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Assessing the Economic and Environmental Impacts of Alternative Renewable Portfolio Standards: Winners and Losers

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Abstract: State-mandated renewable portfolio standards affect substantial portions of the total U.S. electricity supply. Renewable portfolio standards are environmentally motivated policies, yet they have the potential to greatly impact economy. There is not an agreement in the literature on the impact of renewable portfolio standards policies on regional economies, especially on job creation. By integrating various methodologies including econometrics, geographic information system, and input–output analysis into a unique system dynamics model, this paper estimates the economic and environmental impacts of various renewable portfolio standards scenarios in the state of New Mexico, located in Southwestern U.S. The state is endowed with traditional fossil fuel resources and substantial renewable energy potential. In this work we estimated and compared the economic and environmental tradeoffs at the county level under three renewable portfolio standards: New Mexico's original standard of 20% renewables, the recently adopted 100% renewables standard, and a reduced renewable standard of 10%. The final one would be a return to a more traditional generation profile. We found that while the 20% standard has the highest market-based economic impact on the state as a whole, it is not significantly different from other scenarios. However, when environmental impacts are included, the 100% standard yields the highest value. In addition, while the state level economic impacts across the three scenarios are not significantly different, the county-level impacts are substantial. This is especially important for a state like New Mexico, which has a high reliance on energy for economic development. A higher renewable portfolio standard appears to be an economic tool to stimulate targeted areas' economic growth. These results have policy implications.

Keywords: renewable portfolio standards; employment; economic output; water use; greenhouse gases; emissions; social benefits

Citation: Mamkhezri, J.; Malczynski, L.A.; Chermak, J.M. Assessing the Economic and Environmental Impacts of Alternative Renewable Portfolio Standards: Winners and Losers. *Energies* **2021**, *14*, 3319. https://doi.org/10.3390/en14113319

Academic Editor: George Halkos

Received: 13 May 2021
Accepted: 1 June 2021
Published: 5 June 2021

1. Introduction

Electric utilities in the United States (U.S.) are integrating more renewable energy (RE) sources in their energy mix. In May 2020, 24.3% of electricity generation in the U.S. came from renewable sources (Energy Information Administration, Form EIA-860M). This is partly a result of policies and regulations aimed at mitigating greenhouse-gas (GHG) emissions through programs such as the Regional Greenhouse Gas Initiative in the northeastern part of the U.S., and through the renewable portfolio standard (RPS) at the state level. While the primary objective of these regulations is to address global warming, there can be potential impacts on the economy at a microlevel (i.e., state and county levels). For rural western states, this has become increasingly important, as they strive to diversify their economies.

Debates are ongoing in the literature as to whether RPS policies have a positive (i.e., job creation, GHG and air pollution reduction), negative, or no impact on an economy and the environment (e.g., [1–5]). The main reason for the divergent findings is the inclusion or exclusion of market failure due to environmental amenities in the analyses. For example, NYSERDA [1] assessed New York's RPS impact and found a gain of 24,000 job-years from 2002 to 2037. Divounguy et al. [2] investigated Ohio's 12.5% by 2025 RPS and found that it would result in a loss of more than 134,000 jobs. Upton and Snyder [3] evaluated states with an RPS versus those without, and they found that an RPS standard has no significant impact on increasing RE or reducing GHGs. Zhou and Solomon [4] found that more stringent RPSs result in lowering RE capacity additions, while Carley et al. [5] found the opposite. Further, most of the existing literature focused on either an aggregate scope (e.g., nation-wide) or state-specific assessments and has not considered impacts at lower-level jurisdictions (e.g., county level). Lastly, much of the literature overlooked the fundamental dynamics within the energy sector. The objective of this paper is to contribute to this line of research and assess the economic and environmental impact of renewable energy and the tradeoffs on a regional economy.

In particular, we are interested in answering the question of what are the economic and environmental impacts of varying RPSs on regional economies. This is a rather complex question, and answering it is aided by the use of system simulation [6–11]. Thus, in this work we develop, validate, and utilize a system dynamics (SD) based simulation model that integrates results from various methodologies such as input–output analysis, econometrics, and Geographic Information System (GIS). Combining these methodologies in an innovative approach to analyze the SD model is one key contribution of this paper. We execute our analysis in our case study of New Mexico, a southwestern state in the U.S. with an RPS and high potential for both fossil fuel (traditional) and RE sources. We hypothesize that RPS levels have substantial environmental and economic impacts on regional economies. This paper is an attempt to quantify those impacts.

Our findings suggest a net increase of jobs in rural counties that are most suitable for future RE installations. Depending on the scenario, our model estimated increasing 137–156 thousand cumulative, full-time equivalent jobs, 19 to 24 billion USD (2017$) cumulative gross economic output, and 12,987 to 13,219 and 974 to 1122 billion liters of cumulative water withdrawal and consumption respectively from 2017 to 2050. These scenarios also resulted in increasing millions of avian mortalities, as well as millions of tonnes of GHG emissions and thousands of tonnes of air pollutants, each of which leads to billions of dollars in climatic and air-quality costs (social costs). Lastly, we found that higher RPS standards lead to greater benefits to the state when externalities and social benefits/costs are taken into account.

2. Background

The burning of fossil fuel (i.e., coal, natural gas, and oil) is the main source of GHG emissions in the U.S., and this contributes to climate change. Combusting fossil fuels for electricity generation not only emits air pollution but also requires an immense amount of water. There is extensive literature that demonstrates the correlation between air pollution and premature mortality/morbidity [12–18]. Maupin et al. [19] showed that roughly 40% of all of the U.S. freshwater withdrawal was used for thermoelectric power plants in 2010. Policymakers, as a result, are seeking to promote policies that lead to integrating more environmentally friendly generation sources with less externalities.

Electricity generation is moving towards integrating a higher level of RE and a lower level of fossil fuels in the U.S. due to regulatory mandated laws such as the RPS as well as cost competitiveness. Thirty states and the District of Columbia currently have an RPS in place. RPSs mandate that electric utilities source a portion of their generation from RE within a certain timeframe. Although the main goal of an RPS is environmentally oriented—that is, to mitigate GHG emissions and/or save water—these policies have the potential to impact economies. Previous research on the impact of RPSs shows that the policies are capable of yielding positive economic impacts if positive externalities (zero or close to zero water usage, zero emission, etc.) are taken into account [20,21]. Barbose et al. [20] demonstrated that meeting requirements mandated by RPSs led to supporting

200 thousand jobs and a reduction of 59 million tonnes of CO_2 in the U.S. in 2013. Wiser et al. [21] quantified positive externalities of RE and estimated that existing RPS policies lead to improving air quality and reducing climatic damages (258 billion USD), which not only compensates the increase in electric system costs (23 to 194 billion USD) but also exceeds those costs over the period of 2015–2050.

There are a handful of peer-reviewed papers and national laboratory reports that look at the feasibility of providing global energy through RE (e.g., [22–25]). For example, Jacobson and colleagues [22] estimated a portfolio mix that enables the United States to sustain its entire energy needs—including electricity, transportation, heating/cooling, and industry—using renewable energy by 2050. Similarly, Cole et al. [25] assessed different scenarios of achieving various levels of RE in only the power sector by 2050. Further, previous economic impact studies of constructing and operating RE projects suggested that the economic impacts to states are considerable [17,26,27]. Similarly, studies on environmental impact of RE showed significant climate and air quality benefits [28–31]. For instance, Millstein et al. [29] found that solar and wind development resulted in benefits of 30–113 billion USD (2015) and 5–107 billion USD from air quality and climate, respectively, while avoiding 3000–12,700 premature mortalities in 2007–2015. Most of these studies produced state-level or nation-wide job/environmental impact estimates, which in turn meant less understanding of lower-level dynamics such as job/environmental impacts across counties. These studies also did not consider the underlying dynamics within the energy sector.

To address the aforementioned gaps in the literature, we combine various methodologies to develop an SD model. SDs are a derivative of the work developed by Forrester [32], in which he introduced a novel approach to integrate multiloop feedback systems. So long as relationships among variables are known, this approach makes modeling complex systems possible [33]. The SD model of this paper integrates results from input–output analysis, econometrics, and GIS to form a unique framework that provides both the public and policymakers improved information with which to make decisions. The model is developed at a monthly time-step from January 2004 through January 2050. Multiple programs are used to analyze the complex electricity problems common to most utilities. Specifically, Jobs and Economic Development Impact (JEDI) coupled with Impact Analysis for Planning (IMPLAN) are used to calculate job multipliers by energy type and by county; Stata is used to estimate electricity demand; ArcGIS is utilized to estimate the potential of renewable and natural gas electricity generation by county, as well as the optimal location for siting additional power plants; lastly, results from previous models are all embodied in Powersim Studio, which is used to analyze various energy mix scenarios.

The objective of the SD model is to estimate electricity generation and consumption by different fuel sources and various sectors respectively. We provide a roadmap to assess the explicit and implicit impacts of various energy mix scenarios at the state and county level and at different points in time. Explicit impacts may include potential jobs and economic gross output associated with current and potential future electricity generation, and implicit impacts may include positive health effects and social benefits of reducing ambient emissions. We apply this roadmap to our case study of New Mexico.

2.1. Study Area: New Mexico

New Mexico has considerable potential for both fossil fuel and RE resources. It holds about 3%, 4%, and 5% of the United States' total estimated recoverable coal reserves, proved crude oil, and natural gas respectively and it possesses the second-largest uranium reserves in the nation. Most of the state's natural gas and crude oil are located in the San Juan and Permian Basins in the northwestern and southeastern part of the state, respectively, while coal reserves are mainly located in the San Juan and Raton Basins in the northern part of the state. The vast areas of New Mexico with available geophysiological landmass that receives high wind and sunlight levels are optimal for increasing RE usage. New Mexico ranks third in both solar and wind potential in the U.S. [34].

New Mexico's economy is ranked 46th in the nation. The energy industry, especially oil and natural gas extraction, is a main contributor to New Mexico's economy. The state receives approximately 2 billion and 300 million USD per year in direct (e.g., severance, property taxes, royalty, and rental income) and indirect (sales and income taxes) revenues, respectively, from oil and gas production. Depending on the state of the economy, based on recent state finance facts, revenues from oil and gas can contribute about 40% to New Mexico's general fund tax revenue. Thus, fluctuating oil and gas prices affect New Mexico's economy immensely.

On one hand, the energy industry is responsible for emitting GHG and ambient pollution as well as increased water usage in New Mexico. GHG contributes to climate change, while air pollution causes premature mortality and morbidity, and freshwater has historically been insufficient in New Mexico. On the other hand, RE is becoming more and more cost-competitive compared to fossil fuel technologies. Thus, it makes logical and economic sense for policymakers to promote policies such as an RPS in order to integrate more RE into New Mexico's energy mix.

At the time of analysis, New Mexico's RPS required all large electric utilities to generate 20% of their in-state electricity sales from RE resources by 2020. Although it did not pass, a bill (Senate Bill 312) was introduced to increase New Mexico's RPS previous level to 25% by 2020, 35% by 2025, 50% by 2030, 65% by 2035, and 80% by 2040 in the 53rd legislative session in 2017. A modified version of this bill was reintroduced in January 2019 (House Bill 15) and was passed in the 54th legislative session in March 2019 (Senate Bill 489). In addition to the requirements set by Senate Bill 312, Senate Bill 489 sets a 100% RPS by 2045 that is sourced from zero carbon resources. This makes New Mexico the third state in the U.S. after California and Hawaii and before Washington, New York, Maine, and Virginia to mandate a 100% RPS. Thus, New Mexico's current RPS policy requires 20% in-state electricity sales from RE resources by 2020, 40% by 2025, 50% by 2030, 80% by 2040, and 100% by 2045.

Currently, there are three large electric utilities in New Mexico: the Public Service Company of New Mexico, El Paso Electric, and Xcel Energy, with the first serving the largest customer pool in the state. Further, as New Mexico has considerable potential in both wind and solar energy, the Public Regulation Commission set diversity targets (carve-outs) for different types of RE to create a diversified portfolio. Based on this portfolio, the utilities are required to source at least 30%, 20%, and 3% of their in-state electricity sales from wind, utility-scale photovoltaic solar (PV), and residential photovoltaic solar (RPV), respectively, by 2020 (see Table 1). RPS requires the New Mexico's rural electric distribution cooperatives to generate 10% of their in-state electricity sale from renewable sources. We did not consider a rural cooperatives constraint in our analysis.

Table 1. Carve-outs regulated by renewable portfolio standard.

Source	Minimum Amount
Wind	30%
Utility-scale solar (PV)	20%
Residential/distributed solar (RPV)	3%

2.2. Scenario Construction

Our analysis investigated the number of jobs and their locations by energy source, as well as environmental impact based on thirty-four prices, three technological-costs, and three RPS scenarios. Each of these scenarios are described briefly below.

We adopted 34 price scenarios—i.e., electricity price by sector, Henry Hub natural gas price, and electric sector fuel cost (coal and natural gas)—developed by the Energy Information Administration's (EIA) Annual Energy Outlook 2018 (AEO2018), along with three technology cost scenarios developed by the National Renewable Energy Laboratory (NREL) [25]. A list of AEO2018 scenarios are summarized in the supplementary document (Table S1). The cost scenarios includes low, mid, and high (constant) cost and performance estimates for wind, PV, RPV, natural gas (both baseload (combined-cycle; NGb) and peaker (single-cycle; NGp)), and coal from 2016 to 2050. Low-cost wind and solar scenarios utilize low-cost estimates for land-based wind, along with PV and RPV technologies, while high-cost scenarios use constant costs at or near the 2018 cost estimates. The mid-case scenario assumes prospective advances in the RE arena technology. The low- and high-cost scenarios for fossil fuel beyond 2016 relies on two case estimates from AEO2018, i.e., the high oil and gas resource and technology case and the low oil and gas resource and technology case, respectively. The mid-case scenario serves as a reference case for fossil fuel technology costs adopted from AEO (2018). Overall, the SD model is capable of assessing 918 ($34 \times 3 \times 3 \times 3$) different scenarios. For the purpose of brevity, we focus on the three most plausible future scenarios: the new RPS, the previous RPS, and a future where integrating RE in the electric grid is discouraged. Under the first scenario, i.e., 100% RPS, we assume a future with scarce natural resources with costly fossil fuel and cheap RE technologies that make 100% RPS by 2050 possible. The second scenario, i.e., 10% RPS, is the opposite of the first scenario, in that we assume abundant natural resources with cheap fossil fuel and expensive RE technologies, hence a decreased RPS (10% by 2050). Lastly, we implement a status quo scenario, i.e., 20% RPS, that assumes reference case AEO prices with mid-case technology cost of fossil fuel and constant RE technology cost, along with business-as-usual RPS (RPS 20% by 2020 and on). Below we summarize each scenario.

I. 100% RPS: AEO price = low oil and gas resource and technology; RE cost = low; fossil fuel cost = high; RPS = Senate Bill RPS (100%)
II. 10% RPS: AEO price = high oil and gas resource and technology; RE cost = high; fossil fuel cost = low; RPS = decrease RPS (10%)
III. 20% RPS: AEO prices = reference case; RE cost = high; fossil fuel cost = mid; RPS = status quo RPS (20%)

3. Materials and Methods

Our model consists of five submodels: (1) demand; (2) supply; (3) gap between supply and demand (hereafter "gap"); (4) jobs; and (5) environmental impact, with more than 1200 variables. The first submodel consists of two modules that together estimate electricity demand beyond 2016. The second submodel includes six modules that altogether project megawatt-hour (MWh) generation. The gap and the jobs submodels each contain seven modules. Finally, the environmental impact submodel contains only one module. A detailed description of the model is provided in the Supplementary Materials (Section B) and a related work [35]. Here, we briefly describe the overarching dynamics of the model.

Our model is based on a series of stocks and flows. Stocks can change from period to period; the changes are governed by "flows". The flows, based on either natural science-based rules, human choice, or policies, or a combination thereof, are the set of rules that dictate the change in the stocks. Figure 1 provides a schematic of the model. Arrows provide the connections between stocks and flows. In all cases, the arrows represent the direction of interaction. Associated with each stock, flow, and connecting arrow is a set of quantifiable relationships and rules that allow us to model the system and assess the impact and tradeoffs between sectors within a time period as well as over time.

The basic structure of the modeling components is the physical market for electricity, which (in the figure) is at the intersection of supply and demand and is governed by an exogenous price path. As mentioned in the scenario definitions section, we implemented 34 price scenarios developed by EIA's 2018 AEO report. Thus, "exogenous" here does not mean a fixed value over time but rather is a given independent variable that fluctuates by month and over time. Supply depends on capacity and capacity utilization, which is aggregated from individual generation sources of capacity, utilization, and net exports into/out of state, while demand depends on in-state (domestic) consumption. In-state demand is the aggregation of individual sectoral demands, which can be impacted by market conditions (price) and population impacts.

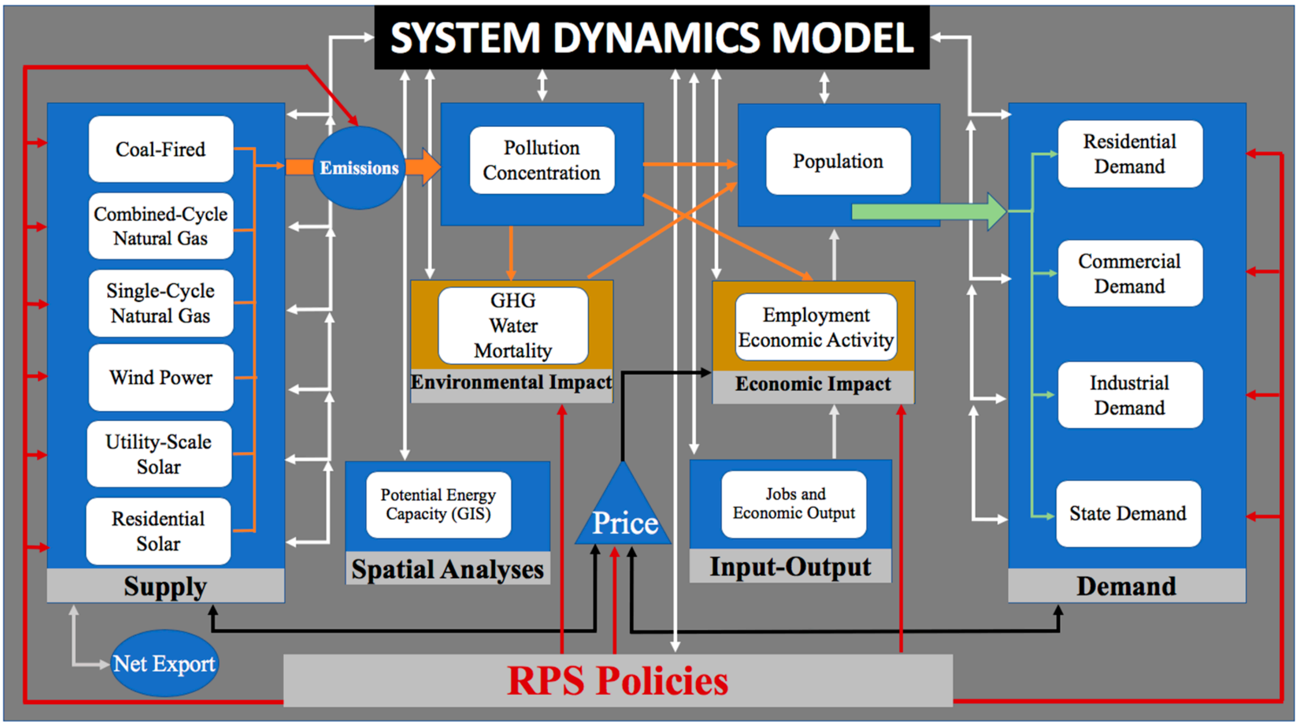


Figure 1. Modeling schematic.

The electricity market outcome at each time step maps into economic activity, estimated in dollars, which is one part of our macroeconomic module. The level of economic activity impacts the job outcome through changes in the demand for workers. It should be noted that population can also be impacted by the job impact as it could result in net out- or in-migration.

The linkage between the electricity market and the environment (potential external impacts) is represented through a pollution component, where emissions during a time step add to the concentration level of the pollutant. We depict direct impacts of pollution through impacts on economic activity and through population (e.g., health impacts). It should be noted that there are a number of potential indirect links through, for example, consumer groups. In addition to pollution, our basic model includes water resources and human and avian mortalities. Further, RPS policies are included. Depending on the policy, the generation capacity, supply, demand, market prices, emissions, economic activity, or jobs could be impacted. Finally, all of these modules and methodologies are gathered in a unique SD model. Figure 2 summarizes the causal loop diagram utilized in developing the SD model.

In order to read the causal loop diagram depicted in Figure 2, we begin by imagining the variable at the base of the arrow increasing in value; the sign at the arrowhead indicates the increase (+) or decrease (−) in the variable at the arrowhead, all other variables unchanged. Lastly, parallel lines crossing an arrow indicate delay in impact from the variable at the base of the arrow to the variable in the head of the arrow. The causal loop diagram presents the logic behind our SD model. The following is an explanation of one path in the diagram.

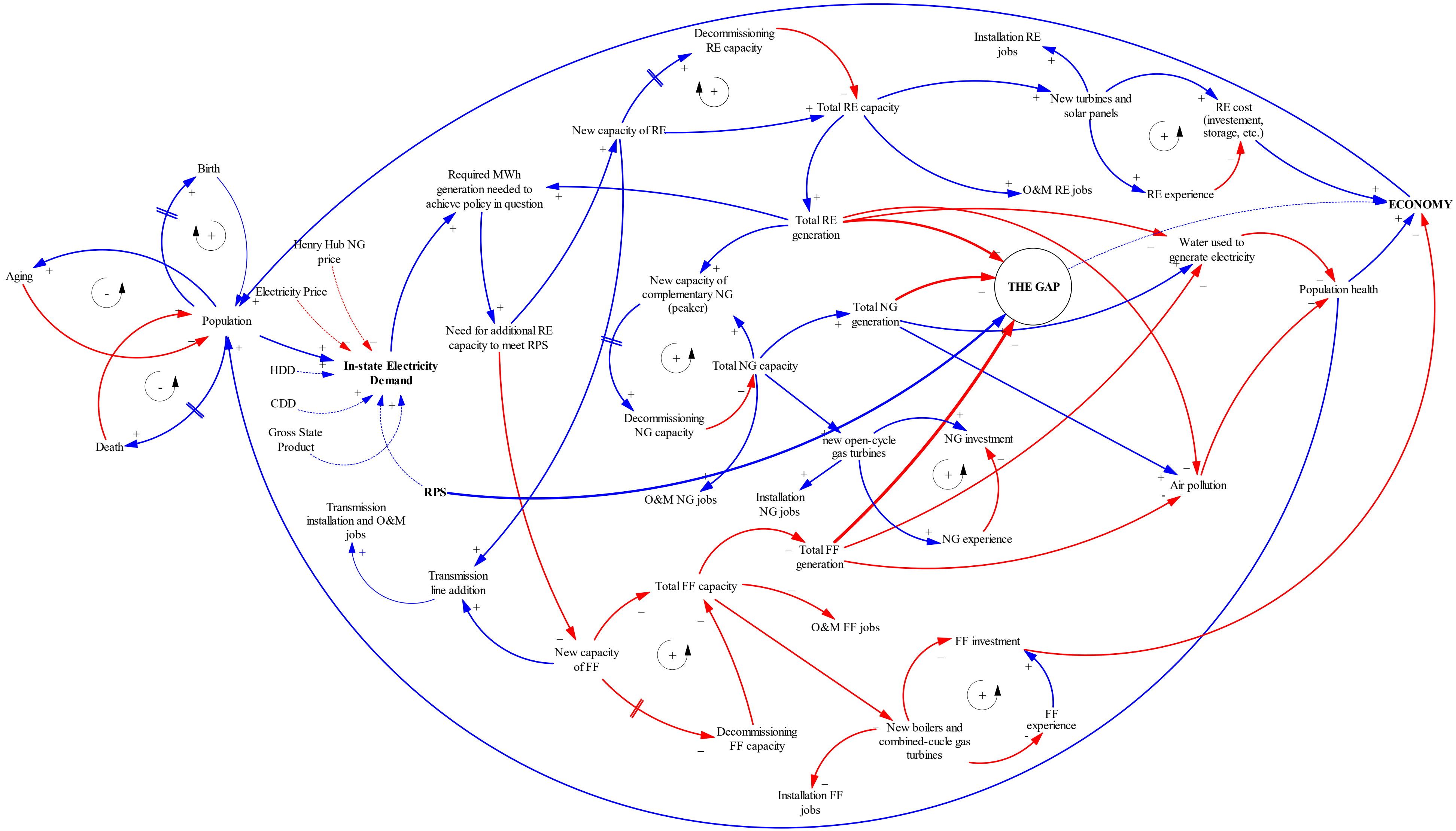


Figure 2. Causal loop diagram utilized to develop the SD model.

The required generation to achieve a certain level of RPS increases as in-state electricity demand increases, which increases the need for additional RE capacity to meet the corresponding RPS level. The higher the need for additional RE capacity, the higher the new capacity of RE. As the new capacity of RE rises, the total RE capacity rises, and the capacity that is decommissioned in the future increases with a delay. A higher level of RE capacity that is to be decommissioned decreases the total RE capacity, creating an enforcing loop (see Figure 2). On one hand, the higher the RE capacity, the higher the RE generation, hence the higher the need for peaker natural gas, storage, and transmission lines. On the other hand, if we assume that a higher level of RE generation replaces fossil fuel generation, then a higher level of RE generation results in lower GHG and air pollution, thereby lowering population mortality and morbidity (social cost). A higher level of RE generation can also decrease the gap caused by a discrepancy between supply and demand for electricity and/or RPS requirement. The same logic holds true for the remaining components of the causal loop diagram.

Data

Data were obtained from numerous sources including, the U.S. Energy Information Administration (various survey forms, AEO2018, and Layer Information for Interactive State Maps shapefiles), Emissions and Generation Resource Integrated Database (eGRID) of the U.S. Environmental Protection Agency (EPA), the National Renewable Energy Laboratories (JEDI, Annual Technology Baseline, wind data, and solar data), the New Mexico Public Regulation Commission, the United States Geological Survey, the U.S. Bureau of Economic Analysis, the United States Census Bureau, and the Western Electricity Coordinating Council, as well as the energy literature. Except for RPV data, we obtained generation data from EIA-923 and EIA-861 (annual and monthly data). The data includes historical nameplate capacity of the existing power plants, generation, power plants' locations (county and latitude/longitude), operating and planned retirement year times, and capacity factors. The data for the existing RPV capacity were obtained from the New Mexico Public Regulation Commission. Further, IMPLAN 2016 data were used to calculate jobs and output multipliers for each energy source. Lastly, economic benefit/cost of air pollution and GHG reduction multipliers came from the energy literature. Table S2 of the Supplementary Materials summarizes the key data sources.

4. Results

In this section, we present our results. We first review electricity generation under the three modeled scenarios. Next, we discuss state-level and county-level economic and environmental impacts. Economic impact results are presented for full-time equivalent employment and gross economic output. Environmental impacts, on the other hand, are reported in terms of GHG emissions, air pollution, water usage, and human and avian mortality associated with each of our three modeled scenarios. These impacts are experienced once the plants are in the O&M phase. Thus, environmental impact results are reported for the operations period solely and on a state- and county-level basis. Finally, we compare results across scenarios to expose whether results are statistically significantly different. If they are, we then identify state and county levels that experience job gains (winners) and job losses (losers).

4.1. Generation

Figure 3 shows the total electricity generation under the three modeled scenarios, and Figure 4 presents the generation mix through 2050. Based on the 20% RPS scenario, as with the other two scenarios, RE and fossil fuel generations encompassed respectively 17% and 83% of total generation in 2017. In 2030, generation shares are 15% and 85% for RE and fossil fuel, respectively. Compared to the 20% RPS scenario, RE generations are 9% higher in the generation mix under the 100% RPS scenario (24%) and 5% lower under the 10% RPS scenario (12%). All scenarios estimated a dip in electricity generation from 2036 until the end of 2037. This is due to the decommissioning of the existing coal-fired power plants in that period. The dip in the overall electricity generation is expected to be compensated by importing nuclear energy from Arizona. The figures depict generation from both within the state and not imported into the state.

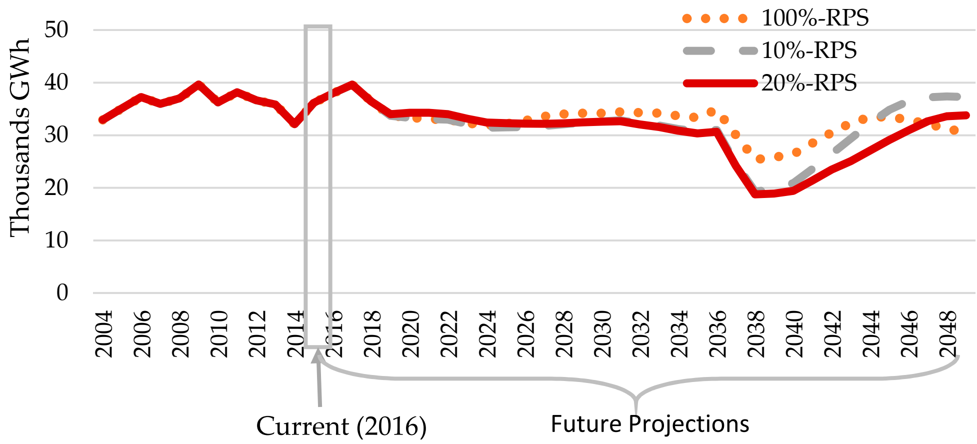


Figure 3. Total annual electricity generation under the three modeled scenarios.

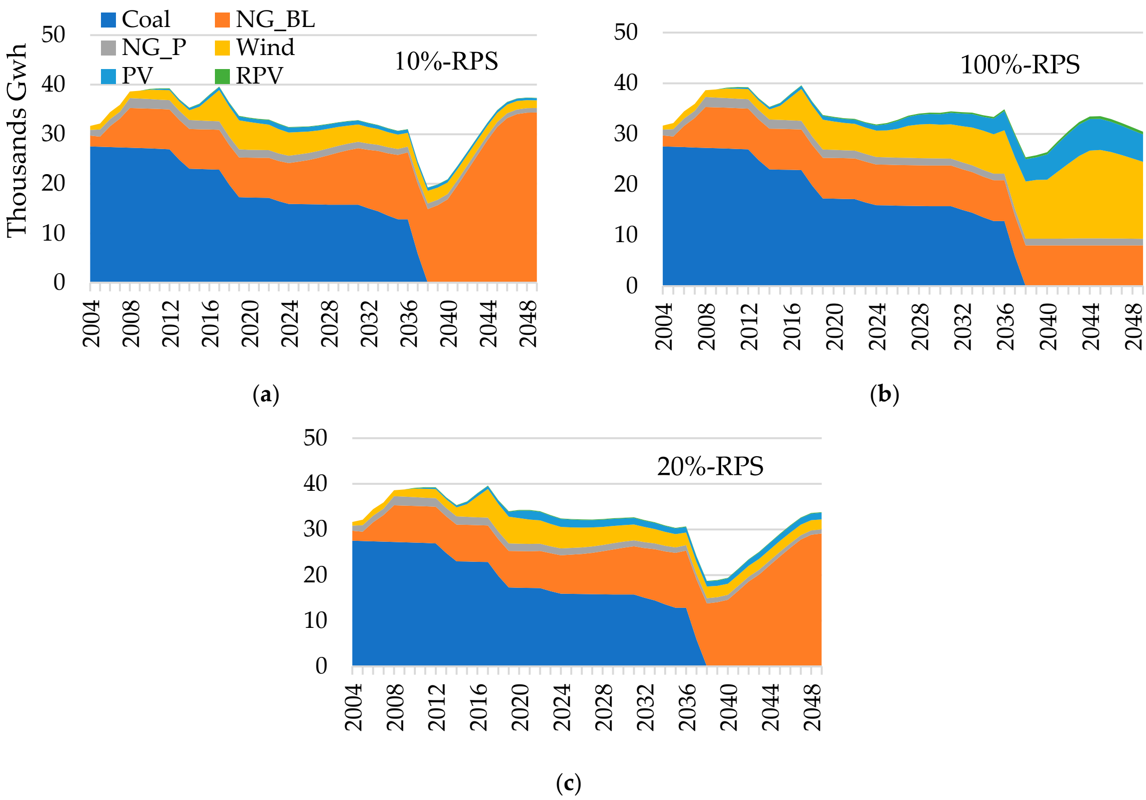


Figure 4. Annual electricity generation (in thousand GWh or TWh) by all six energy sources: (**a**) 10% RPS; (**b**) 100% RPS; (**c**) 10% RPS scenarios.

As presented in Figure 4, for the scenarios we estimated the amount and type of energy source to replace coal generation. By 2050, RE generation increases to 52%, while fossil fuel generation drops to 48% under the 20% RPS scenario. The 100% RPS scenario and the 10% RPS scenario result in a 11% higher and a 48% lower RE generation, respectively, when compared with the 20% RPS scenario. As mentioned, RPS requires utility companies to generate a portion of their in-state sales from RE. Thus, it is possible to have fossil fuel generation even under the 100% RPS scenario. The takeaway here is that different energy scenarios lead to different energy mixes, which therefore means different environmental and economic impacts.

4.2. Economic Impacts

Our model is capable of estimating employment and gross economic output by three categories: direct (onsite), indirect, and induced. Total impact is the sum of direct, indirect, and induced impacts. Since direct, indirect, and induced impacts are a fixed fraction of total impact, we only discuss total impacts here. In what follows, we first discuss employment impact at the state and county level. We then compare results across scenarios and identify whether there are winners or losers. Next, we summarize total economic output results in a similar approach. Further discussion of the results, especially more granular level results (e.g., different types of energy sources during different phases), can be found in the Supplementary Materials (Section C).

Figure 5 summarizes the cumulative total employment impact by the 20% RPS scenario and the other two modeled scenarios. We estimated a total employment impact on New Mexico in construction and O&M to be as follows: 151,857 (42,517 RE and 109,340 fossil fuel), 151,284 (112,593 RE and 38,691 fossil fuel), and 155,520 (26,271 RE and 129,248 fossil fuel) full-time equivalent jobs according to the 20% RPS, 100% RPS, and 10% RPS scenarios, respectively, from January 2017 to January 2050. Thus, compared to the 20% RPS scenario, the 100% RPS one (RE intensive scenarios) results in 573 fewer cumulative (construction and O&M) full-time equivalent jobs, while the 10% RPS one (most fossil fuel intensive scenario) yields 3663 more cumulative jobs. Note that these results are based on the assumption that all labor is provided locally. This assumption, which is on a 0–100% scale, can also be changed in the original SD model. What is important here is that this assumption does not impact the dynamics within modules and only results in lower direct economic impact (labor and economic output) across scenarios.

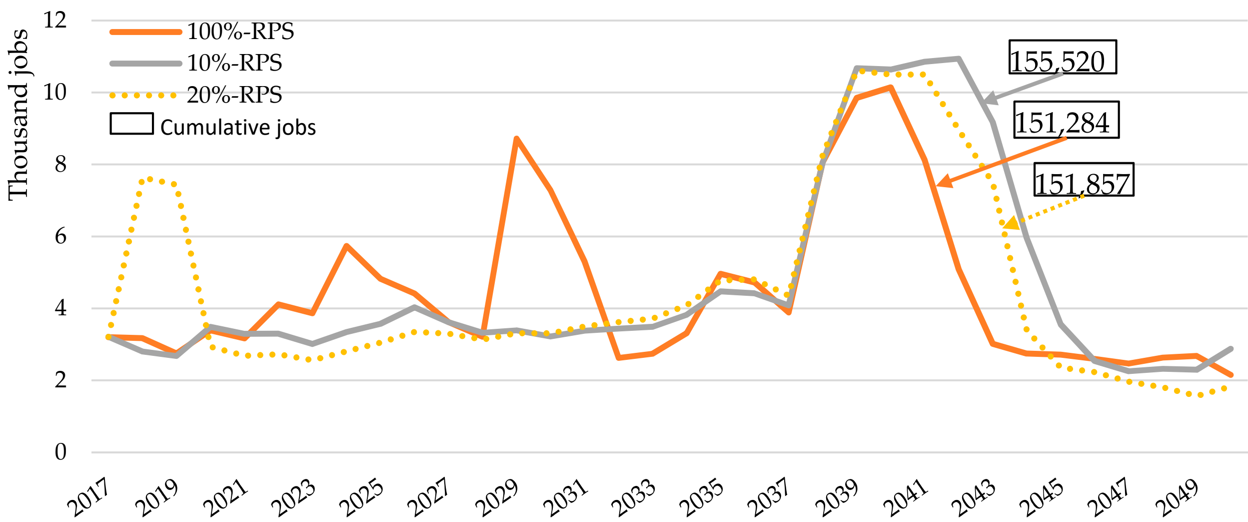


Figure 5. Temporal cumulative jobs (construction and O&M) by modeled scenarios from January 2017 to January 2050.

As demonstrated in Figure 5, all scenarios estimate a boost in energy employment after 2037. This is because existing coal-fired power plants are expected to retire in 2037, meaning there should be no new installation. Depending on the scenario, coal generation is expected to be replaced by either renewables or natural gas after 2037, and thus jobs related to coal are also likely to be replaced by renewable or natural gas jobs. Although the 100% RPS scenario yields fewer cumulative total jobs than the 20% RPS case, its impact fluctuates and is more diverse throughout the timespan of the study. Figure 3 depicts the employment distribution by the three modeled scenarios from 2017 through January 2050. Any spikes in the estimated employment numbers can be due to whether RPS and RE carveout requirements are met. We performed nonparametric tests such as the Kolmogorov–Smirnov tests to compare the equality of distributions of total employment across scenarios. The test results suggest that the null hypothesis of equality of distributions across the three scenarios cannot be rejected. In other words, at the state level, the employment impact of these three scenarios are not statistically significantly different. Thus, we found that the state of New Mexico is not a winner or a loser in terms of job gains or losses at the state level under all of the assessed scenarios. Temporal and cumulative employment impacts during construction and O&M phases are provided in the Supplementary Materials (Section C).

Now, we turn our attention to county-level employment results. Table 2 summarizes the annual average employment for all three scenarios by county. This table demonstrates an important result of the current study: some counties will be winners, and others will be losers. Figure 6 puts these results in perspective; it shows employment gain and loss per 10,000 labor force for the 100% RPS case versus the reference case of 20% RPS. Lastly, the Kolmogorov–Smirnov test results at the county level support the statistically significantly different employment distributions as well.

Table 2. Annual average employment by county and modeled scenarios *.

County	20% RPS	100% RPS	10% RPS
Bernalillo	301	83	320
Catron	22	93	3
Chaves	19	121	8
Cibola	23	118	4
Colfax	26	128	6
Curry	211	275	188
De Baca	23	94	3
Dona Ana	397	225	393
Eddy	285	121	289
Grant	284	119	291
Guadalupe	44	132	24
Harding	23	115	3
Hidalgo	294	120	300
Lea	536	443	498
Lincoln	7	45	3
Los Alamos	41	31	35
Luna	442	334	419
Mc Kinley	303	67	325
Mora	23	126	3
Otero	16	114	6
Quay	79	160	59
Rio Arriba	23	112	3
Roosevelt	137	210	117
Sandoval	39	58	34
San Juan	764	569	762
San Miguel	23	110	4
Santa Fe	12	35	7
Sierra	22	108	3
Socorro	22	108	3
Taos	23	97	3
Torrance	155	235	136
Union	81	163	61
Valencia	306	84	322

* Average values are from 2017 to 2050.

Economic output follows the employment results closely: when there is employment impact, there is economic output impact as well. Construction and O&M employees, depending on type of energy source, earn an average annual salary (with benefit) of 35,000 to 58,000 USD (2017$) and 56,000 to 76,000 USD (2017$) per year, respectively [36]. Under the 20% RPS scenario, these employments result in a cumulative (sum of construction and

O&M) total economic output of 24 billion USD (2017$) (18% RE and 49% O&M) per year from 2017 to 2050. The 100% RPS and 10% RPS scenarios respectively lead to roughly 4 (20 USD: 94% RE and 54% O&M) and 2 (22 USD: 4% RE and 45% O&M) billion USD (2017$) per year less than the 20% RPS case. In other words, the 20% RPS scenario yields a cumulative economic output that is 20% and 9% higher than the 100% RPS and 10% RPS scenarios, respectively. Figure 7 summarizes these results.

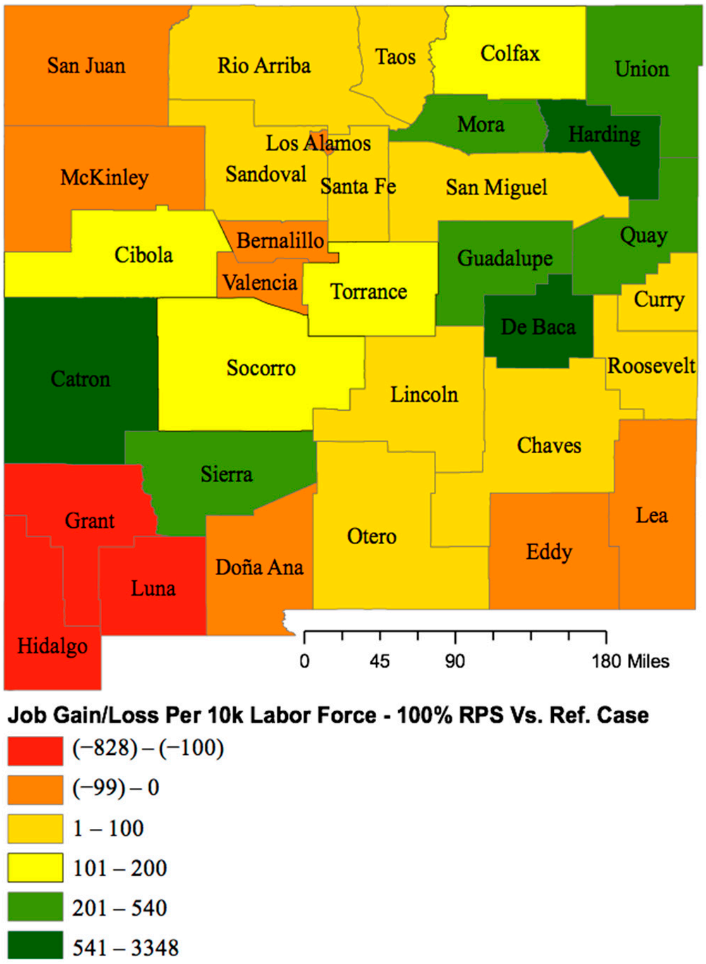


Figure 6. Employment gain and loss per 10,000 labor force under the 100% RPS case compared to the 20% RPS case. Note: Positive values indicate job gains; negative values are job losses.

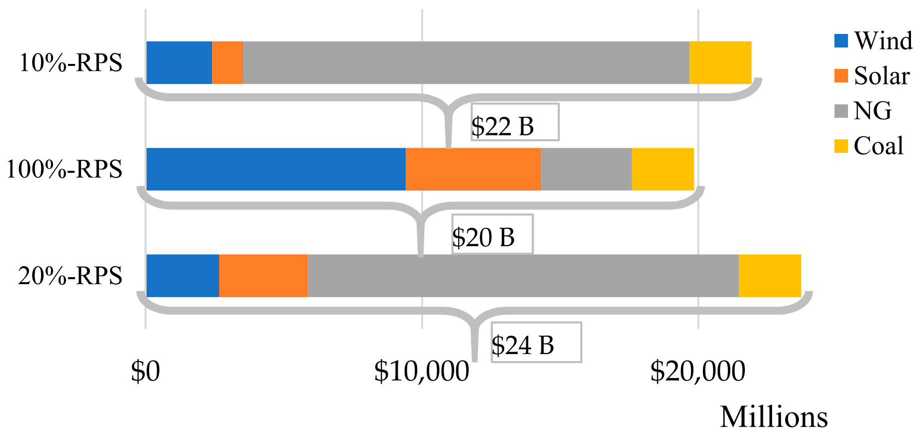


Figure 7. Total annual economic output by energy source and modeled scenarios from 2017 to 2050.

Similar to the state-level employment, economic impact distributions under the three assessed scenarios are not statistically significantly different. However, at the county level, rural counties can benefit under the RE intensive scenario, and counties with fossil fuel infrastructure in place can benefit from the fossil fuel intensive scenarios (namely the more populous counties).

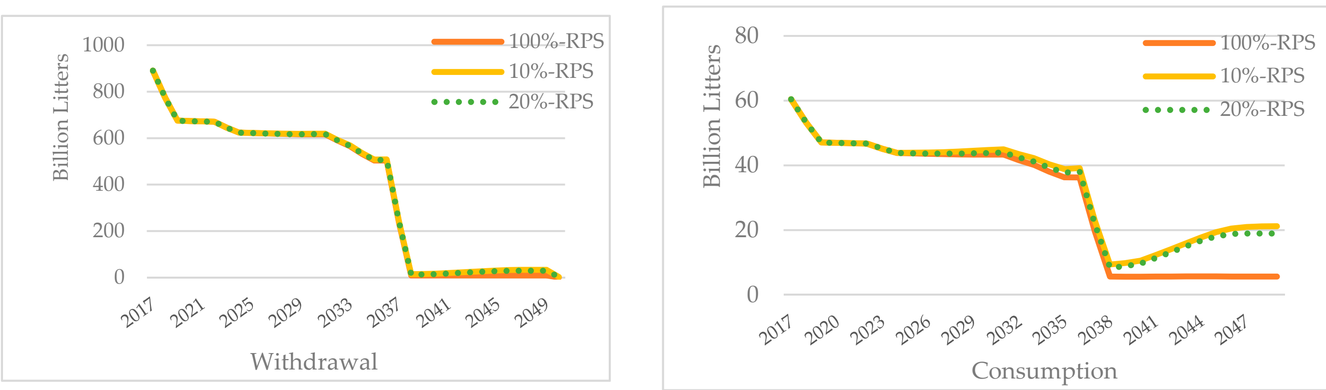
4.3. Environmental Impacts

Based on all of the three modeled scenarios, coal-fired power plants are assumed to fully retire after 2037. This is mainly due to the fact that the existing coal-fired power plants are aging (>40 years), and fuel contracts with coal mines are ending; more importantly, it is highly likely that coal will no longer be cost-competitive. Given these situations, we expect that there would be no new coal-fired power plants constructed in the future (see Figure 4). Note that these power plants are the most water-intense and polluting technologies in our set of energy sources (see Table S6). Eliminating coal from New Mexico's energy mix would result in fewer negative externalities (GHG, ambient pollutions, and water usage) from fossil fuel overall. Different technology costs along with RPS requirements drive the energy source that would eventually replace coal. The more RE replaces coal, the fewer negative externalities and the higher the social benefit from the replacement.

In what follows, we first discuss cumulative water withdrawal and consumption results at the state and county level. We then compare results across scenarios and identify whether there is water saved at the state and county levels. We take a similar approach in explaining emissions. Finally, we discuss the social benefit/cost of different scenarios.

4.3.1. Water Usage

Figure 8 depicts the temporal water withdrawal and consumption from 2017 to 2050. The 20% RPS scenario suggests a cumulative 13,178 and 1096 billion liters of water withdrawal and consumption throughout the study timeline. Compared to the 20% RPS scenario, the 100% RPS scenario uses less water for withdrawal and for consumption by 190 and 122 billion liters, respectively. The 10% RPS scenario, with the highest level of fossil fuels in the energy mix, uses 41 and 26 billion liters of water more than the 20% RPS scenario for water withdrawal and consumption, respectively.



(**a**) (**b**)

Figure 8. Water withdrawal and consumption over time by the electric sector under the three modeled scenarios. (**a**) Water withdrawal; (**b**) Water consumption.

Considering an average price of 0.00689 USD/liter for water consumption by each energy source [37], the 20% RPS scenario results in a total cost of 527 million USD ($2017) in water consumption for electricity generation. Compared to the 20% RPS scenario, the 100% RPS scenario results in saving 58 million USD for water savings, while the 10% RPS scenario increases costs by 13 million USD, as it is more water intense.

To compare water consumption distributions across scenarios, we performed Kolmogorov–Smirnov tests. Test results provided us with evidence to reject the null hypothesis of equality of distributions between the 100% RPS and 20% RPS scenarios even at the state level. On the whole, we did not find similar results when comparing the 10% RPS scenario against the 20% RPS one.

Table 3 summarizes the annual average million liters of water consumption by county and the three scenarios; Figure 9 translates this information to per capita (county) water consumption saved or lost. While the majority of counties see no changes, the majority of impacts are the savings. Our nonparametric test results further support the alternative hypothesis of unique water consumption distributions across scenarios at the county level.

Table 3. Annual average water consumption by county and modeled scenarios *.

County	20% RPS	100% RPS	10% RPS
Bernalillo	46	16	53
Catron	0	0	0
Chaves	0.08	0.68	0.04
Cibola	0	0	0
Colfax	0.23	0.23	0.23
Curry	0	0	0
De Baca	0	0	0
Dona Ana	119	89	126
Eddy	31	1	38
Grant	34	4	41
Guadalupe	0	0	0
Harding	0	0	0
Hidalgo	39	8	45
Lea	217	187	223
Lincoln	0	0	0
Los Alamos	13	7	14
Luna	140	109	146
Mc Kinley	203	173	209
Mora	0	0	0
Otero	0.08	0.68	0.04
Quay	0	0	0
Rio Arriba	0	0	0
Roosevelt	0.08	0.68	0.04
Sandoval	0	0	0
San Juan	1873	1843	1879
San Miguel	0	0	0
Santa Fe	0.08	0.68	0
Sierra	0	0	0
Socorro	0	0	0
Taos	0	0	0
Torrance	0	0	0
Union	0	0	0
Valencia	50	20	56

* Average values are in million liters and from 2017 to 2050; “0” means no change.

4.3.2. Air Pollution and Greenhouse-Gas Emissions

Figures 10 and 11 depict the cumulative impact of air pollution and GHG emissions, along with consecutive social benefit to the state from 2017 to 2050. Cumulatively, the RE intensive scenario emits roughly 91 million tonnes GHG less than the 20% RPS scenario throughout the study timeline, leading to more than 6.8 billion USD (2010$) in cumulative climate benefit. The fossil fuel intensive scenario, on the other hand, emits 3% (19 million tonnes) higher GHG than the 20% RPS one, which causes more than 1400 million USD (2010$) social cost compared to the 20% RPS one. Each one million tonnes of GHG emissions is equivalent to GHG emissions by approximately 2250 million miles driven by an average passenger vehicle. Table 4 summarizes the county level results only for GHG. Based on the Kolmogorov–Smirnov test results, we can reject the null hypotheses of equality of GHG emission distributions when comparing both the 100% RPS and 10% RPS scenarios against the 20% RPS scenario. In other words, the 100% RPS scenario results in statistically significantly lower GHG than the 20% RPS scenario, while the opposite holds true for the 10% RPS scenario. We found similar results at both state and county levels.

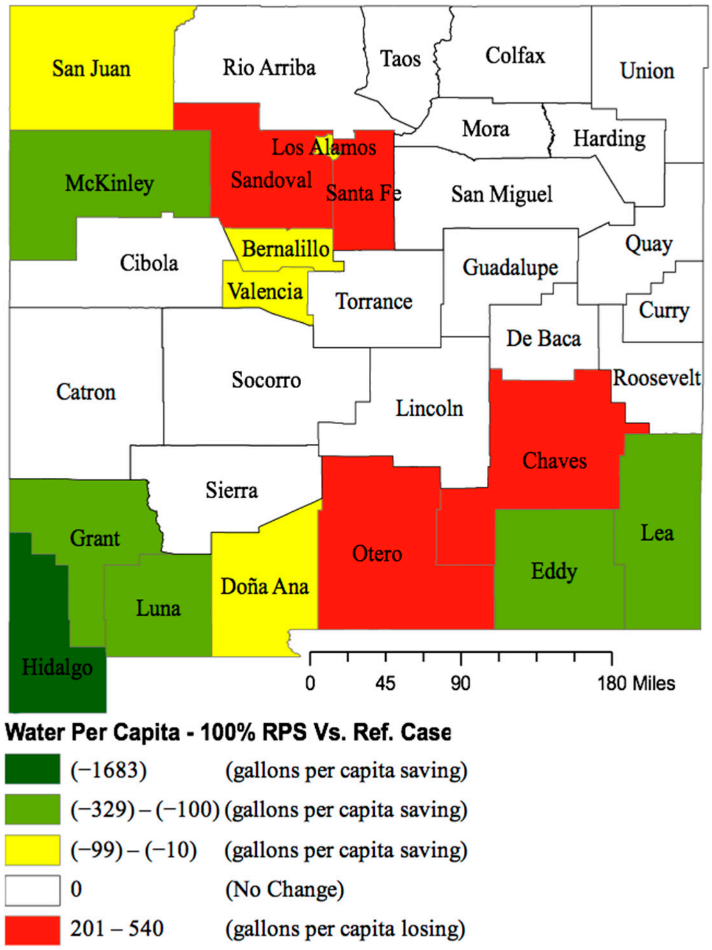


Figure 9. Per capita water consumption saved/lost under the 100% RPS scenario compared to the 20% RPS scenario. Note: Negative value indicates water saved; 1 gallon is ≈3.79 liters.

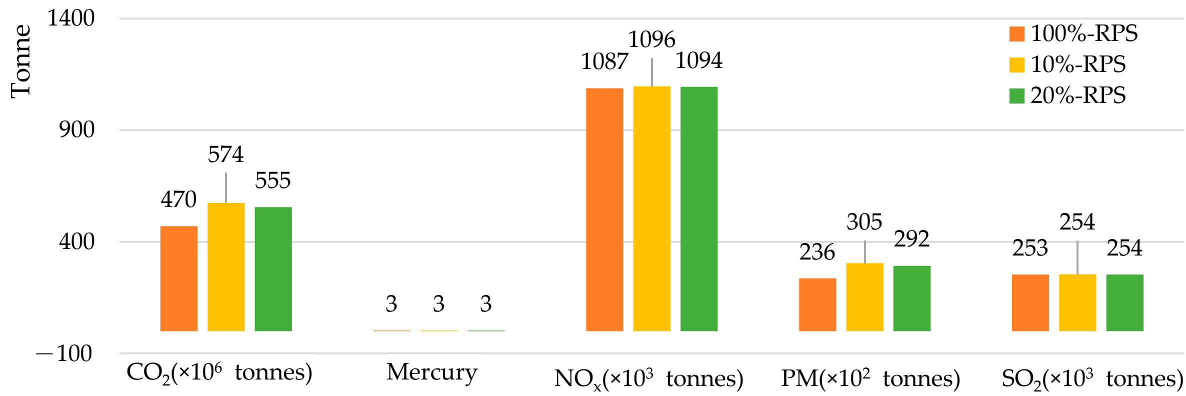


Figure 10. State-level cumulative tonnes of GHG and air emission under the three modeled scenarios from 2017 to 2050.

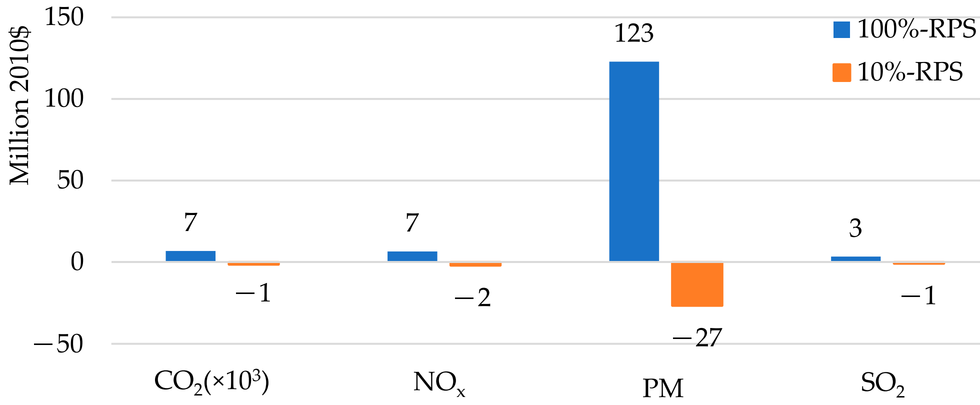


Figure 11. Social impact of air pollution and GHG emission reduction for the 100% RPS and 10% RPS scenarios compared to the 20% RPS scenario from 2017 to 2050.

Table 4. Annual average thousand tonnes of GHG emissions by county and modeled scenarios.

County	20% RPS	100% RPS	10% RPS
Bernalillo	38	18	43
Catron	0	0	0
Chaves	0.09	0.78	0.02
Cibola	0	0	0
Colfax	0.24	0.24	0.24
Curry	0	0	0
De Baca	0	0	0
Dona Ana	90	69	95
Eddy	23	1	27
Grant	26	4	31
Guadalupe	0	0	0
Harding	0	0	0
Hidalgo	32	10	36
Lea	160	139	165
Lincoln	0	0	0
Los Alamos	9	5	10
Luna	101	79	105
Mc Kinley	93	71	97
Mora	0	0	0
Otero	0.09	0.78	0.02
Quay	0	0	0
Rio Arriba	0	0	0
Roosevelt	0	0	0
Sandoval	0.09	0.78	0.02
San Juan	785	764	790
San Miguel	0	0	0
Santa Fe	0.09	0.78	0.02
Sierra	0	0	0
Socorro	0	0	0
Taos	0	0	0
Torrance	0	0	0
Union	0	0	0
Valencia	45	23	49

Note: Average values are in thousand tonnes and from 2017 to 2050; “0” means no change.

Since coal is the only energy source that emits mercury and since it stays unchanged throughout our study period, mercury is therefore assumed to be the same amount in all three scenarios, i.e., 3 tonnes. The 100% RPS scenario results in a roughly 500 tonne reduction in SO_2 emissions (approximately 3 million USD (2010$) in social benefit) compared to the 20% RPS scenario, while the 10% RPS scenario results in an increase of more than

100 tonnes of SO_2 (1 million USD (2010$) in social cost) cumulatively from 2017 to 2050. NO_x emissions in the RE intensive scenario are reduced by 6649 tonnes and a 7 million USD (2010$) increase in social benefits compared to the 20% RPS scenario, while the fossil fuel intensive scenario yields 1990 tonnes more NO_x and 2 million USD (2010$) more in social costs. Lastly, PM emission in the 100% RPS scenario is reduced by 5612 tonnes, resulting in a 123 million USD (2010$) increase in social benefits compared to the reference case scenario, while the 10% RPS scenario yields 1215 tonnes more and 27 million USD (2010$) in social costs.

Table 5 summarizes the cumulative avoided air pollution, social benefit, and the premature mortality and morbidity impact of air pollution under the 100% RPS and the 10% RPS scenarios from 2017 to 2050 compared to the 20% RPS scenario. The 20% RPS scenario is estimated to have 408 to 924 adult fatalities caused by a combination of SO_2, NO_x, and PM pollutants. The 100% RPS scenario has the potential to avoid 23 to 52 premature mortality incidences, while the 10% RPS scenario increases 5 to 11 fatalities due to exposure to ambient pollution, when compared to the reference scenario. While the majority (>90%) of social benefits for each scenario comes from avoiding premature mortality [12], we also estimated a number of additional morbidity benefits, from avoiding nonfatal heart attacks, hospital visits for asthma, or other cardiopulmonary conditions, to fewer lost work or school days. For example, the 100% RPS scenario is estimated to result in avoiding 19 visits to the emergency department or hospital for cardiopulmonary conditions as well as approximately 3000 fewer lost work or school days from 2017 to 2050.

Table 5. Accumulated emissions, social benefits, and mortality and morbidity incidence reductions compared to the reference case scenario (20% RPS) using SO_2, NOx, and PM reductions as a result of RE installation from 2017–2050.

Outcome	100% RPS			10% RPS			20% RPS		
	SO_2	NO_x	PM	SO_2	NO_x	PM	SO_2	NO_x	PM
Emission Reductions (Thousand Tonnes)									
	0.45	6.7	5.7	−0.1	−2	−1.2	*254*	*1094*	*29*
Social Benefits (2010 million USD)									
	3.4	6.6	122.8	−0.7	−2.0	−26.6	*1928*	*1078*	*640*
Premature Mortality Incidences									
Krewski et al. [13] [a]	0	1	22	0	0	−5	*207*	*95*	*107*
Lepeule et al. [14] [a]	1	2	50	0	0	−11	*464*	*219*	*241*
Morbidity Incidences									
Emergency department visits for asthma	0	0	7	0	0	−1	*81*	*37*	*36*
Acute bronchitis	1	2	36	0	0	−8	*372*	*251*	*181*
Lower respiratory symptoms	9	20	464	−2	−6	−100	*4699*	*3178*	*2312*
Upper respiratory symptoms	13	29	679	−3	−9	−146	*6735*	*4540*	*3334*
Minor restricted-activity days	319	643	16,682	−69	−193	−3586	*169,722*	*99,043*	*82,791*
Lost workdays	54	110	2782	−12	−33	−600	*28,485*	*16,673*	*13,975*
Asthma exacerbation	5	1892	630	−2	−522	−156	*5900*	*226,256*	*3938*
Hospital admissions, respiratory	0	0	5	0	0	−1	*48*	*20*	*24*
Hospital admissions, cardiovascular	0	0	6	0	0	−1	*61*	*26*	*30*
Nonfatal Heart Attacks Incidences (Age > 18)									
Peters et al. (2001) [b]	0	1	22	0	0	−5	*202*	*85*	*105*
Pooled estimate of 4 studies	0	0	2	0	0	−1	*22*	*9*	*11*

Note: Positive value means reduction, whereas negative value indicates addition. [a,b] Multipliers from these studies are used to calculate the mortality and morbidity incidences.

Fossil fuel and RE power plants are contributors to avian mortality; fossil fuel plants induce fatality through plant operation, acid rain, mercury, and climate change, while bird fatality associated with wind and PV power plants is mainly due to bird colliding with turbine blades and panels respectively [15,38,39]. Figure 12 summarizes avian mortality caused by different energy sources (i.e., coal, NG, wind, and PV) under different scenarios. The 20% RPS scenario leads to 5.131 million avian fatalities, of which fossil fuel is responsible for approximately 99% of the overall number of deaths. Compared to the 20% RPS scenario, the 100% RPS scenario has the potential to save 441 thousand deaths, while the 10% RPS scenario leads to 106 thousand more avian fatalities. Lastly, the RE intensive scenario leads to more than 4.69 million bird deaths, with fossil fuel sources being responsible for 97% of the overall number.

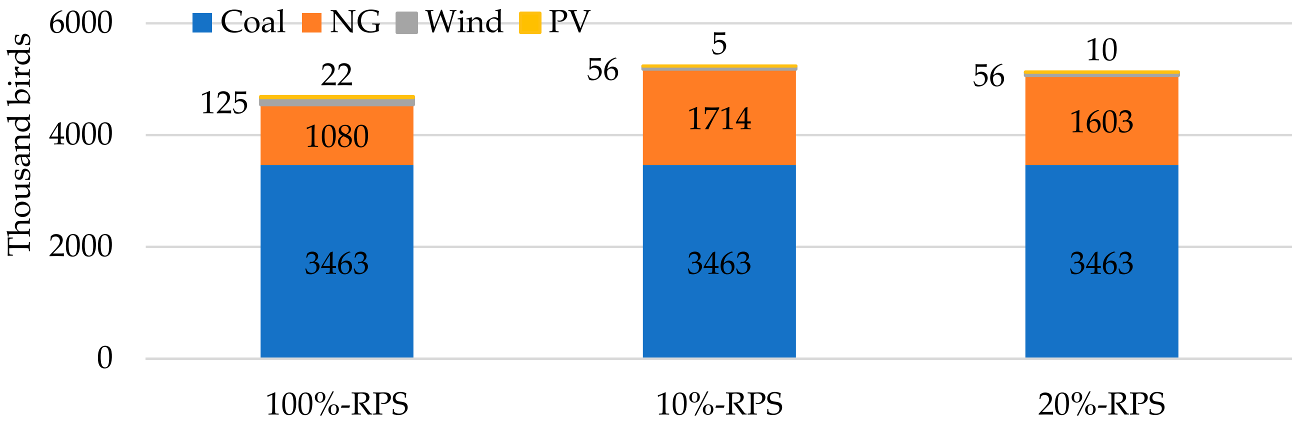


Figure 12. Avian mortality caused by coal, NG, wind, and PV power plants under the three modeled scenarios from 2017 to 2050.

Dissanayake and Ando [40] conducted a choice experiment survey in Illinois and found that their respondents are willing to pay between 1.11 and 1.13 USD for each extra bird per year, and between 7.72 and 10.22 USD for each endangered species annually. Since we were unable to discern different types of birds (generic versus endangered species) in our analysis, we utilized the mean value of the upper-level estimates as to how much each bird death is worth. We estimated that the 100% RPS scenario is capable of saving 3 million USD in bird mortality, while the 10% RPS scenario costs the state 1 million USD more in avian mortality, when compared with the 20% RPS scenario. We performed Kolmogorov–Smirnov tests and *t*-tests on human and avian mortality, and also on air pollutants (except mercury), and we found similar results to those of GHG and water consumption.

4.4. Summary of Cumulative Results

Our analysis seeks to investigate the economic and environmental impacts of the status quo scenario, along with two future scenarios. Without considering environmental impacts such as water usage, air pollution, GHG, and avian mortality, our results suggest that the reference case and the fossil fuel intensive scenarios lead to higher economic output and total employment impacts than the RE intensive scenario, though not statistically significant. Once the environmental impacts are included, these results no longer hold. Compared to the 20% RPS scenario, cumulatively, the 100% RPS scenario results in 3095 million USD (2017$) higher benefit and the 10% RPS scenario in 3325 million USD (2017$) more cost to the state. This makes the 100% RPS the best scenario, 20% RPS the second best, and 10% RPS the worst-case scenario, when both environmental and economic impacts are taken into account. Thus, the higher the RPS level, the higher the overall benefit to the state. Table 6 summarizes the state cumulative results in relation to the 20% RPS scenario. At the county level, compared to the 20% RPS case, we found that RE suitable counties are net gainers (in terms of both economic and environmental impacts), while fossil fuel counties suffer economically and benefit environmentally under the 100% RPS scenario. The opposite holds true when comparing the 10% RPS scenario against the 20% RPS scenario.

Table 6. Summary of cumulative results in relation to the 20% RPS scenario from 2017–2050.

Outcome	100% RPS, in Million USD	10% RPS, in Million USD
Economic Output	−3962 (−120)	−1881 (−57)
Water benefit	59 (2)	−13 (−0.4)
CO_2	6865 (208)	−1402 (−42)
SO_2	3 (0.1)	−1 (−0.03)
NO_x	7 (0.2)	−2 (−0.1)
PM2.5	123 (4)	−27 (−1)
Bird mortality	+3 (0.1)	−1(−0.03)
Total monetary value	3095 (94)	−3325 (−101)
Employment value [a]	−180 (−5)	+328 (10)

Numbers in parentheses are annual values. [a] Employment monetary values are based on salary of 46,500 USD for construction and 66,000 USD for O&M jobs [36], calculated based on the employment count (see Section 4.2) of −573 (−17 annual) jobs and 3663 (111 annual) jobs for the 100% RPS and 10% RPS scenarios, respectively.

5. Conclusions and Policy Implications

Legislators across the globe are supporting policies that move toward electricity generation from renewable resources. To this end, some jurisdictions in the U.S. have enacted regulations, such as the RPS. These provide a mechanism that can result in not only GHG emission reduction but also water preservation. This is especially prudent in geographic locations with limited water resources. Moreover, RPS can support jobs, although the primary policy target of an RPS is not focused squarely on job creation.

This study provided a roadmap of how to quantify the economic and environmental impacts of three scenarios, in which not only the RPS level varies but also the energy sector dynamics, technological cost, and price of energy. Specifically, we modelled New Mexico's newly enacted RPS policy, where it increases from the status quo of 20% by 2020 to 100% by 2050. We also studied a scenario where RPS decreases to 10% by 2050. In so doing, we combined results from input–output (JEDI and IMPLAN) analyses, econometrics (Stata), and GIS (ArcGIS), and we created a unique SD model that enabled us to assess regional economic and environmental impacts of different scenarios. Our contribution to the current body of literature is twofold: not only did we assess different RPS scenarios by considering the underlying dynamics within the energy sector, but we also assessed these impacts at a lower granular level (i.e., county level).

Under the status quo scenario, the estimates in our model accounted for 152 thousand cumulative full-time equivalent jobs, 24 billion USD in economic output, 3648 million USD in air quality cost, 36 billion USD in climatic cost, 527 million USD worth of water use, 5 million avian mortality, and 409–924 premature mortality. Compared with this status quo scenario, our analysis suggests that the RE intensive scenario (100% RPS) leads to less cumulative employment and economic output, but much higher social benefits compared to the 20% RPS scenario, i.e., 500–15,000 fewer cumulative jobs, 3–4 billion USD less in cumulative economic output, 132 million USD less in air quality cost, 7 billion USD less in climatic cost, 58 million USD less in value of water use, 441–485 thousands less in avian mortality, and 23–53 less in premature mortality. The 10% RPS scenario leads to approximately 4000 more jobs, 2 billion USD less in cumulative economic output, 29 million USD more in air quality cost, 1 billion USD more in climatic cost, 13 million USD more in value of water use, 100 thousand more in avian mortalities, and 5–11 more in premature mortality than the 20% RPS scenario. Considering the environmental impacts, our analysis finds that the Senate Bill RPS scenario (100% RPS) is the best scenario, followed by the status quo scenario, and the 10% RPS scenario is the worst case.

Higher levels of RPS policy aligns with support from New Mexicans. In separate work by the co-authors [41,42], we estimated that a sample of New Mexicans are willing to pay 5.4 USD per year on top of their annual electricity bill for each 1% increase in the current level of RPS (20%). To achieve a 100% RPS by 2050, we extrapolate that, all else equal, New Mexicans are willing to pay 58, 180, 373, 581, 803, and 1144 million USD (2017$) in 2020, 2025, 2030, 2035, 2040, and 2050, respectively. Note that the wide range of willingness to pay is due to the way the bill requirements of achieving 80% RPS by 2040 were designed. Under this bill, electric utility companies were required to increase current RPS level to 25% by 2020, 35% by 2025, 50% by 2030, 65% by 2035, and 80% by 2040. The higher the percentage, the higher residents are willing to pay.

Although scenarios with a lower level of RPS might result in supporting a higher number in employment (in the fossil fuel sector), these scenarios lead to much higher social cost of GHG and ambient pollution (i.e., premature mortality and morbidity) and water usage. This suggests that coming up with an overarching policy that benefits both the environment and economy is not an easy task. Policymakers seeking to promote energy policies may need to consider not only the economic benefit associated with energy development but also social welfare. In other words, RPS policies are more desirable when internalizing external costs and hence correcting for market failure [21,43,44].

Further, the most decisive conclusion that can be drawn from job comparison across different scenarios is that the higher the RE development level, the more disperse and rural the employment impact. On the contrary, the higher the level of fossil fuel deployment, the less diverse and rural the job impact. San Juan County among all is expected to experience a net negative (loss) in O&M jobs, i.e., a loss of 780 jobs from coal-fired power plant retirements after 2037 and depending on the scenario, a gain of an annual average of 84 (100% RPS) to 601 (10% RPS) jobs. Concurrently, the state is estimated to experience nearly 686 billion USD (100% RPS) in social benefits, particularly from the coal power plants retirement. The disparity in job and economic output distribution across counties and energy sources suggests that counties with varying energy potential and population density may experience variation in impacts. In other words, some counties are likely to be net gainers while others may suffer.

The results of this study are broadly consistent with that in the literature [20,26,29,45–49]. We do recognize that the majority of these studies had explicit research questions only on wind energy. For example, some studies sought to measure the actual economic impact of a particular wind installation at county level (e.g., [48]), while others estimated a wind vision for the U.S. (e.g., [26,49]) or the environmental and economic impact of RPS policies nationwide for solely one year (i.e., [20]). Similar to Barbose et al. [20], Millstein et al. [29], and Wiser et al. [21], our model suggests that RPS policies have the potential to yield billions of dollars in climatic and air-quality benefits as well as economic benefits. Similar to preceding studies, we found that increasing RPS does not result in stimulating the economy of a state [3,4], but it does impact the environment positively [29,45,50]. Our contribution to the literature is that we demonstrated that increasing RPS does stimulate the economy of the state at the more granular levels (especially rural counties).

The tools and theories integrated for the analysis in this research are broadly transferable across a wide range of topics and/or regions. For example, a similar approach can be taken to evaluate RPS policies in each one of the other 28 states with such regulations. Our model can be modified and used for states with existing 100% RPS policies (Hawaii, California, Washington, Maine, New York, and Virginia), and those with promises for 100% clean electricity (Colorado, Connecticut, Massachusetts, Illinois, Oregon, New Jersey, Nevada, Wisconsin, and Puerto Rico). Additionally, our state-of-the-art modeling and set of methods are applicable to other topics, such as the impact of decarbonization through a battery of smart grid (e.g., smart meter), transportation (e.g., electric vehicle), and energy-efficient buildings; 100% RE for all sectors (i.e., electricity, heating/cooling, transportation, and industry); oil and natural gas extraction; and the agriculture sector on regional economies. Another expansion of this analysis could include developing nations, as well as other developed countries with similar regulatory mandates. One potential limitation of this work is that our model does not calculate electricity rates for each scenario and takes rates as independent. More expensive scenarios could potentially result in higher electricity rates, which can impact economic activity. This is also important as it has the potential to impact customers' perspective and willingness to pay towards higher level of RE diffusion. Another caveat is that we assume that employment impacts are fully provided (100%) by local residents, which is not typically the case in real-world settings; although the model is capable of varying this assumption, we chose not to include this here for the purpose of brevity. Future research should account for data uncertainty and present results as confidence intervals rather than precise values. This can be done by using Monte-Carlo simulations. This study's results provided improved information for state policymakers seeking to alter RPS policies and can also be extrapolated to states with similar energy policies.

Supplementary Materials: The following will be available online at www.jamalmamkhezri.weebly.com/research.html.

Author Contributions: J.M.: Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, resources, software, validation, writing—original draft preparation; L.A.M.: methodology, software, validation, formal analysis, writing—review and editing; J.M.C.: conceptualization, supervision, resources, funding acquisition, writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially funded by the U.S. National Science Foundation awards #IIA-1301346 and OIA-1757207. Jamal Mamkhezri acknowledges support received from the University of New Mexico Center for Regional Studies.

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Not Applicable.

Data Availability Statement: Publicly available datasets were used in this study. Readers are directed to Table S2 for an overview of the key variables' data sources.

Acknowledgments: We thank the late Ronald Cummings, Jennifer Thacher, and Robert Berrens, as well as participants at the 2019 Southern Economic Association (SEA) conference, the 2020 Association of Environmental and Resource Economists at Western Economic Association International conference, the 2020 Energy Policy Institute workshop, the 2020 System Dynamics Society Economics special interest group, and at the 37th and 38th International Conference of the System Dynamics Society for on an earlier version of this paper. We also thank the four anonymous reviewers for their insightful comments. Any errors are, of course, our own.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Abbreviations

Abbreviation	Definition
AEO	Annual Energy Outlook
eGRID	Emissions and Generation Resource Integrated Database
EIA	Energy Information Administration
EPA	Environmental Protection Agency
GHG	Greenhouse-gas
IMPLAN	Impact Analysis for Planning
JEDI	Jobs and Economic Development Impact
MWh	Megawatt-hour
NGp	Peaker Natural Gas
NGb	Baseload Natural Gas
NREL	National Renewable Energy Laboratory
O&M	Operating and maintenance
PV	Utility-scale photovoltaic solar
RE	Renewable energy
RPS	Renewable portfolio standards
RPV	Residential photovoltaic solar
SD	System dynamics

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