100% Clean Renewable Electricity for New Mexico

Sept 19, 2017
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“Planning for a 100% Renewable New Mexico”
Coalition for Clean Affordable Energy
Conference on Sept 19, 2017
Hilton Santa Fe Historic Plaza
Clean Renewable Energy Means Economic Growth for New Mexico

- New Mexico needs to **revive our economy**, help preserve a **livable climate** and make the state a **healthier** place to live.

  - Current RPS maxes at 20% by 2020. Extend to 100%.

- The electricity RPS has **NO IMPACT on oil** jobs or oil revenue, since **oil is not used** in NM to generate electricity. <7% NM nat. gas for electricity.
Why

100% Clean Renewable Energy?
86% Support More Clean Energy

• **HUGE** majorities support expanding Solar and Wind energy, by 7:1
  • Bipartisan support includes 75% of Trump voters

• And strong majorities oppose expanding fossil fuel and nuclear energy.


June 2016
Warming is Happening Now

2016 – The warmest year on record, by far

- [https://www.sciencedaily.com/releases/2017/01/170118112554.htm/](https://www.sciencedaily.com/releases/2017/01/170118112554.htm/)

http://data.giss.nasa.gov/gistemp/graphs/
CO2 Levels: Higher Now Than Any Time in Human History

CO2 is a heat-trapping greenhouse gas

All of human history. Until now.

https://www.ncdc.noaa.gov/indicators/
http://climate.nasa.gov/key_indicators
https://scripps.ucsd.edu/programs/keelingcurve/
Our Current Path: 450ppm by ~2035

450ppm CO2 is cited as driving dangerous 2.0°C warming

Dr. Charles Keeling 1928-2005

CO₂ Concentration (ppm)


CO₂ Latest CO₂ reading
May 02, 2017

408.50 ppm

Dr. Hansen’s limit

https://scripps.ucsd.edu/programs/keelingcurve/
Impacts Are Being Felt Now

https://climate.nasa.gov/interactives/climate-time-machine
Superstorm Irma Sept 2017
Climate Disasters Up 3X Since 1980

Number Of World Natural Catastrophes, 1980-2016

Insurance Information Institute

Source: © 2017 Munich Re, Geo Risks Research, NatCatSERVICE.
Insurance Information Institute [http://www.iii.org/fact-statistic/catastrophes-global](http://www.iii.org/fact-statistic/catastrophes-global)
Global Food Shortages, Then Famine

Worst Case Timing

<table>
<thead>
<tr>
<th>Year / °C warming</th>
<th>% Loss in Crop Yields</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020’s / 1°C</td>
<td>-10%</td>
</tr>
<tr>
<td>2040’s / 2°C</td>
<td>-30%</td>
</tr>
<tr>
<td>2050’s / 3°C</td>
<td>-40%</td>
</tr>
<tr>
<td>2060’s / 4°C</td>
<td>-60%</td>
</tr>
</tbody>
</table>

Tyndal says 4°C by 2050


# Future Warming, by Degree

**Worst case, if we don’t rapidly change course**

<table>
<thead>
<tr>
<th>Decade</th>
<th>Warming °C</th>
<th>% Loss in Crop Yields</th>
<th>Commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020’s</td>
<td>+1°C</td>
<td>-10%</td>
<td>2x-4x worse wildfires, drought in SW, coastal flooding</td>
</tr>
<tr>
<td>2030’s</td>
<td>+1-2°C</td>
<td>-20%</td>
<td>Major food shortages (corn, wheat); coral reefs dying; increasing extreme weather. <strong>Miami 1m underwater.</strong></td>
</tr>
<tr>
<td>2040’s</td>
<td>+2°C</td>
<td>-30%</td>
<td>Most summers hotter than 2003 EU heat wave. 30% species risk extinction. Mountain ecosystems dying. 4x-8x worse wildfires. Pervasive drought in subtropics. <strong>Extensive starvation.</strong></td>
</tr>
<tr>
<td>2050’s</td>
<td>+3°C</td>
<td>-40%</td>
<td>40%-70% species extinction. Amazon &amp; boreal forest dieback. Decline in all cereal crop yields in Africa. Release of CO2 and methane from permafrost, tripling from 1.5C. <strong>Wars. Mass starvation.</strong></td>
</tr>
<tr>
<td>2060’s</td>
<td>+4°C</td>
<td>-60%</td>
<td><strong>Game over.</strong> Ecosystem supports &lt;1 billion people. Climate likely past tipping points for further warming.</td>
</tr>
</tbody>
</table>

*Read more in New York Magazine, July 9, 2017. [The Uninhabitable Earth]*

From: National Academy of Sciences, 2011, the US National Climate Assessment, 2014 & UK Met office


What Must We Do Instead?

Urgently mobilize to convert our energy system from fossil fuels to carbon-free renewables.

Priority 1: Renewable Electricity
Priority 2: Renewable Transport
CO2 Emissions in the US

Figure 1: 2013 U.S. CO2 Emissions

- CO2 emissions from fossil fuels must cease worldwide by 2050 if we hope to avoid catastrophic global warming of 1.5-2.0°C.
- The #1 source of CO2 emissions is burning coal and natural gas to generate electricity.

Source: US Energy Information Administration

http://www.c2es.org/federal/executive/epa/ghg-standards-for-new-power-plants
NM Electricity Generation by Source

- 63% coal, 28% natural gas.
- 0.20% from petroleum

PNM also imports nuclear electricity generated in Az.
Amend the NM ‘Renewable Energy Act’ for 100% RPS

- Current RPS requirements peak & hold in 2020 at 20%
- The proposed schedule keeps the RPS increasing to reach 50% by 2030, towards 100% by 2050.
- Then 2% per year 2040 to 2050
- **SB312** was a 2017 bill for 80% by 2040. It passed the Senate Conservation comm.

<table>
<thead>
<tr>
<th>Year</th>
<th>RPS</th>
</tr>
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<tr>
<td>2020</td>
<td>20%</td>
</tr>
<tr>
<td>2025</td>
<td>35%</td>
</tr>
<tr>
<td><strong>2030</strong></td>
<td>50%</td>
</tr>
<tr>
<td>2035</td>
<td>65%</td>
</tr>
<tr>
<td><strong>2040</strong></td>
<td>80%</td>
</tr>
</tbody>
</table>

3% per year

Current law

Ten States Have Better RPS Policy Than NM

10 states have RPS significantly (>5%) above NM’s 20%, ie HI, CA, OR, CO, MN, NY, ME, VT, RI, CT. Plus USVI

A 100% Renewable Energy Mix for NM:

- **50% Wind**
- **40% Solar** (39.6%)
  - 30.3% utility scale
  - 5.5% residential
  - 3.8% comm / govt
- **10% Geothermal**
- Recommended by Stanford University based each state’s native resources.

Energy mix for NM as recommended by published analysis for all US States, from Stanford University. [www.thesolutionsproject.org](http://www.thesolutionsproject.org).
Summary: What to Build to Reach 100% RPS

For 30 years, (2021-2050), NM would install on avg 200 MW/year:

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- This will supply the 23M MWh consumed within our state. Growth=0

2016 electricity revenue was $1.9B for Utilities + Co-ops. $178M is 9%
Why it will work

- Old power plants **must be replaced** as they age. NM’s aging coal plants average **40 yrs old**. The RPS helps NM be proactive, replacing them with clean renewables at **zero fuel cost**.
- Utilities will do the major investment, plus cities, businesses & homeowners. Renters too, if we pass ‘**community solar**’.
- Electricity **costs will ultimately drop** as we convert to zero-fuel electricity.
- Known & **predictable fixed costs** for electricity reduce investment risk for companies moving into NM. (no fuel = no fuel price increases)
- We leverage NM’s **natural advantages**: available **land, wind, sun, geothermal**, and an underemployed **workforce**.
NM Fuel Savings Pay for Investment

- New Mexico spends $482M/year on coal & gas fuel to generate electricity.
- For every 10% we add to CR Energy, we save $48M/year on fuel.
- **Fuel savings pay for all investment after 2030.** Until then, net CRE investments average $127M/yr. And savings increase every year.
- So after we reach 50% by 2030, fuel savings pay for all new RE investment.

*WSG= wind, solar & geothermal*
The Benefits It Will Bring

- **Jobs of the future** in a growing economic sector, replacing jobs of the past.
- Plus:
  - Cleaner air & water
  - Less water consumption
  - Healthier New Mexicans (less emphysema, asthma, etc), with fewer deaths and lower health care spending. Medicaid is ~31% of the NM state budget
  - Helps stop climate change
New Mexico’s Great Wind & Solar

#12 in Wind

1,112 MW

#2 in Solar

406 MW

http://www.seia.org/map/majorprojectsmap.php

8m/s = 18 mph
Per the USGS:
Geothermal power plants are currently generating 2,500MW in six states: Alaska, California, Hawaii, Idaho, Nevada, and Utah. The electric power generation potential from identified geothermal systems is 9,057 Megawatts-electric (MWe), over 13 states.

The mean estimated power production potential from undiscovered geothermal resources is 30,033 MWe.

Additionally, another estimated 517,800 MWe could be generated through implementation of technology for creating geothermal reservoirs in regions characterized by high temperature, but low permeability, rock formations.
US Solar Jobs Are Booming

Nearly 209,000 Americans work in solar > double the number in 2010, at more than 9,000 companies in every U.S. state. By 2020, that number will double to more than 420,000 workers.

http://www.seia.org/research-resources/solar-industry-data
Wind & Solar Costs Dropping

“On an LCOE* basis, onshore wind is the cheapest form of electricity; utility-scale thin-film solar PV is the second cheapest.” – Lazard Investments & Banking

*LCOE = levelized cost of energy

Source: Lazard

https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-100/
63% of **New US Power from Solar & Wind**

- The EIA reported the US added 26 GW of electric generating capacity in 2016. **63% from Solar + Wind.**
  - 9.5GW Solar + 6.8GW wind
- 2016 will be the first year in which utility-scale solar additions exceed additions from any other single energy source.

The Solar Foundation reported that in 2016, New Mexico has:

- **76** Solar companies
- **2,929** solar industry jobs, a growth rate of **54%** in one year.
- Installers median wage of **$20** per hr*

* 2015 data

http://www.thesolarfoundation.org/solar-jobs-census/

By Extending RPS, NM Should Add >1000 Solar Jobs

- In 2015 New Mexico had 1,899 solar workers, supporting that year’s installation of **56 MW/yr**.
  - That’s 34 workers per MW/yr.
- The **new RPS should double that install rate to 116 MW/year**. So the NM solar workforce must double from 2015, to about 3,900.
- This **adds 1,000 jobs** just for solar. We’ll need these workers by 2021.
  - Then **add even more jobs** by installing more solar for export. And more still, with a solar **Gigafactory**.

NM is the closest windy state to California

CA needs more wind but will have to import it.
New Wind Projects 2016-2017
And New Transmission

- **Big wind new projects:**
  - El Cabo 298 MW
  - Broadview 297 MW
  - Grady 200 MW

- **Three major export transmission lines:**
  - Centennial West Clean Line
  - SunZia
  - SouthLine

US Wind Turbine Manufacturing

But New Mexico is **one of only three states** with **no** wind turbine manufacturing.

*Building: towers, blades, generators, gearboxes, hubs, nacelles, etc*

Seeking more renewables, Kit Carson Co-op exits relationship with Tri-State G&T

June 2016  “30% Solar by 2022”

- Kit Carson Electric Cooperative in New Mexico has exited its agreement with the Tri-State Generation and Transmission Association and is entering a long-term deal with Guzman Renewable Energy Partners of Florida.
- Kit Carson Electric says the switch will save its 30,000 customers $50 million over the term of the 10-year agreement.
- 30 MW of solar arrays to be built from May 2017-2022, when locally generated solar energy will supply around 30 percent of Kit Carson’s total electricity demand, and 100 percent of its needs during daylight hours on sunny days. Solar production will exceed electricity demand during peak hours. Land is also being set aside for battery storage.

[http://www.kitcarson.com/content/kcec-solar-initiative](http://www.kitcarson.com/content/kcec-solar-initiative)
Summary

- The clean energy sector is booming worldwide as costs have dropped to make solar and wind the **cheapest sources of new energy**.
- NM has **world-class** Solar, Wind & Geothermal resources ready to develop – but to win, **we must strengthen NM’s RPS policy**.
- Let’s spark a NM investment boom in clean energy, bringing **thousands of good jobs** – by committing our state to clean renewable electricity: 50% by 2030 & 100% by 2050.
  - And remember - electricity RPS has **NO IMPACT on oil** jobs or oil revenue. Oil is **not used** in NM to generate electricity; <7% uses nat. gas.
350 New Mexico is the New Mexico chapter of 350.org. We’re an international grassroots organization building a global movement to fight climate change.

Our work: We seek an urgent and ‘just transition’ of New Mexico’s energy economy from fossil fuels to 100% clean renewable energy, in time to prevent global warming of 1.5-2.0°C. We work to:

- Convert electricity generation to 100% renewable energy before 2050, with 50% by 2030
- Keep 80% of fossil fuels in the ground
- Educate the public on the urgency of acting on climate, with plans to do so
- Promote sustainable practices and work in coalition with like-minded groups

Find 350NM:
On Facebook: 350 New Mexico
On the Web: www.350NM.org
On Twitter: @350NM
On Instagram: @350NewMexico
The national site: www.350.org
Cats Kill 10,000x More Birds Than Wind

- **Study**: fossil fuel power plants kill 35 times more birds per GWh than wind turbines

Source: National Audubon Society

Wind and Solar are Complementary

Fig. 1 presents an example of the combined use of wind (variable), solar rooftop PV (variable), concentrated solar power (CSP, or solar thermal) with storage (variable), geothermal (base-load), and hydroelectric (dispatchable) to match hourly power demand plus transmission and distribution losses on two days in California in 2005.

99.8% of delivered energy during these days could be produced from WWS technology.

Fig. 1. Least-cost dispatch on 2 days in 2005 in which 100% of California’s electricity demand plus transmission/distribution losses are met with load-matching renewables. Notes: System capacities: 73.5 GW of wind; 26.4 GW of CSP; 28.2 GW of photovoltaics; 4.8 GW of geothermal; 20.8 GW of hydroelectric; and 24.8 GW of natural gas. Transmission and distribution losses are 7% of the demand. The least-cost optimization accounts for the day-ahead forecast of hourly resources, carbon emissions, wind curtailment, and thermal storage at CSP facilities. The hydroelectric supply is based on historical reservoir discharge data and currently imported generation from the Pacific Northwest. The wind and solar supplies were obtained by aggregating hourly wind and solar power at several sites in California estimated from wind speed and solar irradiance data for those hours applied to a specific turbine power curve, a specific concentrated solar plant configuration (parabolic trough collectors on single-axis trackers), and specific rooftop PV characteristics. The geothermal supply was limited by California’s developable resources. From Hart and Jacobson (under review).

"99.8% of delivered energy during these days could be produced from WWS technology.”

**RPS Benefits**

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**2016 Report by US Dep of Energy***:

- **Health**: In the ‘High RE’ case, the health benefits of these reduced emissions are estimated for the US to be **$558 billion** on a present-value basis (or 5.0¢/kWh-RE).

- **Water use**: Cumulatively (2015-2050), each MWh of RE serving existing RPS represents average **savings of 3,400 gallons of water** withdrawal and 290 gallons of consumption, **down 18%**.
  - NM uses 23M-MWh of electricity

- Plus jobs increase and fuel use drops.

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*https://emp.lbl.gov/sites/default/files/rps_fact_sheet_final.pdf*
The Abq City Council approved 25% Solar electricity for city buildings ‘by 2025’. After analysis, vote was 9-0. O-17-42

- Financed w $52M in CREB low interest bonds
- Funding for first 50% of projects (12 for $25M & 998KW) was approved June 2017, now in RFP. All projects cash positive from year 1. R-17-207
- Saves the city money. 6 yr payback
- Project completion expected within two years

Sen. Heinrich’s office: city toolkit on-line Q3’17
- Contact Katie Richardson
New Mexico Health Savings

- 353 fewer deaths per year from air pollution
- $2.4B /year saved in avoided health costs

Avoided Mortality and Illness Costs

Avoided health costs per year:

- $2.4B
- 2% of state GDP

Air pollution deaths avoided every year: 353

Plan pays for itself in as little as 2 years from air pollution and climate cost savings alone

http://thesolutionsproject.org/infographic/#nm
Webinar Summary

- **Part 1** is the presentation used at the Sept 1, 2017 interim committee on Economic and Rural Development, “Moving New Mexico towards 100% clean renewable energy”

- **Part 2** is a deep dive into the model and calculations used to generate the conclusions, charts and tables in part 1. How much to build, what does it cost, how much do we save in fuel, etc.
Webinar Pt 2: 100% CRE Model

Sept 7, 2017 Webinar Recording: https://fccdl.in/xpNqUSXzA
Webinar: Explaining the Models

● How does the NM **100% CRE model** calculate:

1. **How much to build** of nameplate capacity for solar, wind & geothermal generation?
2. How much it will **cost**?
3. How much is the **fuel savings**?
4. What % of NM **natural gas production** goes to electricity?
### Summary:

**What to Build to Reach 100% RPS**

For 30 years, (2021-2050), NM would **install** on **avg 200 MW/year**:

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*This will supply the 23M MWh consumed within our state*

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**2016 electricity revenue was $1.9B for Utilities + Co-ops. $178M is 9%**

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**Scope 2021 through 80% by 2040 (ie SB312)**
- Wind - install 116 MW/yr and spend $118 M/yr
- Solar - install 98MW/yr and spend $69M/yr
- GeoT- install 13 MW/yr and spend $31M/yr

http://thesolutionsproject.org/
Calculating the 100% RPS Build

To generate just the electricity consumed within New Mexico

How much CRE* electric generation capacity needs to be built from 2021-2050? For that we need:

- Load growth assumption 2021-2050 (=flat)
- Electricity sales in NM (=23M MWh per EIA)
- Added capacity to cover peaking and storage (+11.59% Jacobson)
- Capacity factors by CRE source, for conversion to nameplate
  - Capacity factors = 45% wind, 30% solar, 90% geothermal
- Mix of CRE sources: (50% wind, 40% solar, 10% geothermal)
- How much CRE will already be built by 2020 (=20%)

<table>
<thead>
<tr>
<th>NM CRE Power Component</th>
<th>MWh</th>
<th>MW</th>
<th>MW/CF</th>
<th>Cap’y Factr</th>
</tr>
</thead>
<tbody>
<tr>
<td>NM 2014 Avg Pwr +11.59%</td>
<td>25,739,338</td>
<td>2936</td>
<td>3263</td>
<td>45%</td>
</tr>
<tr>
<td>50% Wind</td>
<td>-</td>
<td>1468</td>
<td>326</td>
<td>45%</td>
</tr>
<tr>
<td>40% Solar</td>
<td>-</td>
<td>1175</td>
<td>3861</td>
<td>30%</td>
</tr>
<tr>
<td>10% Geothermal</td>
<td>-</td>
<td>294</td>
<td>326</td>
<td>90%</td>
</tr>
<tr>
<td>Total nameplate gen’n</td>
<td></td>
<td></td>
<td>7450</td>
<td></td>
</tr>
</tbody>
</table>

*CRE = clean renewable energy
EIA 826: Electricity Sales

Report: EIA-826  Electricity Sales by State and Utility (renamed as 861M)

Form EIA-861M (formerly EIA-826) detailed data

Monthly Release Date: June 28, 2017 for April 2017 data

Estimated Small Scale Solar Photovoltaic Net Generation and Capacity for April 2017 re-released: Correction/revision notices

Find detailed data at right for: net metering | small scale PV estimate | sales and revenue | advanced metering | green pricing

The Form EIA-861M "Monthly Electric Power Industry Report" collects sales of electricity and associated revenue, each month, from a statistically chosen sample of electric utilities in the United States. The respondents to the Form EIA-861M are chosen from the Form EIA-861, "Annual Electric Power Industry Report." Methodology is based on the "Annual Electric Utility Report." Methodology is based on the "Model-Based Sampling, Inference and Imputation."
Electricity Consumption in NM

Per the US EIA spreadsheet EIA-826, NM electricity sales in 2015 were **23.066 TWh**. Also = **23.066 M MWh**

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<th>Utility</th>
<th>MWh</th>
<th>% of NM</th>
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<tr>
<td>PNM total</td>
<td>8,986,090</td>
<td>39%</td>
</tr>
<tr>
<td>EPE total</td>
<td>1,651,781</td>
<td>7%</td>
</tr>
<tr>
<td>SPS total</td>
<td>5,097,984</td>
<td>22%</td>
</tr>
<tr>
<td>IOU utilities ttl</td>
<td>15,735,855</td>
<td>68%</td>
</tr>
<tr>
<td>Coop/Muni +Adj</td>
<td>7,322,750</td>
<td>32%</td>
</tr>
<tr>
<td>Solar Bhind mtr</td>
<td>7,385</td>
<td>0.03%</td>
</tr>
<tr>
<td><strong>NM total</strong></td>
<td><strong>23,065,990</strong></td>
<td><strong>100%</strong></td>
</tr>
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A similar statistic is published in the US EIA sector risk profile report.

**NEW MEXICO STATE FACTS**

**State Overview**
- Population: 2.09 million (1% total U.S.)
- Housing Units: 0.91 million (1% total U.S.)
- Business Establishments: 0.04 million (1% total U.S.)

**Annual Energy Consumption**
- Electric Power: 23.2 TWH (1% total U.S.)
- Coal: 14,500 MSTN (2% total U.S.)
- Natural Gas: 1,205 Bcf (5% total U.S.)
- Motor Gasoline: 20,900 Mbarrels (1% total U.S.)
- Distillate Fuel: 14,700 Mbarrels (1% total U.S.)

**Annual Energy Production**
- Electric Power Generation: 36.6 TWH (1% total U.S.)
- Coal: 25 TWH, 68% [4.4 GW total capacity]
- Petroleum: 0 TWH, 0% [0 GW total capacity]
- Natural Gas: 8.8 TWH, 24% [3.8 GW total capacity]
- Nuclear: 0 TWH, 0% [0 GW total capacity]
- Hydro: 0.2 TWH, <1% [0.1 GW total capacity]
- Other Renewable: 2.2 TWH, 6% [0.9 GW total capacity]

- Coal: 22,500 MSTN (2% total U.S.)
- Natural Gas: 1,220 Bcf (5% total U.S.)
- Crude Oil: 85,200 Mbarrels (4% total U.S.)
- Ethanol: 600 Mbarrels (1% total U.S.)


http://www.eia.gov/electricity/state/NewMexico/
Methodology for calculations

A. Use New Mexico data from EIA-826, 2015 for electricity sales by source (=23M MWh) (link)

B. Add 11.59% per Jacobson*, to cover peaking and storage. Total=25.7M MWh

C. Convert MWh to MW avg/year (/8766 hrs/yr) = 2,936 MW

D. Calculate nameplate generation required by RE source, by dividing MW by capacity factors. = 7,450MW

Conclusion: To replace the 2015 electricity sales within New Mexico with all Wind, Solar and Geothermal electricity, including an extra 11.59% to cover peaking and storage, we must build the nameplate capacity to generate 7450 MW from 50% Wind, 40% Solar and 10% Geothermal.

*Jacobson: http://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf
Calculating 100% RPS Costs

- How will the installed price per Watt decline between 2021 and 2050? For that we need:
  - Current “installed costs per Watt” for solar (SEIA), wind (AWEA) & geothermal (US EIA)
  - Historical rates of decline (SEIA and AWEA) and forecasts of future decline (NREL)
Solar PV System Costs Are Dropping 7% per year


From 2009-14, the installed price of PV dropped 6-8% per year. And this when installs were <5 GW/yr.

Competition + massive investment will drive future prices to continue to drop at least this fast.

Why?

Because companies will compete on price for the $108B/year we’ll spend to install 200-300 GW/year.

Note: The 7%/yr model is too conservative. Actual installed system prices dropped by 20% in both 2015 and 2016.

Prices dropped 20% in 2015, to $2.15, =2017 forecast
http://www.seia.org/research-resources/solar-market-insight-2015-q3

Another 20% drop in 2016, to $1.57 =2021 forecast
http://www.seia.org/research-resources/solar-market-insight-2015-q3

http://www.seia.org/research-resources/solar-market-insight-report-2016-year-endview
Utility scale PV installed cost dropped to $1.05-1.20/Wdc (fixed & tracking) (per SEIA)

From Q4 2015 to Q4 2016, on average, U.S. PV system pricing fell by nearly 20%
Wind Turbine Costs Also Dropping

- Because:
  - Price competition as the market grows and volumes rise
  - Better designs of generators, blades, electronics, etc.
  - Wind turbines getting taller; lower price per kW.
- Cost reduction study by IEA (May 2012), forecasts a 30% further drop in price by 2030.
- So:

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<thead>
<tr>
<th>Year</th>
<th>2015</th>
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<tr>
<td>$/W</td>
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http://www.evwind.es/2014/03/27/top-10-wind-turbines-suppliers/44405
Geothermal Costs = Flat

- From the US-DOE
  - [https://energy.gov/eere/geothermal/geothermal-faqs#cost_to_develop_geothermal_power_plant](https://energy.gov/eere/geothermal/geothermal-faqs#cost_to_develop_geothermal_power_plant)

  - “The initial cost for the field and power plant is around $2500 per installed kW in the U.S.”
  - (= $2.5/Watt)

- Costs assumed to be flat 2021-2050, probably conservative.
Roll This All Into Spreadsheets

- For solar, for wind and for geothermal, create spreadsheets for the years 2021-2050 that:
  - Build the total nameplate generation required by 2050, with 50% by 2030
  - Use installed $/Watt cost forecasts with reasonable declines based on history and other models, to arrive at total investment
### NM Solar for 100% RPS

**$51M** per year to install an average 103MW per year.

Assume “$/Watt installed” continues to drop at 7%/yr.

If cost reduction stops after 2030, avg costs rise to **$68M/yr**

#### Clean Renewable Energy

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<th>Energy Type</th>
<th># MW/yr</th>
<th>Cost/yr</th>
<th>Power / unit</th>
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#### Financials 2014-

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<th>Cost to replace 30-yr old panels</th>
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</table>

#### Notes

- **NM CRE Power Component**
  - MWh: 25,739,338
  - MW: 2936
  - MW/CF: 7450
  - Cap’y Factr: 3263

- **Yearly Total**
  - Solar: 3,861 MW
  - Solar w/100% CRE, all CSP is PV (May 2015.1)
  - 3,816 MW

- **Assume “$/Watt installed” average 103MW per year.**

- **Total nameplate gen’n**

- **Scenario for NM to achieve 50%, then 100% RPS by 2030 then 2050**

- **New Mexico only**
  - #GW PV: 0.12
  - #MW/yr: 116
  - #MW: 888
  - #yr: 7
  - Net Installs: 102
  - CUM Installs: 109
  - 14
  - 16
  - 18
  - 40
  - 53
  - Avg per yr 7-2050
  - $/Watt installed: 2.51 (7%)/yr
NM Wind for 100% RPS

Average wind investment is $101M per year to install an average 87MW per year.

Avg cost reduction assumed at 1%/year, front-end weighted. (Aug 2017 NREL report says that’s conservative and costs could drop 5%/yr through 2030)

<table>
<thead>
<tr>
<th>Clean Renewable Energy</th>
<th># MW/yr</th>
<th>Cost/yr</th>
<th>Power/unit</th>
</tr>
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<tbody>
<tr>
<td>Solar Panels</td>
<td>103</td>
<td>$51 M</td>
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<tr>
<td>Yearly Total:</td>
<td>200</td>
<td>$178 M</td>
<td></td>
</tr>
</tbody>
</table>

NREL: costs to drop 50% by 2030 [https://www.ecowatch.com/wind-power-costs-2476701894.html]
### NM Geothermal for 100% RPS

Average geothermal investment of **$26M** per year to build an average of 10MW per year

GeoT costs are assumed flat over time at the 2015 US-EIA value of $2.50/Watt installed

<table>
<thead>
<tr>
<th>Clean Renewable Energy</th>
<th># MW/yr</th>
<th>Cost/yr</th>
<th>Power / unit</th>
</tr>
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<th>Yearly GeoT Installs #MW/yr</th>
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<th>Installed GeoT cost/yr ($M)</th>
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<th>Cost to replace 35-yr old GeoT?</th>
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<td>2040</td>
<td>10</td>
<td>261</td>
<td>24</td>
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<tr>
<td>27%</td>
<td>2041</td>
<td>7</td>
<td>268</td>
<td>16</td>
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<td>$2.50</td>
<td>0.0%</td>
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<tr>
<td>28%</td>
<td>2042</td>
<td>7</td>
<td>274</td>
<td>16</td>
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<tr>
<td>29%</td>
<td>2043</td>
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<td>281</td>
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<tr>
<td>30%</td>
<td>2044</td>
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<td>287</td>
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<tr>
<td>31%</td>
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<td>294</td>
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<tr>
<td>32%</td>
<td>2046</td>
<td>7</td>
<td>300</td>
<td>16</td>
<td>$2.50</td>
<td>$2.50</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td>33%</td>
<td>2047</td>
<td>7</td>
<td>307</td>
<td>16</td>
<td>$2.50</td>
<td>$2.50</td>
<td>0.0%</td>
<td></td>
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<tr>
<td>34%</td>
<td>2048</td>
<td>7</td>
<td>313</td>
<td>16</td>
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<td>$2.50</td>
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<tr>
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<td>2049</td>
<td>7</td>
<td>320</td>
<td>16</td>
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<tr>
<td>36%</td>
<td>2050</td>
<td>7</td>
<td>326</td>
<td>16</td>
<td>$2.50</td>
<td>$2.50</td>
<td>0.0%</td>
<td></td>
</tr>
</tbody>
</table>

**Avg** | 10 | $816 | 0.0% | $26 **avg per yr 2021-2050** | 316 GeoTh $/Watt | $2.50 / Watt | Per the US

*Link: [https://energy.gov/eere/geothermal/geothermal-faqs#cost_to_develop_geothermal_power_plant](https://energy.gov/eere/geothermal/geothermal-faqs#cost_to_develop_geothermal_power_plant)*
Calculating NM Fuel Costs

Information needed for these calculations:

- How much does NM spend on fossil fuel
- What is NM % generation by fuel source (coal, gas, nuclear, CRE)
- Costs per BTU for coal and nat gas
- 63% coal, 28% gas.
- PNM also imports nuclear.
How Much Is Spent on Coal & Gas for Electricity Generation in NM

**Question:** What did NM spend on fuel for in-state electricity sales in 2015?

**Methodology**
1. Total sales were 23.1M MWh per EIA-826. [link](http://www.eia.gov/electricity/state/NewMexico/)
2. Subtract the sales from imported nuclear power from PNM's PVNGS. =268MW, per DVW. Convert MW to MWh and use 90% CF to get 2.1M MWh from imported nuclear energy.
3. So sales w/o PVNGS were 23.1-2.1= 21M MWh
4. Allocate that to 63% from coal and 28% from gas, using the %s from generation. The rest is from other sources, mostly Wind& Solar.
5. Use EIA values for cost of power plant fuel, ~$0.022/kWh Coal, $.033/kWh NatGas, and the % of power from coal and gas from item 4 above.
6. Calc spending on coal + nat. gas fuel = $482M

<table>
<thead>
<tr>
<th>NM Sales 2015</th>
<th>MWh</th>
<th>Percent of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>NM total MWh</td>
<td>23,065,990</td>
<td>100%</td>
</tr>
<tr>
<td>PNM total (EIA-826)</td>
<td>8,986,090</td>
<td>39%</td>
</tr>
<tr>
<td>Adjustments</td>
<td>4,422,400</td>
<td>19%</td>
</tr>
<tr>
<td>IOU utilities</td>
<td>15,735,855</td>
<td>68%</td>
</tr>
<tr>
<td>Coop/Muni +Adjts</td>
<td>7,322,750</td>
<td>32%</td>
</tr>
<tr>
<td>Solar Bhind mtr</td>
<td>7,385</td>
<td>0%</td>
</tr>
<tr>
<td>NM total</td>
<td>23,065,990</td>
<td></td>
</tr>
</tbody>
</table>

Adjustments: 4,422,400

| NM MWh w/o PVNGS | 20,951,631 |

Electricity generation is per EIA. But includes exports [http://www.eia.gov/electricity/state/NewMexico/].
Fuel Savings

Fuel spending has been $482M/yr (in 2014)

Fuel savings per year are relative to 2014. They grow as RPS % increases.

Fuel savings reach $211/yr in 2030 and more than pay for all future investments.
**NM Fuel Savings Pay for Investment**

- Net CRE costs avg $127M thru 2030.
- But consider: the SJGS maintenance budget in 2013 was $40M. Plus $10/yr for capex. Plus costs of pollution controls, etc.

**New Mexico spends $482M/year on coal & gas fuel to generate electricity**

- For every 10% we add to CR Energy, we’ll save another $48M/year on fuel.

- **Fuel savings pay for all investment after 2030.** Until then, net CRE investments average $127M/yr. And savings increase every year.

- So after we reach 50% by 2030, fuel savings pay for all new RE investment.

*WSG= wind, solar & geothermal*
7% of NM Gas Used for Electricity

This 7% is for NM electricity generation, and some NM generated power is exported. Thus less than 7% of produced gas is used to generate just the electricity consumed within NM.

7% of NM natural gas production was consumed in-state to **generate** electricity in 2014 (per EIA)

This would be the approx impact on NM gas revenue and jobs of converting to 100% CR electricity

All data is from 2014 per the US Energy Information Agency (US EIA)

<table>
<thead>
<tr>
<th>Calcs</th>
<th>Value</th>
<th>Comment</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/1000</td>
<td>10,408</td>
<td>Btu/kWh, Power Plant Heat rate of Natural gas (US EIA)</td>
<td>Btu/kWh</td>
</tr>
<tr>
<td>A</td>
<td>10,408,000</td>
<td>Btu/MWh, Power Plant Heat rate of Natural gas</td>
<td>calc</td>
</tr>
<tr>
<td>B</td>
<td>8,975,656</td>
<td>MWh of electricity generated from natural gas in NM</td>
<td>MWh NG</td>
</tr>
<tr>
<td>C</td>
<td>1,355,000,000,000,000</td>
<td>Btu of natural gas produced in NM (1,355T Btu)</td>
<td>NG Prod</td>
</tr>
<tr>
<td>B*A</td>
<td>93,418,627,648,000</td>
<td>93T Btu of Natural Gas used to generate electricity in 2014</td>
<td>calc</td>
</tr>
<tr>
<td>(B*A)/C</td>
<td>6.89%</td>
<td>7% of NM NG production used in-state to generate electricity</td>
<td>calc</td>
</tr>
</tbody>
</table>

[http://www.eia.gov/electricity/state/NewMexico/](http://www.eia.gov/electricity/state/NewMexico/)

http://www.eia.gov/electricity/state/NewMexico/
What About Storage and Transmission?

- The 100% CRE model forecasts only the costs for generation. Does not include storage and transmission.
- We’ll need a national smart grid
  - Cost of a USA Smart Grid was estimated by UMich at $476B, or $23.8B/yr for 20 years. Includes storage. Benefits = $2T
- Transmission
  - South Australia’s Transgrid says transition to 100% is urgent, feasible. New transmission adds 4% to cost.

Cost of a US Smart Grid - $24B/yr

- Cost of a US Smart Grid was estimated at $476B, or $23.8 B for 20 years
- Benefits? $2T

HVDC transmission lines help greatly to minimize losses and keep costs down.
### 2016 Revenues by Utility - NM

#### 2016 Retail Electric Revenue for NM Utilities (PRC filings) (w/o Muni's)

<table>
<thead>
<tr>
<th>Notes</th>
<th>Utility</th>
<th>2016 Revenue</th>
<th>%</th>
<th>total kWh</th>
<th>% of kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>PNM</td>
<td>$ 900,584,323</td>
<td>47.5%</td>
<td>8,951,425,000</td>
<td>42.3%</td>
</tr>
<tr>
<td>B</td>
<td>El Paso Electric</td>
<td>$ 178,836,423</td>
<td>9.4%</td>
<td>1,653,465,000</td>
<td>7.8%</td>
</tr>
<tr>
<td>C</td>
<td>Xcel Energy (SPS)</td>
<td>$ 345,726,851</td>
<td>18.2%</td>
<td>5,279,146,000</td>
<td>25.0%</td>
</tr>
</tbody>
</table>

| Subttl Investor Owned Utilities | $ 1,425,147,597 | 75.1%      | 15,884,036,000 | 75.1% |

| Tri-State 1  | Central New Mexico Elec Coop   | $ 32,842,651 | 1.7% | 218,211,587 | 1.0% |
| Tri-State 2  | Continental Divide             | $ 58,960     | 0.003%| 711,743,000 | 3.4% |
| Tri-State 3  | Jemez Mountains                | $ 47,184,047 | 2.5% | 370,891,000 | 1.8% |
| Tri-State 4  | Mora-San Miguel                | $ 11,589,380 | 0.6% | 69,984,149  | 0.3% |
| Tri-State 5  | Otero County                   | $ 31,022,055 | 1.6% | 183,982,000 | 0.9% |
| Tri-State 6  | Sierra                         | $ 8,324,535  | 0.4% | 63,192,850  | 0.3% |
| Tri-State 7  | Springer                       | $ 21,308,523 | 1.1% | 268,550,512 | 1.3% |
| West-Farm 8  | Central Valley                 | $ 61,579,851 | 3.2% | 765,864,795 | 3.6% |
| X-border 9  | Duncan Valley                  | $ 387,053    | 0.020%| 3,668,000   | 0.02% |
| X-border 10 | Kit Carson                     | $ 40,061,319 | 2.1% | 265,801,775 | 1.3% |
| X-border 11 | Navopache                      | $ 1,515,251  | 0.1% | 9,936,000   | 0.05% |
| X-border 12 | Rio Grande                     | $ 32,661,178 | 1.7% | 271,325,000 | 1.3% |
| Tri-State 13 | Socorro                        | $ 24,372,000 | 1.3% | 177,300,000 | 0.8% |
| Tri-State 14 | Columbus                       | $ 13,405,161 | 0.7% | 97,674,000  | 0.5% |
| West-Farm 15 | Farmers                        | $ 34,047,432 | 1.8% | 358,615,000 | 1.7% |
| West-Farm 16 | Lea County                     | $ 56,003,918 | 3.0% | 796,682,000 | 3.8% |
| Tri-State 17 | Northern Rio Arriba            | $ 4,047,330  | 0.2% | 24,345,000  | 0.1% |
| West-Farm 18 | Roosevelt County               | $ 15,183,835 | 0.8% | 149,219,000 | 0.7% |
| Tri-State 19 | Southwestern Elec Coop         | $ 35,910,635 | 1.9% | 451,088,000 | 2.1% |

| Subtotal of 19 Co-ops | $ 471,505,114 | 24.9% | 5,258,073,668 | 24.9% |

| Total of 3 IOU's+19 Co-ops | $ 1,896,652,711 | 100% | 21,142,109,668 | 100.0% |

- **2021 (max) req'd investmt in CRE**: $296,401,944 (15.6% of 2016 retail elect revenue)
- **Avg 30yr req'd investmt in CRE**: $178,836,070 (9.4% of 2016 retail elect revenue)

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**Source:**
PRC web site compliance filings per rule 510, using the New Mexico Jurisdictional Customer Info Form

**Note:**
For 3%/yr RPS