulverized coal plants, we use EIA's higher costs for a single unit plant (600–650 megawatts—MW) instead of dual unit plants (1,200–1,300 MW), which is more consistent with data from proposed and recently built projects (SNL 2017). For plants with carbon capture and sequestration (CCS), we use the same assumptions as NREL and EIA.

- **Natural Gas**. For new plants, we use NREL's assumptions, which are based on the average of EIA's assumptions for conventional and advanced plants in 2016. We do not include EIA's projected cost reductions due to learning because we assume these are mature technologies. 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 used EIA's assumed costs for 2016, but we did not include EIA's projected capital cost reductions, given the historical and recent experience of cost increases in the United States. We also assume existing plants will receive a 20-year license extension, allowing them to operate for 60 years and will then be retired due to safety and economic issues. To date, no existing plant has received or applied for an operating license extension beyond 60 years.

- **Onshore and Offshore Wind**. We used NREL's cost and performance projections from their median cost reduction case, as described in the DOE Wind Vision (DOE 2015). These cost and performance projections are based on NREL's estimate of median values from their review of recent literature.

- **Utility-scale solar photovoltaics (PV)**. We use NREL's regional cost and performance projections from NREL's Annual Technology Baseline (ATB) 2016, using the mid-cost scenario with an average capacity factor of 20 percent (NREL 2016).

- **Distributed solar photovoltaics (PV).** ReEDS does not endogenously simulate the uptake of distributed PV systems (those typically installed on site by residential or commercial customers). Instead, users must select the appropriate projections for uptake of these systems as an exogenous input to the model. We use the projections from the ATB 2016's average capacity factor (16.1 percent) high-cost scenario, which was based on a recent survey of system price projections (NREL 2016).

- **Solar CSP**. We assume concentrating solar plants will include six hours of storage and used the capital and O&M cost projections from NREL's average capacity factor, mid-cost reduction scenario (NREL 2016).

- **Biomass**. We use EIA's initial capital costs for new fluidized bed combustion plants and for biomass co-firing with coal but do not include EIA's projected cost reductions due to learning because we assume it is a mature technology. 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). We additionally limit the coal capacity that can be retrofit to co-fire biomass to 10 percent of a plant's capacity, compared with the 15 percent maximum used in NREL assumptions.

- **Hydro, geothermal, landfill gas and storage technologies**. We did not make any changes to NREL's assumptions for these technologies.

Electricity sales and energy efficiency projections. ReEDS does not endogenously model electricity sales or efficiency; instead users provide assumptions of future use. As a default, electricity sales are taken from the EIA's AEO 2016 projections. 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 2016 reference case. UCS adjusts these projections to account for reductions in load growth resulting from currently enacted state energy efficiency resource standards (EERS) that are not included in the AEO 2016. Our adjustments follow the approach used by the Environmental Protection Agency in Projected Impacts of State Energy Efficiency and Renewable Energy Policies (EPA 2014). We assume full compliance with EERS policies that had been enacted as of the end of March 2017.

State renewable portfolio standard (RPS) programs. ReEDS uses RPS data from a 2015 BNEF RPS database. UCS adjusts ReEDS' representation of the state programs to account for recent legislation and demand forecasts. Our adjustments are based on the Lawrence Berkeley Laboratory's 2017 RPS Annual Status Report and industry reports and projections (LBL 2017).

Accounting for recent or planned changes to generating resource or transmission availability. We reviewed ReEDS assumptions for expected changes in power-plant capacity and transmission lines in the near term and compared that with our understanding, based on SNL data and industry reports and projections, of real-world conditions. Our updates to ReEDS include:

- Accounting for prescribed builds of newly constructed or under construction generating resources (including natural gas, nuclear, coal, wind, and utility-scale solar facilities) using a combination of SNL and industry association data published as of February 24, 2017;
- Accounting for recent or recently announced coal-plant retirements through 2030 based on data published as of July 2016;
- Accounting for recent or recently announced nuclear-plant retirements based on data published as of February 14, 2017;
- Accounting for transmission projects under construction or in an advanced stage of development using a combination of SNL and industry association data published as of January 30, 2017; and
- Including California's requirement for storage (AB 2514).

TABLE 1. **Comparison of Overnight Capital Costs for Electric Generation Technologies (2016$/kW)**

	UCS 2016 Assumptions				EIA AEO 2016		
Technology	**2020**	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**
Natural Gas CC	1,006	960	925	892	1,006	960	925
Natural Gas-CC-CCS	2,056	1,884	1,744	1,605	2,056	1,884	1,744
Natural Gas CT	859	816	785	755	859	816	785
Coal-Supercritical PC	3,532	3,443	3,353	3,264	3,532	3,443	3,353
Coal-IGCC	3,773	3,564	3,398	3,234	3,773	3,564	3,398
Coal-PC-CCS	6,341	5,958	5,590	5,590	6,341	5,958	5,590
Nuclear	5,546	5,327	5,031	4,736	5,546	5,327	5,031
Hydro*							
Biomass, dedicated	3,677	3,536	3,395	3,254	3,677	3,536	3,395
Biomass, cofired with coal**	2,989	2,989	2,989	2,989	299	299	299
Solar PV-Utility	1,435	1,031	929	844	3,088	2,798	2,561
Solar PV-Residential	2,447	2,447	2,447	2,447	4,832	3,950	3,725
Solar PV-Commercial	2,039	2,039	2,039	2,039	4,107	3,236	3,048
Solar CSP-With 6 hour Storage	6,985	6,942	6,942	6,942	*AEO 2016 does not include CSP with storage*		
Wind-Onshore							
- class 3	1,791	1,776	1,775	1,775			
- class 4	1,791	1,776	1,775	1,775			
- class 5	1,725	1,680	1,675	1,675			
- class 6***	1,619	1,564	1,558	1,558	2,216	2,079	1,921
- class 7	1,619	1,564	1,558	1,558			
Wind-Shallow Offshore	4,665	3,969	3,862	3,740	*AEO 2016 does not include shallow offshore wind*		
Wind-Deep Offshore	5,150	4,379	4,261	4,126	6,058	5,724	5,390
Landfill gas	8,452	8,238	8,025	7,811	8,452	8,238	8,025

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

* Hydro capital costs are too detailed to show in this table; ReEDs uses supply curves with capital cost variation by potential resource capacity.

** The cost for biomass co-firing is per kW of biomass capacity.

*** Capital costs for wind in AEO2016 represent technologies for class 6 resources. ReEDS uses "techno-resource groups" instead of wind power classes to represent wind cost and performance parameters; this is an approximate comparison for classes 3 through 7.

TABLE 2. **Operations and Maintenance (O&M) and Heat Rate Assumptions.**

Technology	Fixed O&M ($2016/kW-yr)	Variable O&M ($2016/MWh)	Heat Rate (Btu/kWh)	
			2020	2050
Natural Gas-CC	14.7	3.5	6,624	6,567
Natural Gas-CC-CCS	32.7	7.0	7,504	7,493
Natural Gas CT	7.4	13.3	9,756	9,500
Coal-Supercritical PC	32.6	1.7	8,760	8,740
Coal-IGCC	52.9	7.4	7,867	7,450
Coal-PC-CCS	75.0	8.7	9,105	8,307
Nuclear	96.0	2.2	10,479	10,479
Biomass	108.8	5.4	13,500	13,500
Solar PV-utility	22.4	0.0	n/a	n/a
Solar PV- residential	15.6	0.0	n/a	n/a
Wind-Onshore	52	0.0	n/a	n/a
Wind-Shallow Offshore	136	0.0	n/a	n/a

Abbreviations are as follows: Combined-cycle (CC), combustion turbine (CT), carbon capture and storage (CCS), pulverized coal (PC), photovoltaic (PV), integrated gasification and combined-cycle (IGCC). Fixed and variable O&M costs are for 2020 through 2050; costs for earlier years are higher.

TABLE 3. **Comparison of Solar Capacity Factors**

Technology	UCS 2016 Assumptions
Solar PV-utility	17-28%
Solar CSP-With 6-hour Storage	28% to 38%

TABLE 4. **Comparison of Wind Capacity Factors**

	UCS 2016 Modifications					EIA AEO 2016			
Technology	**2014**	**2020**	**2030**	**2040**	**2050**	**2014**	**2020**	**2030**	**2040**
Wind-Onshore Class 3	32.0%	34.5%	37.0%	38.3%	39.6%	28%	29%	31%	31%
Wind-Onshore Class 4	37.7%	40.7%	43.6%	45.1%	46.7%	32%	33%	34%	34%
Wind-Onshore Class 5	43.9%	46.5%	49.2%	50.8%	52.5%	36%	37%	38%	38%
Wind-Onshore Class 6	46.6%	49.0%	51.5%	53.2%	54.9%	40%	41%	30%	42%
Wind-Onshore Class 7	51.1%	53.7%	56.4%	58.2%	60.1%	n/a	n/a	n/a	n/a
Wind-Offshore Class 4	46.9%	47.9%	51.3%	51.8%	52.4%	32%	33%	35%	35%
Wind-Offshore Class 5	34.6%	35.4%	37.9%	38.3%	38.8%	36%	37%	39%	39%
Wind-Offshore Class 6	40.3%	41.2%	44.1%	44.7%	45.2%	40%	41%	43%	43%
Wind-Offshore Class 7	43.2%	44.2%	47.3%	47.9%	48.4%	44%	44%	45%	45%

Calculation of the monetary value of carbon dioxide (CO_2) reduction benefits. To determine the monetary value of CO_2 reductions, we use the US government's estimates of the "social cost of carbon (SCC)"—an estimate of the damages, expressed in dollars, resulting from the addition of a metric ton of CO_2 to the atmosphere in a given year. We multiply the tons of CO_2 reduced in our scenarios by the SCC to derive the CO_2 reduction benefits, or avoided damages.

We use the SCC values reported in the 2016 Technical Support Document issued by the Interagency Working Group on the Social Cost of Greenhouse Gases (2016), shown here in Table 5.

TABLE 5. **Social Costs of Carbon Values**

Year	Social Cost of Carbon (2016$ per ton of CO_2)[1]
2016	44
2020	49
2025	53
2030	58

[1] Assuming a 3 percent discount rate.

SOURCE: INTERAGENCY WORKING GROUP ON SOCIAL COST OF GREENHOUSE GASES 2016, TABLE A1.

Calculation of the monetary value of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) reduction benefits. To value SO_2 and NO_x emissions reductions, we again use estimates from the EPA *Regulatory Impact Assessment for the CPP Final Rule* of the dollar value of the health benefits per ton of SO_2 and NO_x reduced by different industrial sectors, including the electricity sector (EPA 2015).

In particular, for the 2020, 2025, and 2030 emissions reductions generated in our models, we use the values in EPA's Tables 4A-3 to 4A-5. These values are expressed in 2011$ using a 7 percent discount rate, so we convert them to 2016$ so as to be consistent with other dollar values in our analysis.

Assumptions Underlying the UCS Version of the Jobs and Economic Development Impact Model

The Jobs and Economic Development Impact models, developed by NREL, are easy-to-use tools that estimate the gross economic impacts of constructing and operating power generation, transmission, and biofuel plants at the state or national level (NREL n.d.). This analysis primarily used the default values in the JEDI Land Based Wind (vW12.23.16), JEDI PV (vPV12.23.16), and JEDI Transmission Line (vTL12.23.16) models to estimate the number of jobs and potential economic impacts of renewable energy project development in New Mexico, with additional local information added. This input-output model provides estimates for jobs,[1] earnings,[2] output,[3] and value added[4] across three categories:

- Direct Impacts: Project development[5] and onsite labor impacts[6]
- Indirect Impacts: Local revenue and supply-chain impacts[7]
- Induced Impacts[8]

The results in this analysis reflect gross impacts from projects, not net impacts, such as changes in electricity rates, local economic development losses associated with the possible displacement of other local energy sources, and displacement of other economic activity due to a project (NREL n.d.).

CHARACTERIZATION OF LAND-BASED WIND DEVELOPMENT ASSUMPTIONS, 2017 TO 2030

Evaluation Method: The Project Cost Data default values, based on interviews with industry experts and project developers and engineering cost models, were used for this analysis.

Project Location: New Mexico

Year of Construction: 2017 to 2030

Money Value (Dollar Year): 2016 was selected as the default dollar year.

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[1] Jobs refers to full-time equivalent (FTE) employment for one year. 1 FTE = 2080 hours.
[2] Earnings refers to wage and salary compensation paid to workers.
[3] Output refers to economic activity or the value of production in the state or local economy.
[4] Value added is the difference between total gross output and the cost of intermediate inputs. It is comprised of payments made to workers (wages and salaries and benefits), proprietary income, other property type income (payments from interest, rents, royalties, dividends, and profits), indirect business taxes (excise and sales taxes paid by individuals to businesses, and taxes on production and imports less.
[5] Project Development refers to Construction and Interconnection Labor as well as Construction Related Services
[6] Onsite Labor Impacts refers to the final demand changes that occur in the onsite spending for wind farm workers (i.e., spending on field technicians, administration and management).
[7] Local Revenue includes property tax and landowner leases as well as any return on investment paid to local owners; Supply chain impacts include all components and off-site labor for the wind project. Local Revenue includes property tax and landowner leases as well as any return on investment paid to local owners; Supply chain impacts include all components and off-site labor for the wind project.
[8] Induced Impacts refers to the changes that occur in household spending as household income increases or decreases as a result of the direct and indirect effects from the final demand (i.e., purchases of goods and services) changes.

Total Project Size–Nameplate Capacity (MW): The project size was determined by the yearly additional nameplate capacity from 2017 to 2030, extrapolated from the renewable energy capacity built in the ReEDS analysis. Due to economies of scale for projects above 20 MW, the number of projects does not change the calculation; therefore, the input for "Total Project Size" is the total added capacity for that year.

Wind Turbine Size (kilowatt—kW): For computational purposes, a 2,300 kW turbine was used to be consistent with wind projects currently under development in New Mexico.

Installed Project Cost ($/kW): Installed project costs are based on the inputs to the ReEDS model, as described above and reflected in Table 1, for the respective year in which the capacity is installed.

Operations and Maintenance Cost ($/kW): Annual Fixed Operations and Maintenance Costs are based on the inputs to the ReEDS model, as described above and listed in Table 2.

Property Taxes: Nationally, default annual property tax payments are $7,399/MW (DOE 2015).

Land Lease Payments: The default land lease cost per turbine is $6,900/turbine.

CHARACTERIZATION OF SOLAR PV UTILITY-SCALE AND RESIDENTIAL DEVELOPMENT ASSUMPTIONS, 2017 TO 2030

Evaluation Method: The Project Cost Data default values, which are based on interviews with industry experts and project developers and engineering cost models, were used for this analysis.

Project Location: New Mexico

Year of Construction: 2017 to 2030

Money Value (Dollar Year): 2016 was selected as the default dollar year.

Solar Cell/Module Material: Crystalline silicon

System Tracking: Fixed mount

Utility-Scale Average System Size—DC Nameplate Capacity (kW): 1,000 kW was selected based on analysis from *Tracking the Sun IV*, for systems installed for each sector in 2010 (LBL 2011).

Residential Average System Size—DC Nameplate Capacity (kW): 5 kW was selected based on analysis from *Tracking the Sun IV*, for systems installed for each sector in 2010 (LBL 2011).

Total Project Size—DC Nameplate Capacity (kW): The project size was determined by the yearly additional nameplate capacity from 2017 to 2030, extrapolated from the renewable energy capacity built in the ReEDS analysis. The input for "Total Project Size" is the total added capacity for that year.

Utility-Scale Base Installed System Cost ($/kW$_{DC}$): Installed system costs are based on the inputs to the ReEDS model, as described above and reflected in Table 1, for the respective year in which the capacity is installed.

Residential Base Installed System Cost ($/kW$_{DC}$): Installed system costs are based on the inputs to the ReEDS model, as described above and reflected in Table 1, for the respective year in which the capacity is installed.

Utility-Scale Annual Direct Operations and Maintenance Cost ($/kW): Annual fixed operations and maintenance costs are based on the inputs to the ReEDS model, as described above and listed in Table 2.

Residential Annual Direct Operations and Maintenance Cost ($/kW): Annual fixed operations and maintenance costs are based on the inputs to the ReEDS model, as described above and listed in Table 2.

Utility-Scale Property Taxes: A value of $2,863/MW was used as an approximate for state, federal, and private lands (Bureau of Land Management 2016).

Residential Property Taxes: Exempt

Utility-Scale Land Lease Payments: An average of $500/acre of land was used assuming an average of 8.9 acres/MW of utility-scale solar (NREL 2013).

Residential Land Lease Payments: N/A

CHARACTERIZATION OF TRANSMISSION LINE DEVELOPMENT ASSUMPTIONS, 2017 TO 2030

Evaluation Method: The Project Cost Data default values, which are based on interviews with industry experts and project developers and engineering cost models, were used for this analysis.

Project Location: New Mexico

Year of Construction: 2017 to 2030

Money Value (Dollar Year): 2016 was selected as the default dollar year.

Transmission Line Type: The typical transmission line types in New Mexico are 345 kilovolts (kV) AC and 500 HVDC (PNM 2010).

Transmission Line Length: Miles of transmission was determined by the added transmission capacity from the ReEDS analysis.

Population Density Classification (Right of Way Access): Rural

Total Project Cost ($Million/Mile): Default cost $1.39 for 345 kV and $7.26 for 500 kV.

ROW Payments: Default payment for public land is $100/acre and for private land $2,000/acre assuming 50/50 usage.

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