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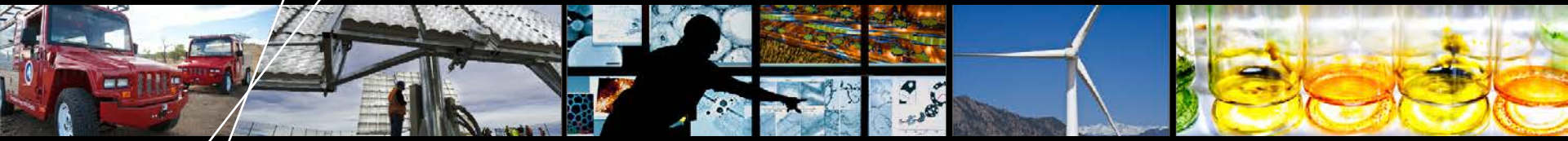
ReEDS Modeling of the President's 2020 U.S. Renewable Electricity Generation Goal



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Model Basis and Context

This analysis was conducted using the NREL ReEDS Model [www.nrel.gov/analysis/ReEDS]. The version of the model used is the NREL Base Model as of October 2013.

***None of the scenarios presented are intended to be forecasts or predictions**; rather, ReEDS provides a self-consistent framework to evaluate the potential impact of different technology, market and policy conditions. This analysis relies on extensive sensitivity analysis that considers a range of future renewable deployment scenarios out to 2020.*

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2020 U.S. Renewable Generation Goal

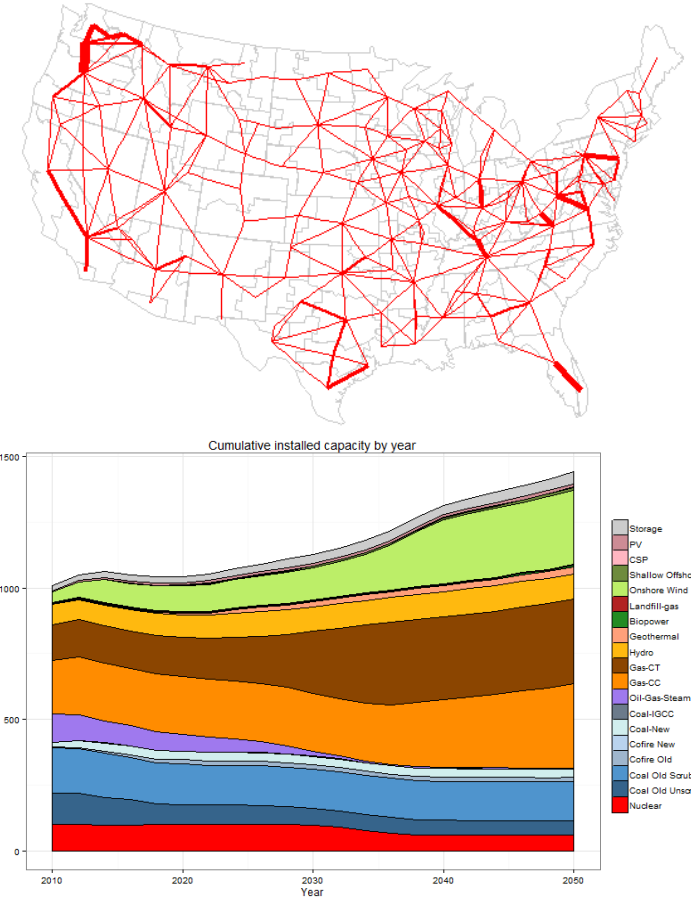
- **Initial Generation Goal [est. 2008]**
  - Doubling of 2008 generation levels of grid-connected Wind, Solar, and Geothermal (WSG) by year-end 2011
    - Goal: 144 TWh
- **Revised Generation Goal [est. 2012]**
  - Quadrupling from 2008 generation levels of grid-connected WSG by 2020 (NREL interpretation*)
    - **Goal: 288 TWh (used as basis for this analysis)**
    - ~7% – 8% of total generation
- **Key Analysis Question:**
  - Can the 288 TWh WSG generation goal be met, and if so, under what conditions?

**There may be other interpretations of the goal (e.g., doubling of 2012 year-end generation, or 340 TWh). See:*
http://www.whitehouse.gov/the-press-office/2013/03/15/fact-sheet-president-obama-s-blueprint-clean-and-secure-energy-future

Modeling Approach

- **What is the ReEDS Model?**
  - A capacity expansion and dispatch model designed for long-term analysis that simulates the build-out and operation of generation and transmission capacity to meet demand from present day to 2050
  - ReEDS' algorithm is designed to economically optimize, in two-year solve increments, the generation and capacity mix while satisfying regional demand requirements and grid system adequacy, technology, resource and policy constraints (including state RPSs)
  - High spatial resolution (134 balancing areas, 356 renewable resource regions)

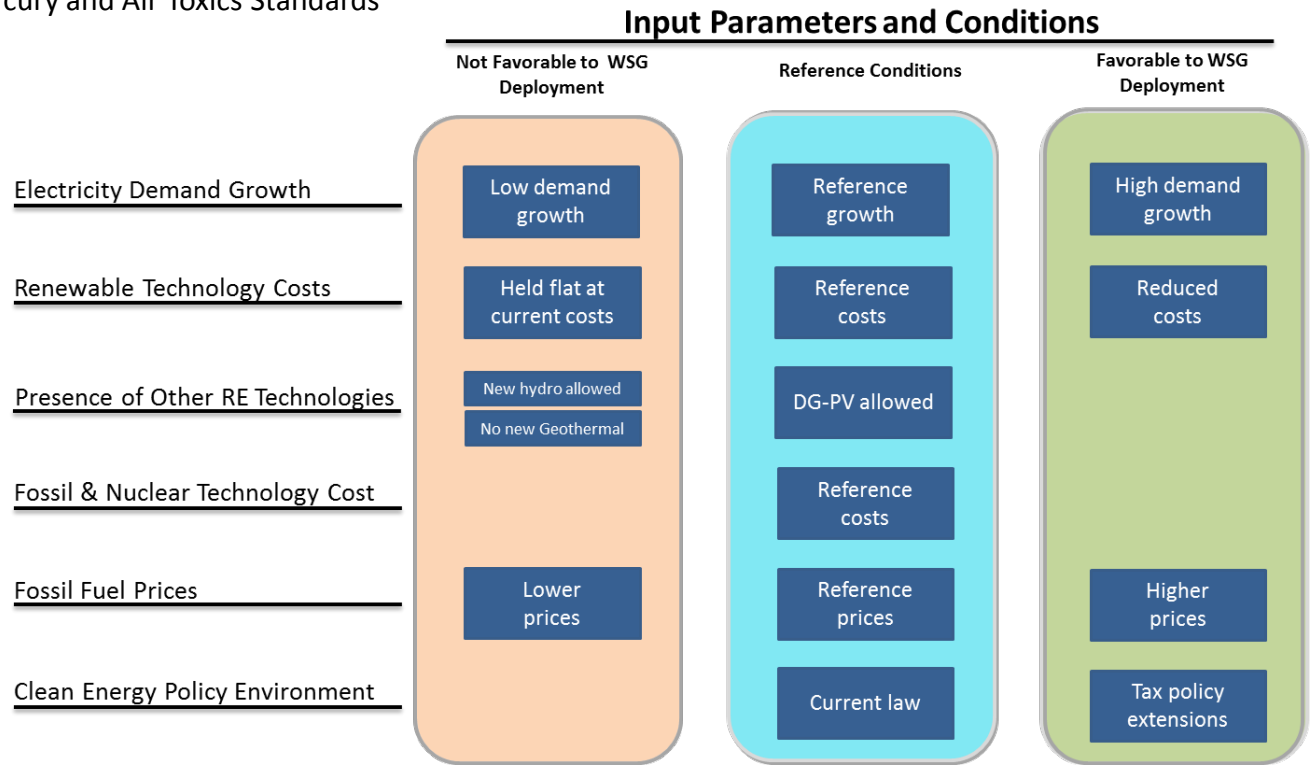
Regional Energy Deployment System (ReEDS) Model



Example ReEDS Outputs

Scenarios

- **21 scenarios were modeled assessing several sensitivities**
- **The 288 TWh goal is not required to be met within the model for any scenario**
  - The ReEDS model simulates the build-out and operation of the least-cost optimized U.S. electricity generation portfolio over time
- **The effects of forthcoming or draft Environmental Protection Agency regulations are <u>not</u> modeled, including:**
  - Carbon pollution standards under the Clean Air Act
    - Section 111(b) for new power plants
    - Section 111(d) for existing power plants
  - Cross-State Air Pollution Rule
  - Mercury and Air Toxics Standards



Limitations and Assumptions

- Limitations
  - **ReEDS two-year temporal resolution** – cumulative or average deployment is a more robust, reliable indicator than discrete values for each solve-year
  - **Limited foresight** – ReEDS does not make decisions based on any expectation of future market conditions
  - **No internal technology learning** – cost reductions from "learning-by-doing" or manufacturing economies of scale are not explicitly modeled
  - **No internal treatment of distributed generation** – deployment trajectories for distributed generation photovoltaic (DG-PV) systems are externally defined, relying on results from the DOE Sunshot Vision Study for all scenario configurations modeled
  - **Other deployment constraints not addressed** – e.g., manufacturing scale-up, permitting, wildlife are not addressed in the optimization
- Assumptions
  - Projects deployed in a given solve-year are planned in the years leading up to construction
  - Only planned/expected transmission projects can be built through 2020
  - Distribution systems can accommodate (DG-PV) systems

Reference Scenario Description

Technology Cost and Performance	
Wind	Median Literature (NREL Internal Analysis, October 2013)
Solar	Sunshot 62.5% (Sunshot Vision Study, 2012)
Geothermal	Hydrothermal and in-field EGS supply curves with no cost reductions over time (Augustine 2013 and Mai et al. forthcoming). No near or deep field EGS are modeled in this analysis period..
Hydroelectric	No new construction allowed
Conventionals	AEO 2013 Reference
Market Conditions	
Demand Growth	AEO 2013 Reference
Fossil Fuel Costs	AEO 2013 Reference
Conventional Retirements	Announced Retirements as of July 2013, Ventyx
Renewable Energy Policy	
Federal Tax Incentives	Existing law only
State RPSs	Existing law in 29 States, including solar carve-outs and REC trading rules

Analysis Assumptions Illustrative Framework

U.S. Economy/ Electricity Demand Growth

L AEO 2013 Low Economic Growth
R AEO 2013 Reference
H AEO 2013 High Economic Growth

Renewable Technology Cost and Performance

I REF RE-ITI (Incremental Tech. Improvement)
R AEO 2013 Reference
5 SS 50% Reduction
E REF RE-ETI (Evolutionary Tech. Improvement)
6 SS 62.5% Reduction
A REF RE-ATI (Advanced Tech. Improvement)
7 SS 75% Reduction (Core Projection)

Natural Gas Prices

HG AEO 2013 High Oil & Gas Resource
R AEO 2013 Reference
LG AEO 2013 Low Oil & Gas Resource

Clean Energy Policy/Regulatory Environment

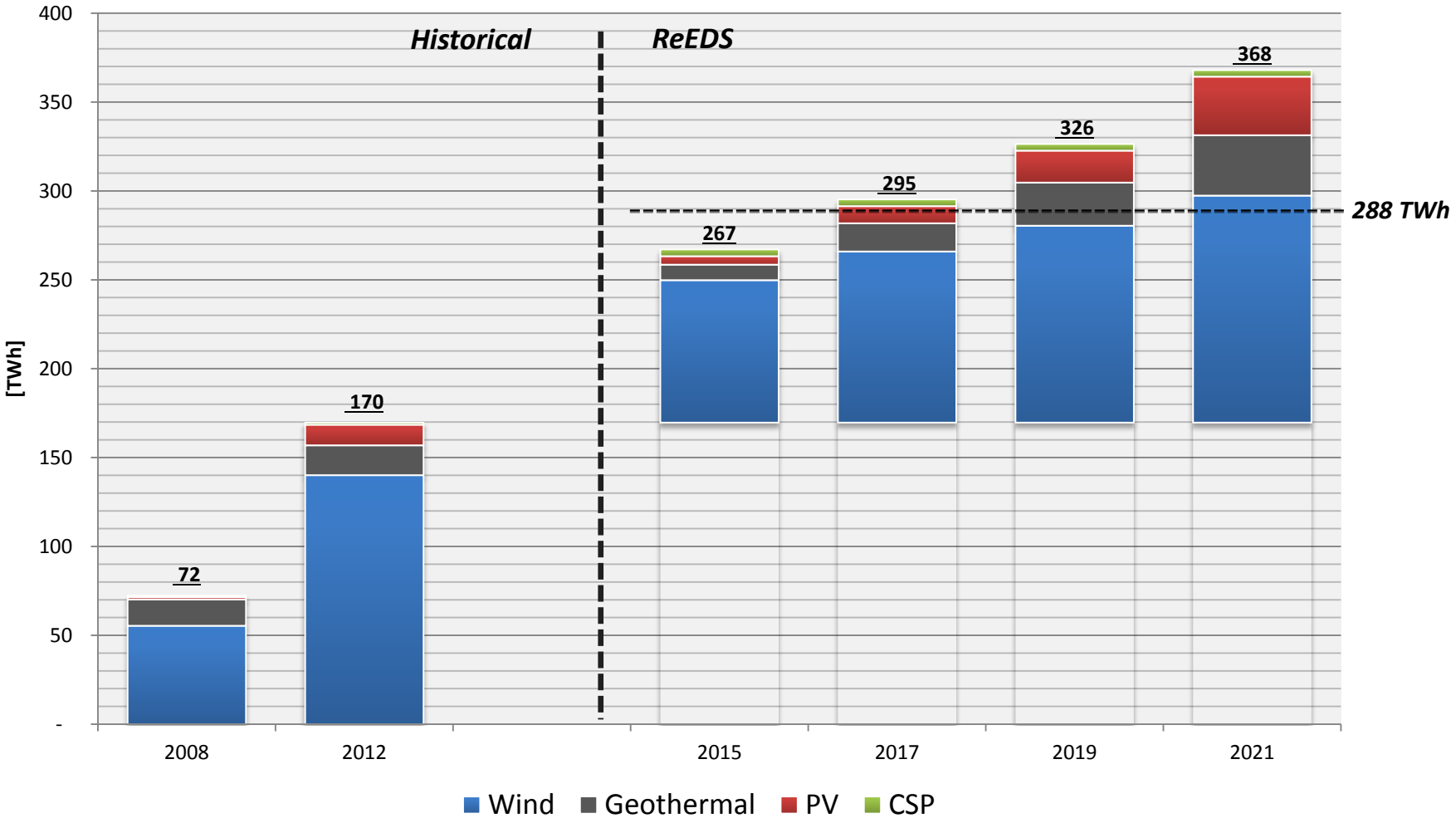
This Study
- ★ Reference Scenario
- ★ Reduced RE Technology Costs Scenario
- ★ Least Favorable RE Deployment Conditions Bound
- ★ Most Favorable RE Deployment Conditions Bound

Key to Published Reference Studies
AEO: EIA Annual Energy Outlook (AEO) 2013 Scenario s
REF: Renewable Electricity Futures Study - NREL (2012), Mai et al 2014
SS: SunShot Vision Study - DOE (2012), Eurek et al 2013 (applies to solar techs only)

Solar Treatment Notes
'Sunshot 62.5%' trajectory reduces from $4.0/W in 2010 to $1.5/W by 2020 for Utility PV.
DG-PV is exogenously input based on the corresponding cost reduction trajectory from Sunshot Vision Study
Concentrated Solar Power also follows the 62.5% cost reduction trajectory from Sunshot Vision Study

Reference Scenario Results

- **The Administration goal is achieved in the Reference scenario by 2017**



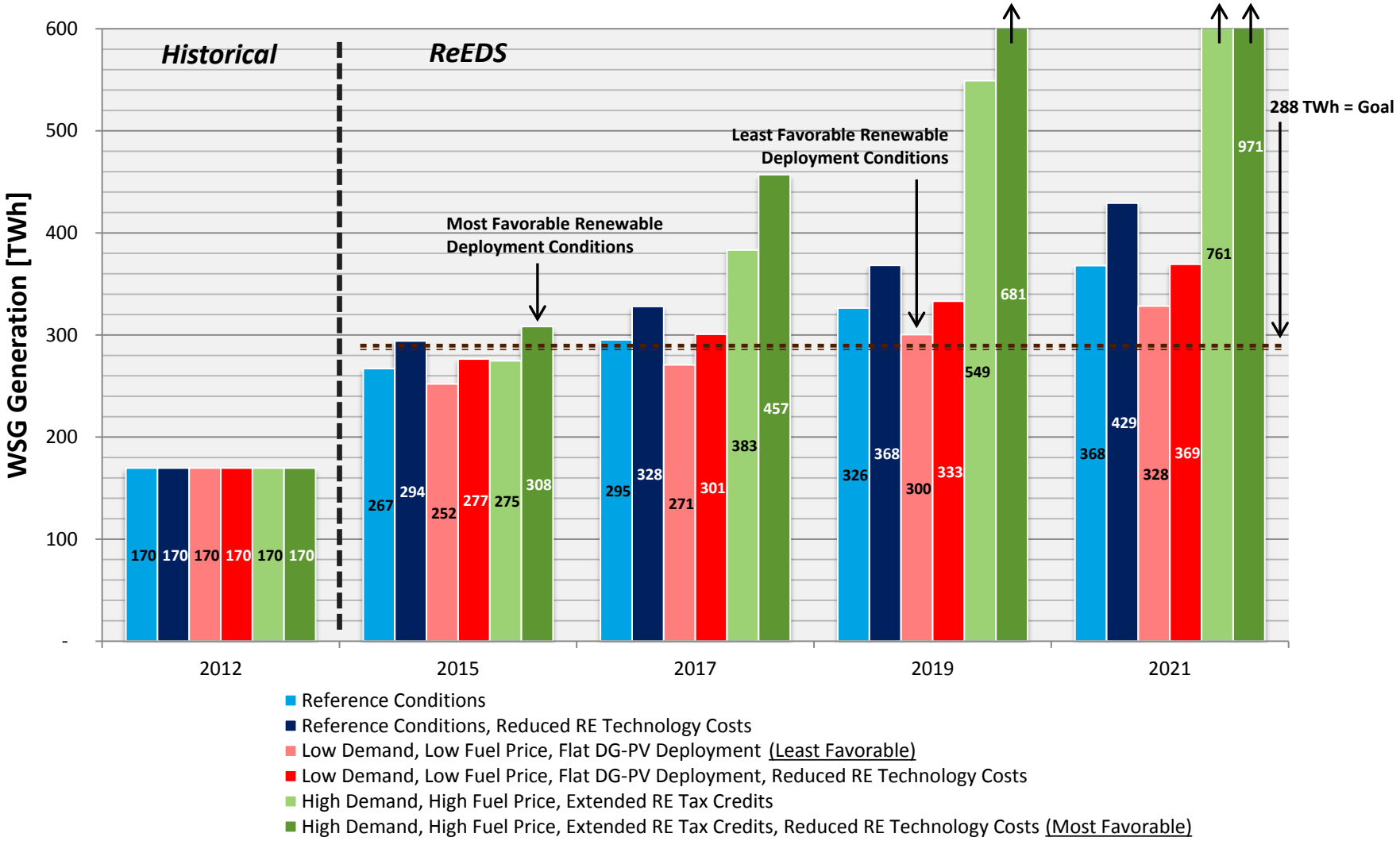
Notes

Projected generation numbers for a given year are based on plants that are operational on January 1st of that year. PV includes both utility and DG-PV.

Historical generation data is a synthesis of the following sources: Larry Sherwood/IREC Solar Market Trends Reports, SEIA/GTM Solar Industry Year in Review Reports, Form EIA-923, EIA Electric Power Monthly Tables 1.1 and 1.1A. PV generation assumes a capacity factor of 18%; CSP assumes a capacity factor of 25%.

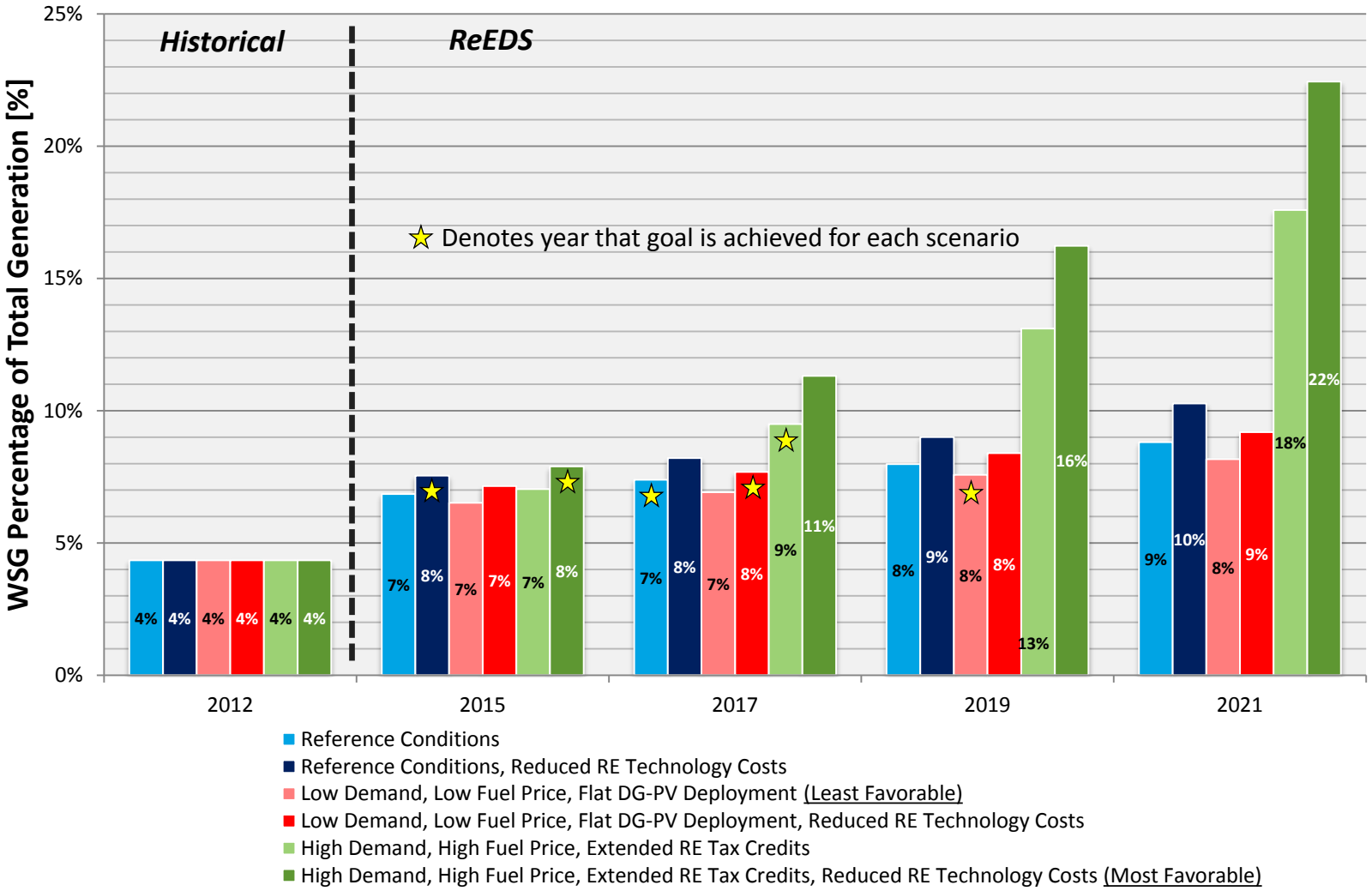
Bounding Scenario Modeling Results – Absolute Generation

- **The Goal is met under all conditions shown below**
  - Under more favorable conditions, the goal is met as early as 2015
  - Under unfavorable conditions modeled, the goal is met by 2019



Bounding Scenario Modeling Results – Percentage of Total Generation

- **The Goal is satisfied when wind, solar and geothermal generation make up approximately 7%–8% of national annual generation (depending on the electricity demand trajectory assumed)**



Summary Findings (1/2)

- **The 288 TWh Renewable Generation Goal is met under all modeled scenarios**
  - Reference scenario modeling results, which assume no tax policy extensions or accelerated research, development, demonstration and deployment (RD^3) activities (e.g., DOE-EERE activities), show this goal is met in **2017**
  - Favorable conditions for WSG deployment (e.g., Reduced RE Technology Costs) may result in the goal being met as early as 2015
  - Under unfavorable deployment conditions, modeling results indicate the goal is achieved by 2019
  - Modeling results indicate that under Reference conditions, state Renewable Portfolio Standard (RPS) requirements drive **45%** of the required new generation for goal attainment in 2017
- **Multiple technologies contribute to achieving the goal**
  - Wind (land-based) is the primary contributor to achieving the goal (e.g., 78% of required new generation in the Reference scenario)
    - Wind: **70% increase** from 2012 generation levels by 2017
  - Geothermal (hydrothermal, in-field enhanced geothermal systems (EGS)) and Solar (utility PV, distributed PV, concentrated solar power (CSP)) generation provide significant contributions
    - Geothermal: **94% increase** from 2012 generation levels by 2017
    - Solar: **115% increase** from 2012 generation levels by 2017
    - When these technologies are limited or completely excluded, Wind largely makes up the difference and the goal is still met in 2017

Summary Findings (2/2)

- **In the 2014–2020 timeframe, projected WSG generation is sensitive to RE technology cost assumptions and policy extensions, but is relatively insensitive to the range of electricity demand and fuel prices considered in AEO 2013**
- **Cost reductions resulting from accelerated RE improvement activities (e.g., DOE-EERE RD^3) accelerate generation additions by roughly 2 years**
- **Tax credit extensions have a substantial impact on increasing RE generation, particularly in concert with favorable market conditions**
  - In this analysis, wind is principally affected
- **The combination of policy and RD^3 activities is greater than the sum of the individual contributions of either one alone**
- **ReEDS results differ significantly from DOE-EIA Annual Energy Outlook (AEO) 2014 Reference Case (284 TWh WSG generation in 2020)**
  - Divergence due to difference of renewable cost assumptions and treatment of variable generation

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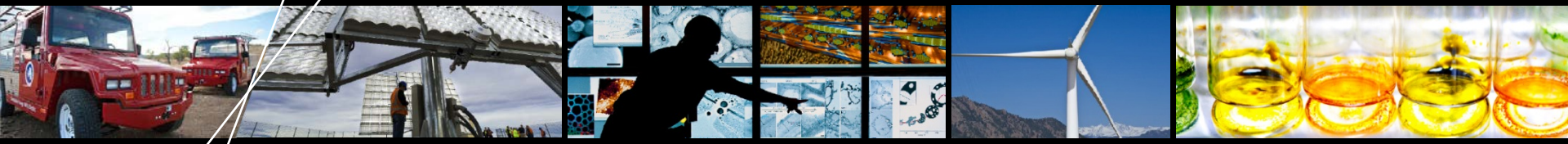


Appendix A – Scenario and Key Input Descriptions

Scenario List

A1 – Reference [*2017*]

A2 – Low Fuel Price [*2019*]

A3 – High Fuel Price [*2017*]

A4 – *Bound* – Low Demand Growth, Low Fuel Price, No DG-PV Deployment post-2014 [*2019*]

A5 – *Bound* – High Demand Growth, High Fuel Price, Extended Renewable Tax Credits [*2017*]

A6 – *Bound* – Reduced RE Technology Costs, Low Demand Growth, Low Fuel Price, No DG-PV Deployment post-2014 [*2017*]

A7 – *Bound* – Reduced RE Technology Costs, High Demand Growth, High Fuel Price, Extended Renewable Tax Credits [*2015*]

A8 – Reduced RE Technology Costs [*2015*]

A9 – Reduced RE Technology Costs, New Hydroelectric Construction Allowed [*2015*]

A10 – Extended Wind Tax Credits (to 2020) [*2017*]

A11 – Extended Solar Tax Credits (to 2020) [*2017*]

A12 – Extended Wind/Solar Tax Credits (to 2020) [*2017*]

A13 – Low Demand Growth [*2019*]

A14 – High Demand Growth [*2017*]

A15 – No DG-PV Deployment post-2014 [*2017*]

A16 – New Hydroelectric Constructed Allowed [*2019*]

A17 – No New Geothermal Construction [*2017*]

A18 – Extended Wind Tax Credits (to 2016) [*2017*]

A19 – Reduced RE Technology Costs, Low Demand Growth [*2015*]

A20 – Reduced RE Technology Costs, Low Fuel Price [*2017*]

A21 – Flat Technology Costs [*2019*]

RE = Renewable Energy
DG-PV = Distributed Generation Photovoltaics

Listed scenario attributes are those which deviate from Reference conditions
[Green text denotes the year in which the Goal is achieved for each scenario]

Scenario Inputs

Demand Trajectory	Data Source
Low Demand Growth	AEO 2013 Low Economic Growth
Reference	AEO 2013 Reference Case
High Demand Growth	AEO 2013 High Economic Growth

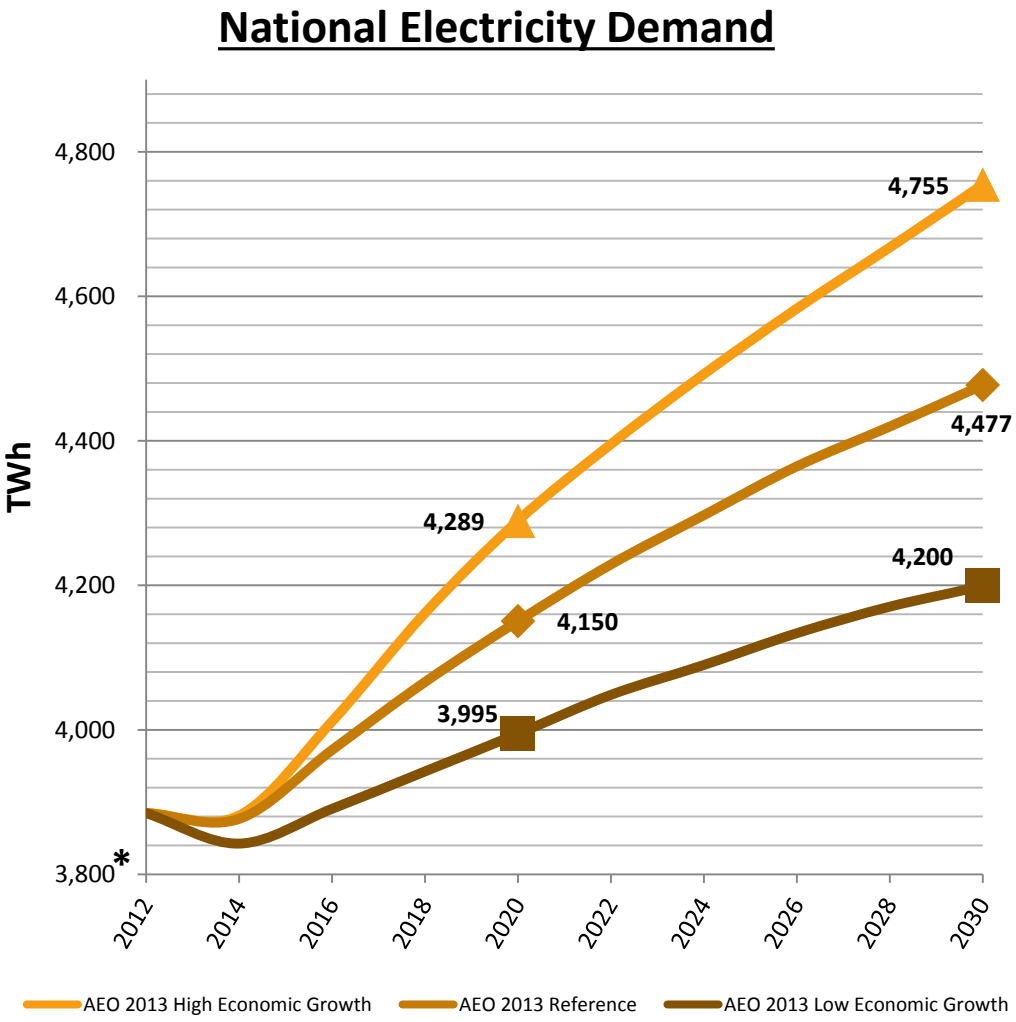
Fuel Price	Data Source
Low Fuel Price	AEO 2013 High Oil & Gas Resource, Low Coal Prices
Reference	AEO 2013 Reference Case
High Fuel Price	AEO 2013 Low Oil & Gas Resource, High Coal Prices

Technology Costs	Data Source
Reference - Wind	Median Literature (NREL Internal Analysis , October 2013)
Reduced RE Technology Costs – Wind	High Cost Reduction (NREL Internal Analysis , October 2013)
Reference – Solar	Sunshot 62.5% ($4.0/W in 2010 to $1.5/W by 2020 for Utility PV, associated Sunshot DG-PV trajectory)
Reduced RE Technology Costs – Solar	Sunshot 75.0% ($4.0/W in 2010 to $1.0/W by 2020 for Utility PV, associated Sunshot DG-PV trajectory)
Reference – Geothermal	Augustine 2013 and Mai et al. forthcoming
Reduced RE Technology Costs – Geothermal	Augustine 2013, Mat et al. forthcoming, and DOE FY 2014 Congressional Budget Request, Volume 3.
Hydroelectric	Hall D.G., Hunt R.T., Reeves S.R., and Carroll G.R. (2003)

Retirements	Data Source
All Scenarios	Ventyx, Announced Retirements as of July 2013 (57 GW Coal 2020)

AEO = Annual Energy Outlook

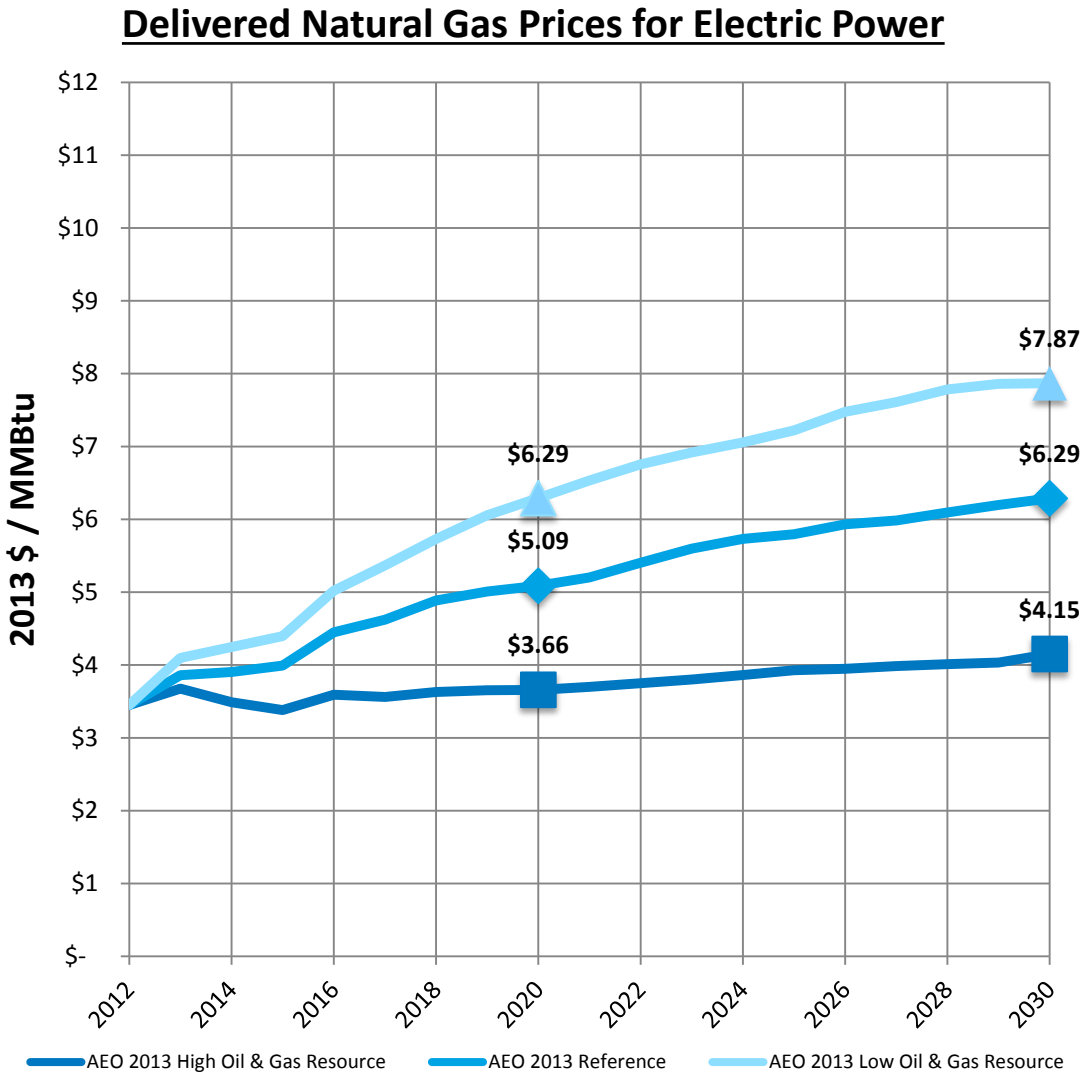
Electricity Demand Trajectories through 2030



- **AEO 2013 High Economic Growth**
  - Average Annual Load Growth
    - 2013 – 2020: 1.2%/yr
    - 2021 – 2030: 1.0%/yr
- **AEO 2013 Reference**
  - Average Annual Load Growth
    - 2013 – 2020: 0.8%/yr
    - 2021 – 2030: 0.8%/yr
- **AEO 2013 Low Economic Growth**
  - Average Annual Load Growth
    - 2013 – 2020: 0.4%/yr
    - 2021 – 2030: 0.5%/yr

**Y Axis does not begin at 0.*

Natural Gas Prices through 2030



- **AEO 2013 Low Oil & Gas Resource**
  - Increase from 2012 price by 2020 / 2030: 82% / 128%
  - 24% / 25% above Reference prices in 2020 / 2030
- **AEO 2013 Reference**
  - Increase from 2012 price by 2020 / 2030: 47% / 82%
- **AEO 2013 High Oil & Gas Resource**
  - Increase from 2012 price by 2020 / 2030 : 6% / 20%
  - 28% / 34% below Reference prices in 2020 / 2030

Supply curves for the ReEDS model are developed using the above natural gas cost trajectories and corresponding electric sector usage projections (not pictured) from AEO 2013. Natural gas prices shown above do not directly reflect the output prices from ReEDS, which models price elasticity of demand for natural gas.

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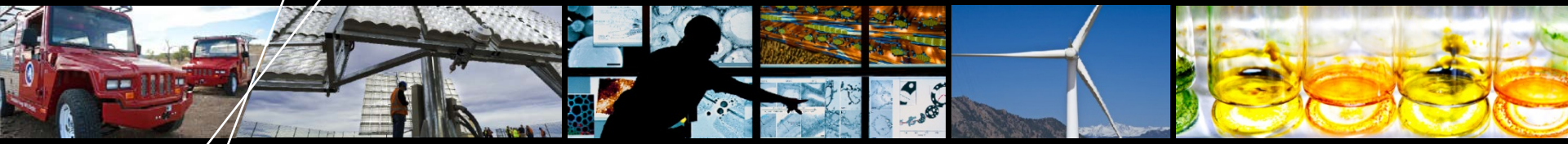
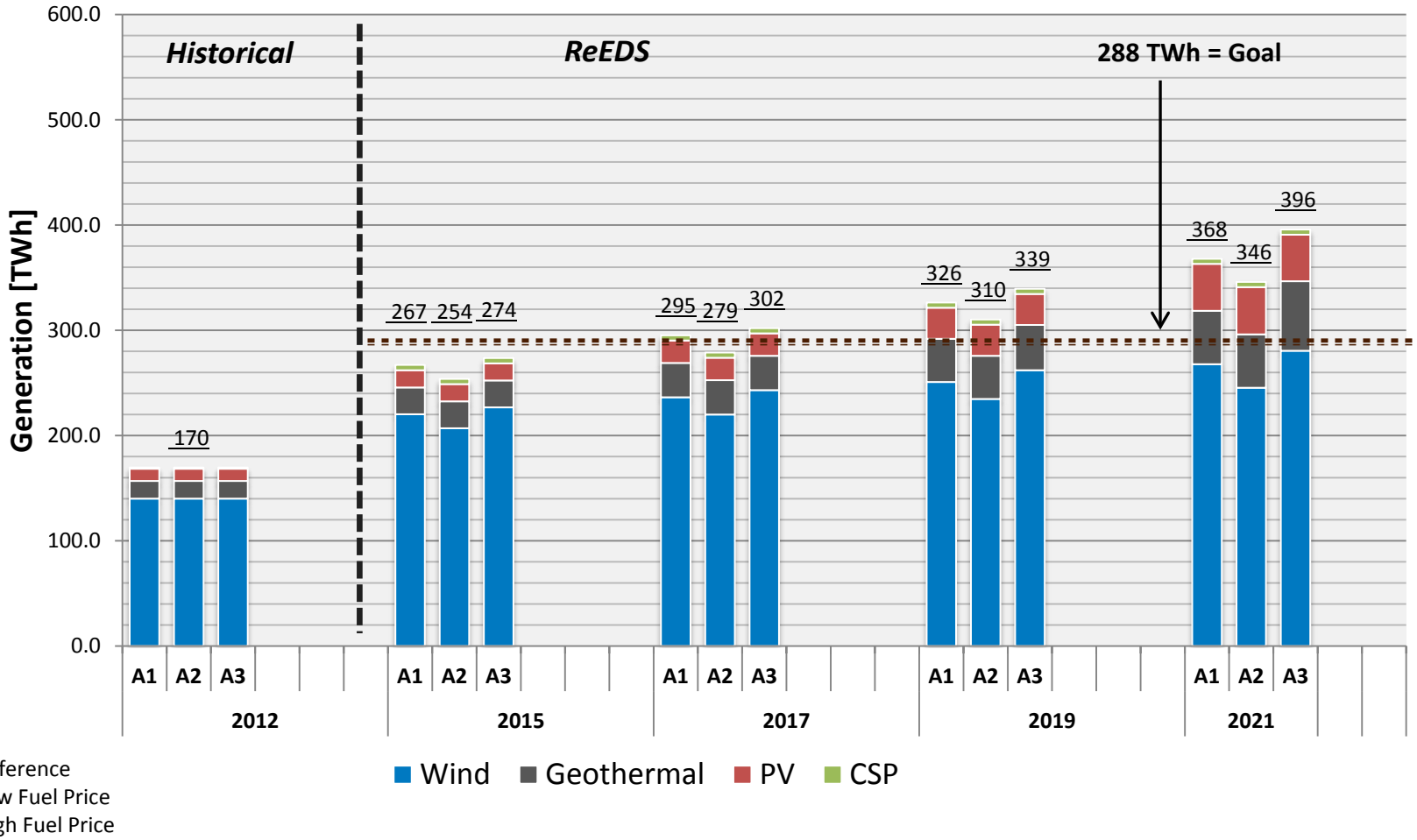


Appendix B – Sensitivity Comparisons

Sensitivity – Fuel Price Assumptions

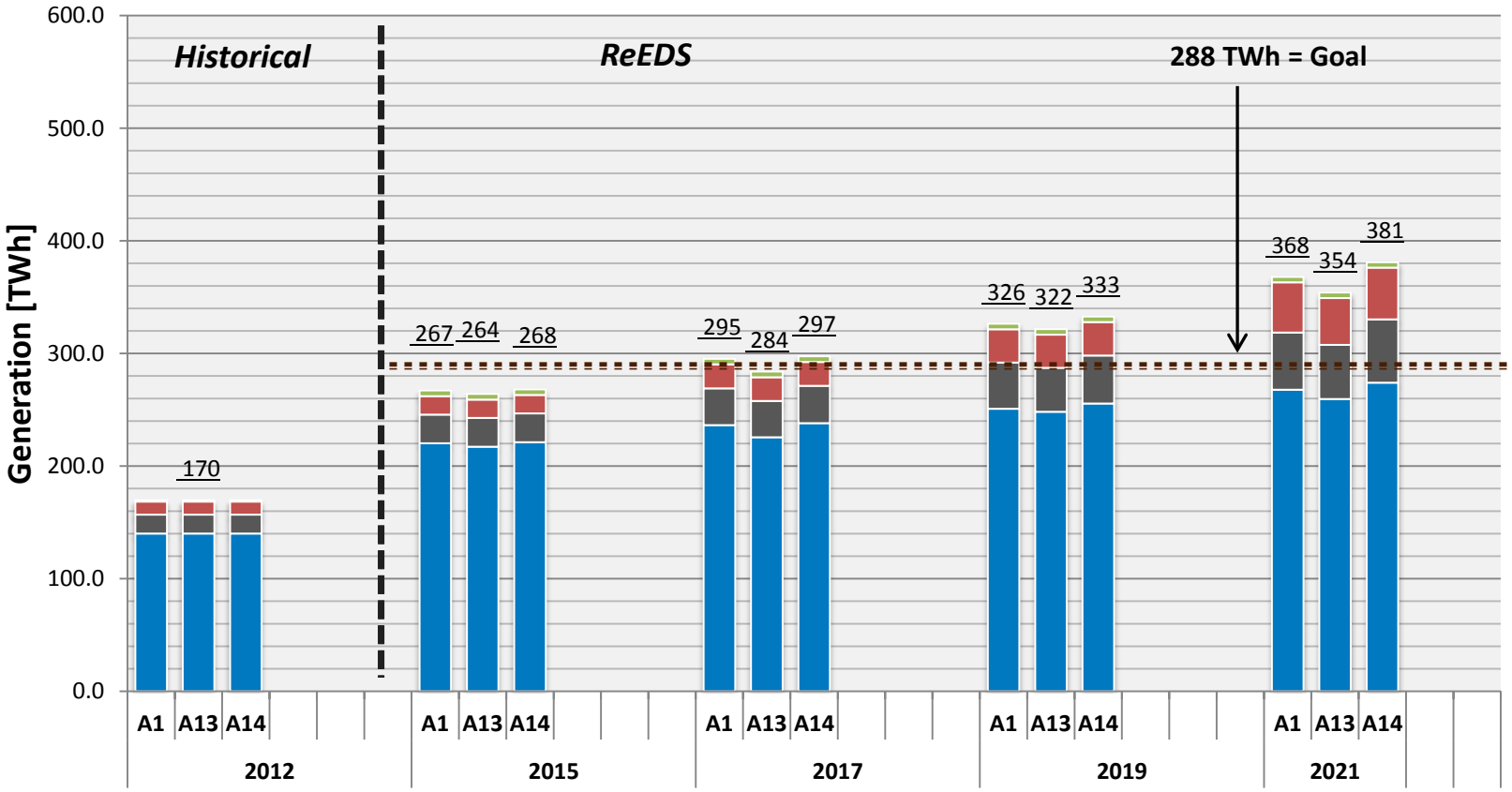
- **Continued low fuel prices may push back achievement of goal by 1–2 years**
  - Sensitivities primarily shift Wind-Gas economics



A1 – Reference
A2 – Low Fuel Price
A3 – High Fuel Price

Sensitivity – Demand Assumptions

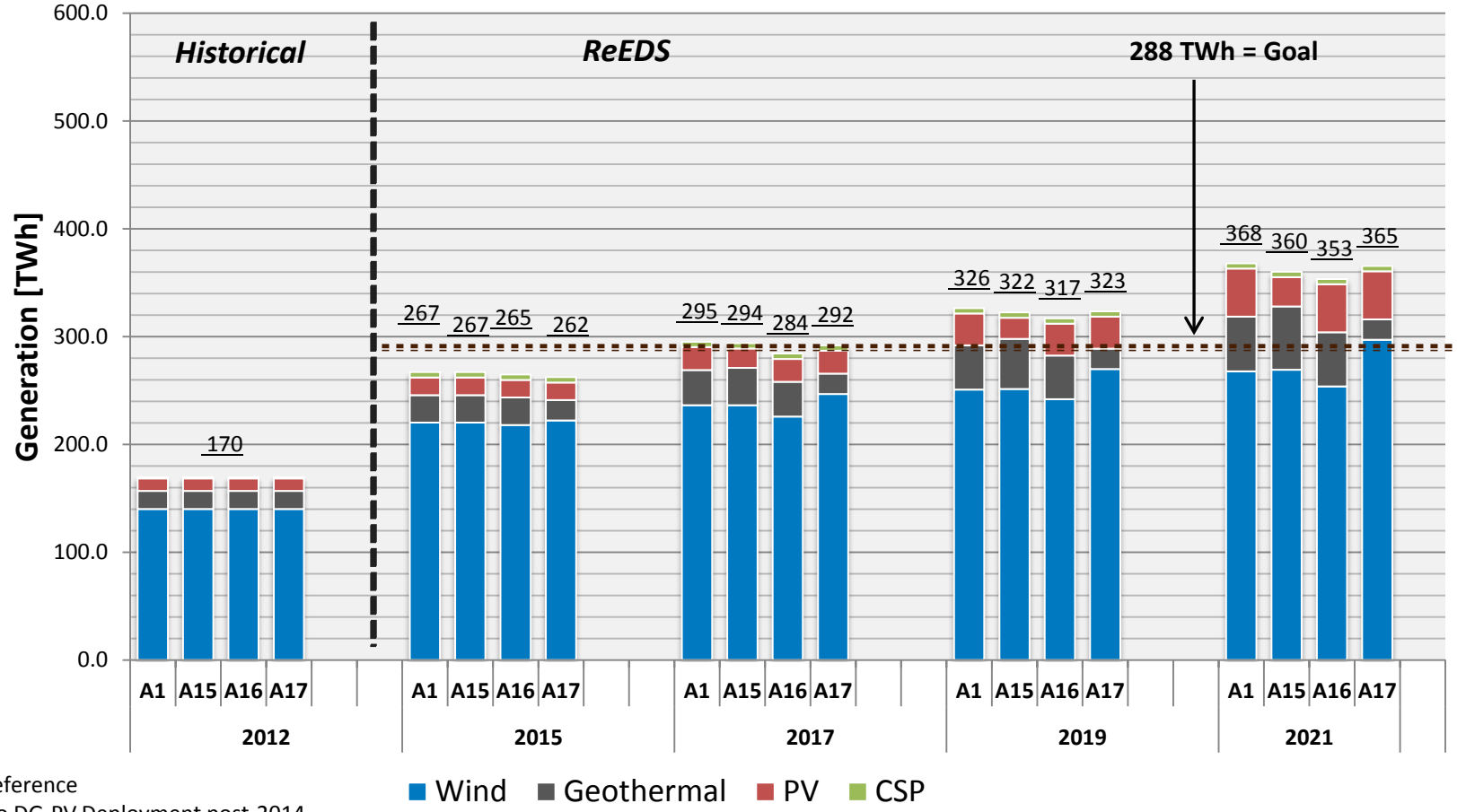
- **Low demand growth conditions push back goal achievement by ~1 year**
  - Demand impacts size of market for new capacity – primarily affects Wind deployment



A1 – Reference
A13 – Low Demand Growth
A14 – High Demand Growth

Sensitivity – Presence of Other Technologies

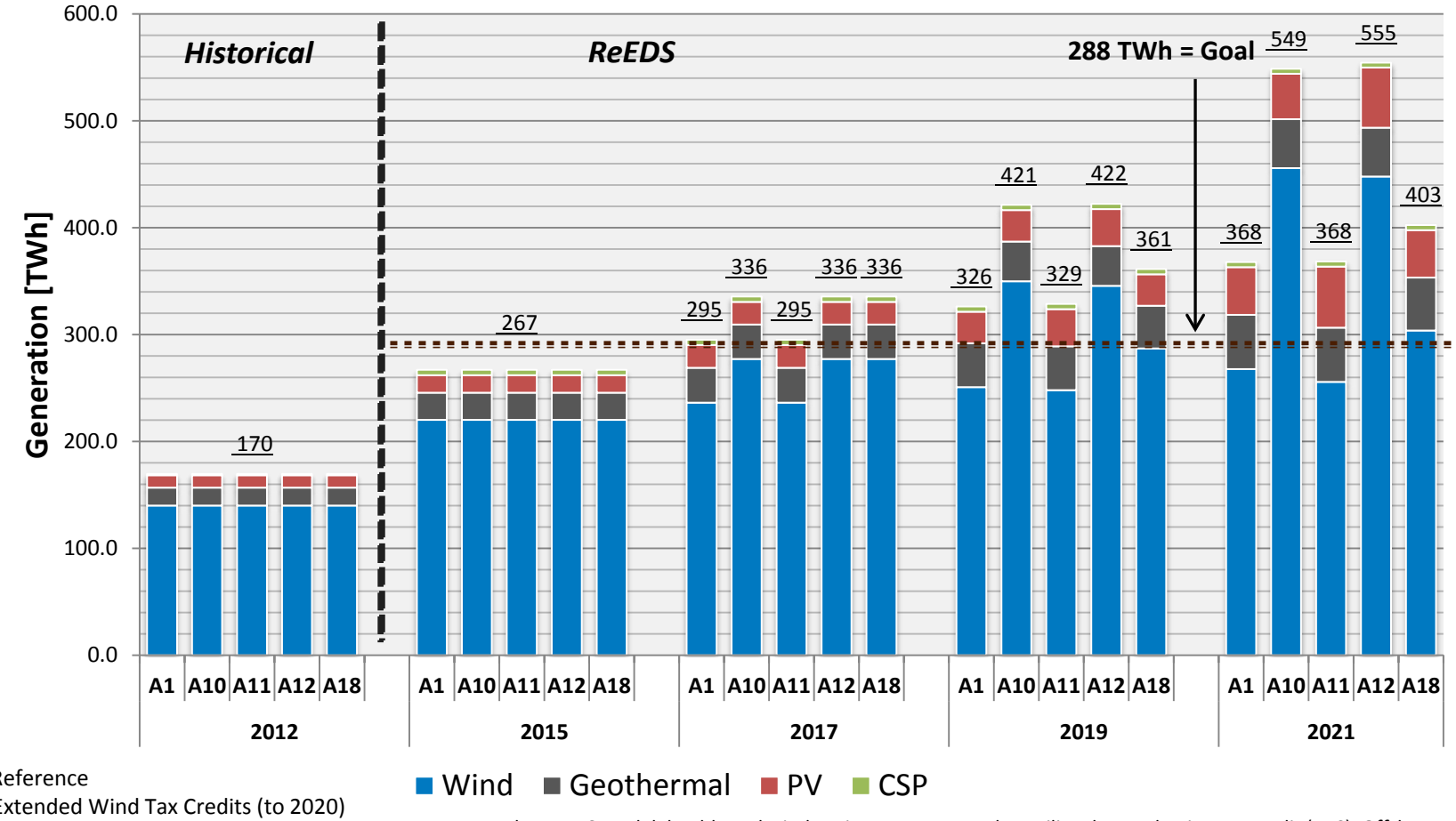
- **New hydro construction reduces projected wind generation, potentially delaying goal achievement by ~2 years**
  - New hydro construction displaces mostly non-RE generation (wind is only 20% of the total displaced)
- **No other modeled technology restriction conditions delay goal achievement significantly**
  - When new DG-PV or geothermal are excluded in the future, wind largely makes up the difference



A1 – Reference
A15 – No DG-PV Deployment post-2014
A16 – New Hydro Constructed Allowed
A17 – No New Geothermal Construction

Sensitivity – Tax Credit Extensions

- **Tax credit extensions increase wind and solar generation**
  - The impact of solar tax credits are understated, as we have not altered the DG-PV trajectory to reflect enhanced economics
  - Tax credit extensions have a larger impact in out years

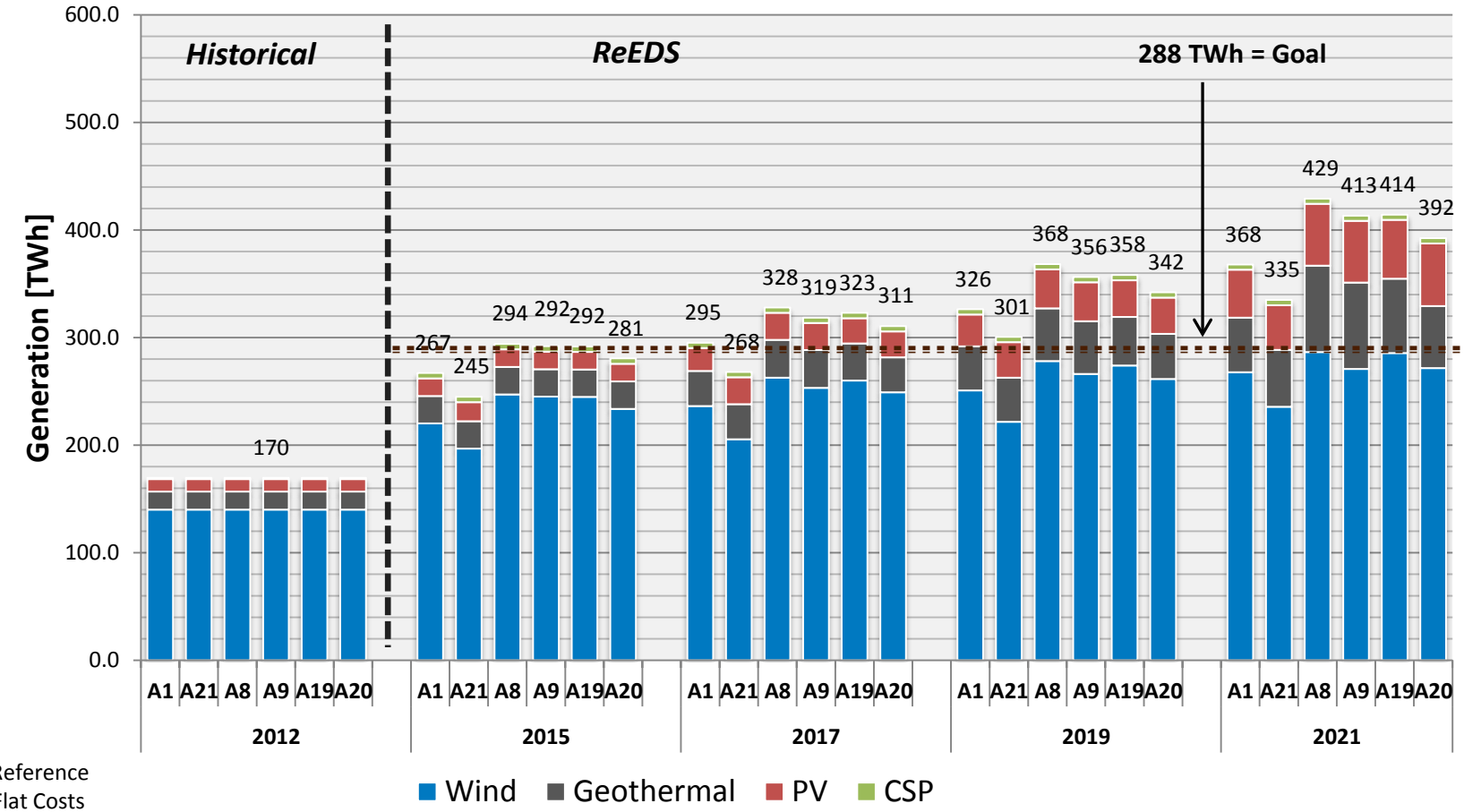


A1 – Reference
A10 – Extended Wind Tax Credits (to 2020)
A11 – Extended Solar Tax Credits (to 2020)
A12 – Extended Wind/Solar Tax Credits (to 2020)
A18 – Extended Wind Tax Credits (to 2016)

In the ReEDS model, land-based wind projects are assumed to utilize the production tax credit (PTC). Offshore wind projects are assumed to utilize the investment tax credit (ITC). Solar projects are assumed to utilize the ITC. Geothermal projects are modeled to utilize a 10% ITC with no expiration, and therefore do not require an extension scenario.

Sensitivity – Renewable Technology Cost Assumptions

- **When reduced RE technology costs are assumed, the goal may be met in 2015**
  - Exception: 'Low Fuel Price' sensitivity – Goal may be met in 2017
- **With no WSG cost reductions after 2014, the goal may still be met by 2019**



A1 – Reference
A21 – Flat Costs
A8 – Reduced RE Technology Costs
A9 – Reduced RE Technology Costs, New Hydro Construction Allowed
A19 – Reduced RE Technology Costs, Low Demand Growth
A20 – Reduced RE Technology Costs, Low Fuel Price

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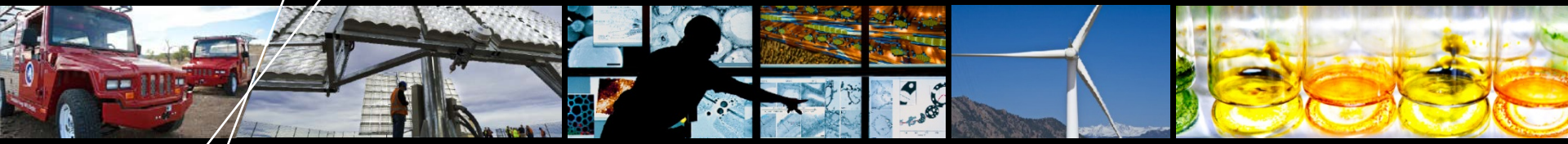
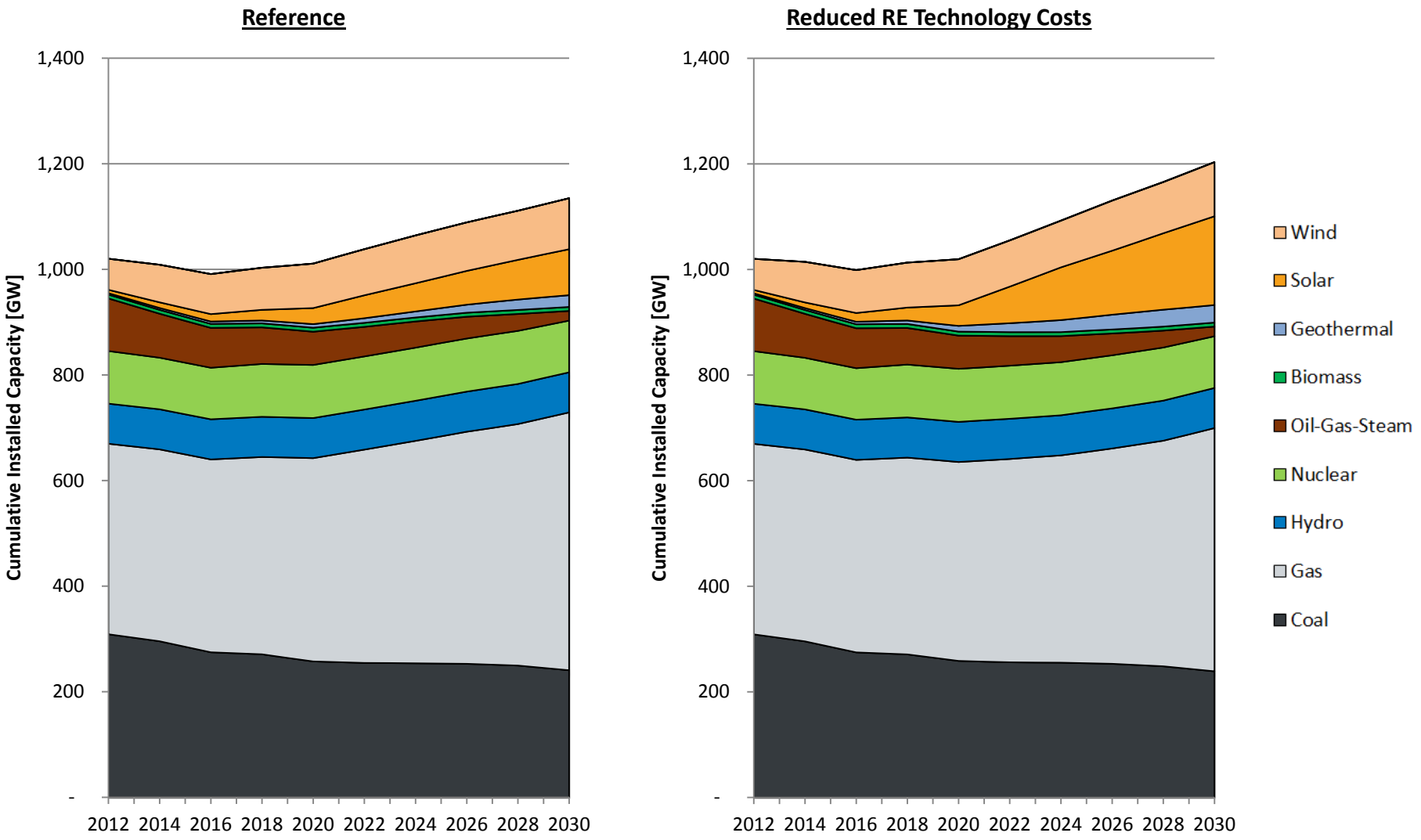
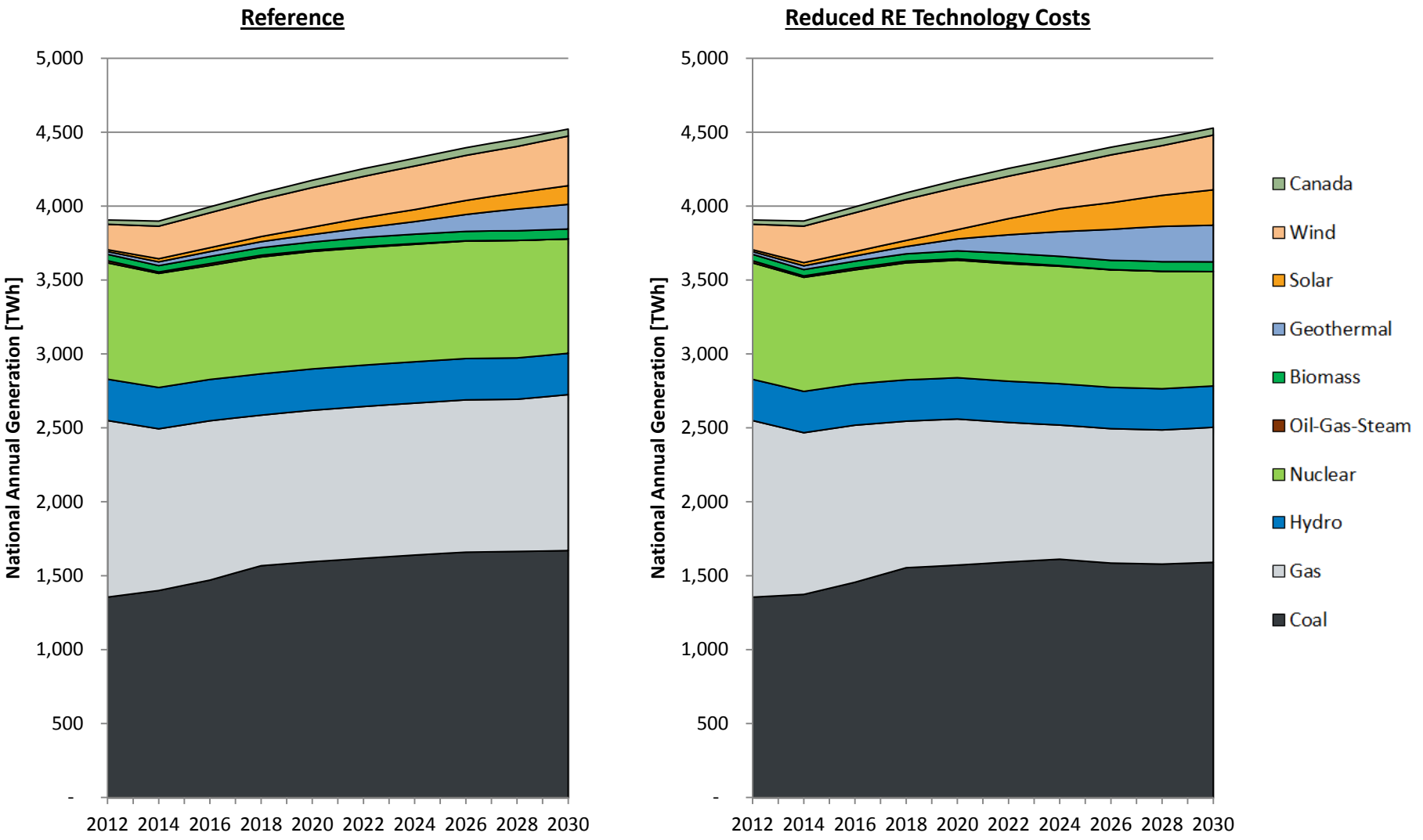


Appendix C – Long Term Results for 'Reference' and 'Reduced RE Technology Costs' Scenarios

National Installed Capacity through 2030



National Annual Generation through 2030



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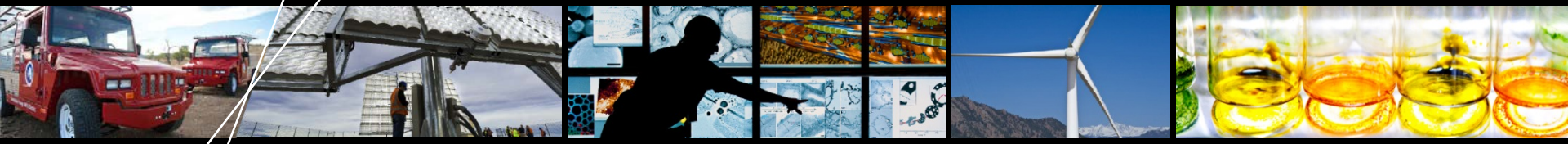


Appendix D – State Level Results for 'Reference' and 'Reduced RE Technology Costs' Scenarios

Disclaimer

Future state-level capacity and generation results are highly uncertain, sensitive to model assumptions, and do not present predictions or projections from the National Renewable Energy Laboratory, the Department of Energy, or the U.S. Government. The results presented in the following slides are derived from a modeling exercise that employs simplifications including model decision-making that is necessarily different from real-world decisions. In particular, the ReEDS modeling framework used in this analysis implicitly assumes broad-based, national coordination and optimization of the electricity sector. In practice, however, the electricity sector today is greatly impacted by state policy and regulation, and by regional decision-making. Consequently, the state-level deployment results presented may differ significantly from future deployment. In addition, while the multiple scenarios analyzed cover a range of possible futures, other alternative futures are certainly possible and could drive the geographic deployment distributions differently than what is presented.

2020 State Renewable Generation
'Reference' Scenario

Wind-Solar-Geothermal Generation							
St	TWh	$\%_{2020}$	$\%_{2012}$	St	TWh	$\%_{2020}$	$\%_{2012}$
AL	0.0	0.0%	0.0%	NC	6.4	5.1%	6.0%
AR	0.0	0.0%	0.0%	ND	6.3	16.6%	17.3%
AZ	6.5	6.6%	6.7%	NE	1.6	3.7%	3.6%
CA	78.5	29.5%	33.3%	NH	0.5	3.7%	2.5%
CO	9.4	19.3%	20.5%	NJ	11.7	16.9%	16.8%
CT	5.7	13.2%	15.3%	NM	12.8	33.5%	42.2%
DE	0.2	4.1%	4.3%	NV	9.6	26.8%	27.5%
FL	0.5	0.2%	0.3%	NY	6.1	4.6%	4.4%
GA	0.1	0.1%	0.1%	OH	20.4	12.7%	12.8%
IA	15.4	24.0%	23.9%	OK	21.5	30.0%	30.2%
ID	4.0	22.9%	22.3%	OR	8.9	18.1%	19.7%
IL	11.9	6.4%	6.8%	PA	4.8	2.3%	2.0%
IN	7.0	5.6%	8.2%	RI	0.1	6.8%	3.6%
KS	15.4	33.7%	50.2%	SC	0.1	0.1%	0.1%
KY	0.0	0.0%	0.0%	SD	1.8	19.0%	20.4%
LA	0.6	0.7%	0.7%	TN	0.1	0.1%	0.2%
MA	7.8	20.2%	23.2%	TX	36.5	8.6%	9.2%
MD	2.7	5.4%	5.6%	UT	2.4	5.2%	5.2%
ME	0.6	4.0%	3.8%	VA	0.1	0.1%	0.1%
MI	8.9	7.1%	7.7%	VT	0.5	23.0%	7.0%
MN	9.1	16.0%	15.3%	WA	8.5	7.3%	7.5%
MO	5.6	6.5%	7.2%	WI	9.7	13.2%	12.8%
MS	0.0	0.0%	0.0%	WV	1.7	1.7%	2.6%
MT	2.2	7.7%	15.2%	WY	3.8	15.1%	16.7%

Wind-Solar-Geothermal –Biomass Generation							
St	TWh	$\%_{2020}$	$\%_{2012}$	St	TWh	$\%_{2020}$	$\%_{2012}$
AL	6.9	6.4%	5.9%	NC	11.9	9.6%	11.1%
AR	0.1	0.1%	0.1%	ND	6.3	16.6%	17.3%
AZ	6.7	6.8%	7.0%	NE	1.6	3.8%	3.7%
CA	82.9	31.1%	35.2%	NH	1.2	8.6%	5.7%
CO	9.5	19.5%	20.7%	NJ	12.4	17.9%	17.8%
CT	6.6	15.4%	18.0%	NM	12.9	33.7%	42.4%
DE	0.2	4.8%	5.1%	NV	9.6	26.9%	27.5%
FL	3.8	1.8%	1.9%	NY	8.9	6.7%	6.4%
GA	4.4	2.8%	3.6%	OH	20.8	13.0%	13.1%
IA	15.4	24.1%	24.0%	OK	21.5	30.1%	30.2%
ID	4.1	23.7%	23.1%	OR	9.5	19.3%	21.0%
IL	12.6	6.8%	7.2%	PA	7.8	3.8%	3.3%
IN	7.3	5.8%	8.5%	RI	0.1	11.6%	6.2%
KS	15.4	33.7%	50.3%	SC	1.5	1.5%	1.7%
KY	0.1	0.1%	0.1%	SD	1.8	19.0%	20.4%
LA	1.7	2.1%	2.2%	TN	0.2	0.2%	0.2%
MA	9.1	23.3%	26.8%	TX	38.3	9.1%	9.6%
MD	3.3	6.6%	6.8%	UT	2.5	5.2%	5.3%
ME	3.4	21.5%	20.6%	VA	1.6	2.8%	2.2%
MI	11.1	8.9%	9.6%	VT	1.0	49.1%	15.0%
MN	11.7	20.5%	19.5%	WA	9.9	8.5%	8.8%
MO	6.2	7.3%	8.1%	WI	11.5	15.6%	15.1%
MS	0.5	0.7%	0.8%	WV	1.7	1.7%	2.6%
MT	2.2	7.7%	15.2%	WY	3.8	15.1%	16.7%

TWh *= generation in TWh.* **$\%_{2020}$** *= in-state renewable generation as a percent of total 2020 in-state generation.* **$\%_{2012}$** *= in-state renewable generation as a percent of total 2012 in-state generation.*

Percent generation metrics utilize at-the-generator generation data. 2012 in-state generation is calculated in ReEDS. Transmission and distribution losses are not included in percent calculations, nor are Canadian imports. Variable renewable energy (VRE) curtailments are subtracted from wind and solar outputs to reflect the modelled VRE quantities off-taken to the bulk power sector. Biomass generation consists of the aggregate contributions from dedicated biomass-fueled power plants, landfill gas generation facilities, and biomass co-fired in coal power plants.

2024 State Renewable Generation
'Reference' Scenario

Wind-Solar-Geothermal Generation							
St	TWh	$\%_{2024}$	$\%_{2012}$	St	TWh	$\%_{2024}$	$\%_{2012}$
AL	0.0	0.0%	0.0%	NC	7.5	5.4%	7.0%
AR	0.0	0.1%	0.1%	ND	6.4	16.5%	17.4%
AZ	8.2	8.3%	8.6%	NE	1.7	3.9%	3.8%
CA	123.1	42.1%	52.2%	NH	0.6	3.5%	2.5%
CO	10.5	21.6%	22.8%	NJ	13.5	17.2%	19.3%
CT	5.8	14.0%	15.8%	NM	13.2	34.3%	43.4%
DE	0.3	5.5%	6.0%	NV	11.5	36.3%	33.1%
FL	1.8	0.8%	0.9%	NY	7.1	5.5%	5.1%
GA	0.4	0.3%	0.4%	OH	27.5	16.3%	17.2%
IA	16.1	24.9%	25.1%	OK	21.9	29.2%	30.7%
ID	5.3	29.3%	29.6%	OR	9.1	17.9%	20.1%
IL	18.1	9.4%	10.3%	PA	5.3	2.6%	2.3%
IN	8.7	6.8%	10.2%	RI	0.2	8.3%	8.9%
KS	15.7	30.7%	51.4%	SC	0.2	0.2%	0.2%
KY	0.1	0.1%	0.0%	SD	2.1	21.1%	24.2%
LA	0.9	1.1%	1.1%	TN	0.2	0.2%	0.3%
MA	9.9	22.2%	29.3%	TX	38.8	8.9%	9.8%
MD	2.9	5.7%	6.0%	UT	2.5	5.4%	5.4%
ME	0.7	4.1%	4.1%	VA	0.2	0.4%	0.3%
MI	10.9	8.6%	9.4%	VT	0.5	24.0%	7.4%
MN	9.8	17.2%	16.3%	WA	9.3	8.0%	8.3%
MO	9.0	9.9%	11.7%	WI	9.9	13.2%	13.1%
MS	0.0	0.0%	0.0%	WV	1.7	1.7%	2.6%
MT	6.1	18.4%	42.2%	WY	6.6	22.8%	29.1%

Wind-Solar-Geothermal –Biomass Generation							
St	TWh	$\%_{2024}$	$\%_{2012}$	St	TWh	$\%_{2024}$	$\%_{2012}$
AL	8.7	7.6%	7.4%	NC	13.4	9.7%	12.5%
AR	0.1	0.2%	0.2%	ND	6.4	16.5%	17.4%
AZ	8.4	8.5%	8.8%	NE	1.7	4.0%	3.9%
CA	127.5	43.6%	54.1%	NH	1.3	8.3%	5.9%
CO	10.6	21.8%	23.0%	NJ	14.1	18.1%	20.2%
CT	6.8	16.1%	18.3%	NM	13.2	34.4%	43.6%
DE	0.3	6.2%	6.8%	NV	11.5	36.4%	33.1%
FL	5.3	2.3%	2.7%	NY	9.9	7.7%	7.1%
GA	9.8	6.2%	8.0%	OH	27.9	16.5%	17.5%
IA	16.3	25.1%	25.4%	OK	21.9	29.2%	30.7%
ID	5.4	30.1%	30.4%	OR	9.6	19.1%	21.3%
IL	18.8	9.7%	10.7%	PA	8.3	4.0%	3.5%
IN	8.9	7.0%	10.5%	RI	0.3	10.8%	11.5%
KS	15.7	30.7%	51.5%	SC	1.6	1.5%	1.8%
KY	0.1	0.1%	0.1%	SD	2.1	21.1%	24.2%
LA	2.0	2.4%	2.6%	TN	0.3	0.3%	0.4%
MA	11.1	24.9%	32.9%	TX	40.6	9.3%	10.2%
MD	3.5	6.9%	7.2%	UT	2.6	5.5%	5.5%
ME	3.6	22.0%	22.2%	VA	1.8	3.0%	2.5%
MI	13.1	10.4%	11.3%	VT	1.1	49.8%	15.4%
MN	12.3	21.7%	20.6%	WA	10.7	9.2%	9.5%
MO	9.6	10.6%	12.5%	WI	11.7	15.5%	15.4%
MS	0.5	0.8%	0.8%	WV	1.7	1.8%	2.6%
MT	6.1	18.4%	42.2%	WY	6.6	22.8%	29.1%

TWh *= generation in TWh.* **$\%_{2024}$** *= in-state renewable generation as a percent of total 2024 in-state generation.* **$\%_{2012}$** *= in-state renewable generation as a percent of total 2012 in-state generation.*

Percent generation metrics utilize at-the-generator generation data. 2012 in-state generation is calculated in ReEDS. Transmission and distribution losses are not included in percent calculations, nor are Canadian imports. Variable renewable energy (VRE) curtailments are subtracted from wind and solar outputs to reflect the modelled VRE quantities off-taken to the bulk power sector. Biomass generation consists of the aggregate contributions from dedicated biomass-fueled power plants, landfill gas generation facilities, and biomass co-fired in coal power plants.

2030 State Renewable Generation
'Reference' Scenario

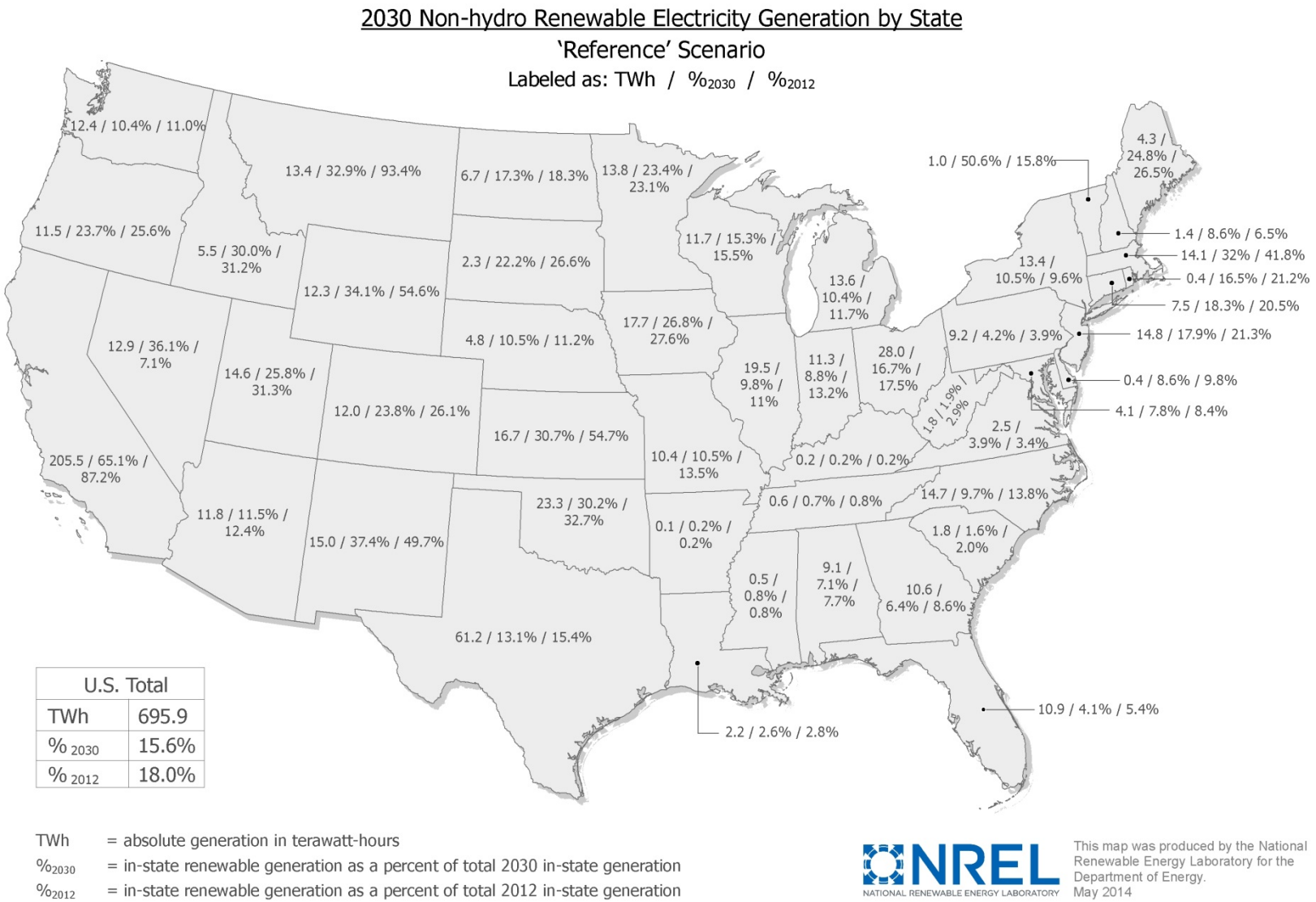
Wind-Solar-Geothermal Generation							
St	TWh	$\%_{2030}$	$\%_{2012}$	St	TWh	$\%_{2030}$	$\%_{2012}$
AL	0.2	0.2%	0.2%	NC	8.2	5.4%	7.7%
AR	0.1	0.1%	0.2%	ND	6.7	17.4%	18.4%
AZ	11.7	11.3%	12.2%	NE	4.8	10.5%	11.2%
CA	201.2	63.7%	85.3%	NH	0.6	3.8%	2.8%
CO	11.9	23.7%	25.9%	NJ	14.2	17.2%	20.4%
CT	6.7	16.1%	18.1%	NM	15.1	37.3%	49.6%
DE	0.4	8.0%	9.0%	NV	12.9	36.1%	37.1%
FL	6.4	2.5%	3.2%	NY	10.7	8.4%	7.7%
GA	1.3	0.8%	1.0%	OH	27.6	16.5%	17.3%
IA	17.6	26.6%	27.4%	OK	23.3	30.2%	32.8%
ID	5.4	29.3%	30.4%	OR	11.0	22.6%	24.4%
IL	18.8	9.5%	10.7%	PA	6.3	2.9%	2.7%
IN	11.1	8.7%	12.9%	RI	0.4	14.5%	18.7%
KS	16.7	30.7%	54.7%	SC	0.4	0.3%	0.4%
KY	0.2	0.2%	0.1%	SD	2.4	22.2%	26.7%
LA	1.1	1.3%	1.4%	TN	0.6	0.7%	0.8%
MA	12.9	29.3%	38.2%	TX	58.4	12.6%	14.7%
MD	3.5	6.7%	7.2%	UT	14.6	25.8%	31.2%
ME	0.8	4.8%	5.2%	VA	1.0	1.5%	1.3%
MI	11.5	8.8%	9.9%	VT	0.5	25.3%	7.9%
MN	11.3	19.1%	18.9%	WA	11.1	9.3%	9.8%
MO	9.8	9.9%	12.7%	WI	10.2	13.2%	13.4%
MS	0.1	0.1%	0.1%	WV	1.9	1.9%	2.9%
MT	13.4	32.9%	93.4%	WY	12.3	34.1%	54.6%

Wind-Solar-Geothermal –Biomass Generation							
St	TWh	$\%_{2030}$	$\%_{2012}$	St	TWh	$\%_{2030}$	$\%_{2012}$
AL	9.1	7.1%	7.8%	NC	14.8	9.8%	13.8%
AR	0.2	0.3%	0.3%	ND	6.7	17.4%	18.4%
AZ	11.9	11.5%	12.4%	NE	4.8	10.6%	11.2%
CA	205.6	65.1%	87.2%	NH	1.4	8.7%	6.5%
CO	12.0	23.9%	26.1%	NJ	14.9	18.0%	21.3%
CT	7.6	18.3%	20.6%	NM	15.1	37.4%	49.7%
DE	0.4	8.7%	9.8%	NV	12.9	36.1%	37.1%
FL	10.9	4.2%	5.4%	NY	13.5	10.5%	9.7%
GA	10.6	6.5%	8.6%	OH	28.0	16.7%	17.6%
IA	17.8	26.9%	27.7%	OK	23.3	30.2%	32.8%
ID	5.6	30.0%	31.2%	OR	11.6	23.8%	25.7%
IL	19.5	9.9%	11.1%	PA	9.2	4.2%	3.9%
IN	11.3	8.8%	13.2%	RI	0.5	16.5%	21.3%
KS	16.8	30.8%	54.8%	SC	1.9	1.7%	2.0%
KY	0.2	0.2%	0.2%	SD	2.4	22.2%	26.7%
LA	2.2	2.6%	2.8%	TN	0.6	0.7%	0.9%
MA	14.1	32.0%	41.8%	TX	61.2	13.2%	15.4%
MD	4.1	7.9%	8.5%	UT	14.7	25.8%	31.3%
ME	4.3	24.9%	26.5%	VA	2.5	4.0%	3.5%
MI	13.6	10.5%	11.8%	VT	1.1	50.6%	15.9%
MN	13.9	23.5%	23.2%	WA	12.4	10.4%	11.0%
MO	10.4	10.5%	13.5%	WI	11.8	15.3%	15.6%
MS	0.6	0.8%	0.9%	WV	1.9	2.0%	2.9%
MT	13.4	32.9%	93.4%	WY	12.3	34.1%	54.7%

TWh *= generation in TWh.* **$\%_{2030}$** *= in-state renewable generation as a percent of total 2030 in-state generation.* **$\%_{2012}$** *= in-state renewable generation as a percent of total 2012 in-state generation.*

Percent generation metrics utilize at-the-generator generation data. 2012 in-state generation is calculated in ReEDS. Transmission and distribution losses are not included in percent calculations, nor are Canadian imports. Variable renewable energy (VRE) curtailments are subtracted from wind and solar outputs to reflect the modelled VRE quantities off-taken to the bulk power sector. Biomass generation consists of the aggregate contributions from dedicated biomass-fueled power plants, landfill gas generation facilities, and biomass co-fired in coal power plants.

2030 State Renewable Generation
'Reference' Scenario



2020 State Renewable Generation
'Reduced RE Technology Costs' Scenario

	Wind-Solar-Geothermal Generation						
St	TWh	$\%_{2020}$	$\%_{2012}$	St	TWh	$\%_{2020}$	$\%_{2012}$
AL	0.0	0.0%	0.0%	**NC**	7.1	5.8%	6.7%
AR	0.0	0.0%	0.0%	**ND**	14.6	31.8%	39.9%
AZ	6.5	6.8%	6.8%	**NE**	1.6	3.7%	3.6%
CA	110.6	40.8%	46.9%	**NH**	0.5	3.8%	2.5%
CO	14.1	26.6%	30.7%	**NJ**	11.7	17.0%	16.8%
CT	5.7	13.6%	15.5%	**NM**	15.4	38.2%	50.7%
DE	0.2	4.3%	4.5%	**NV**	10.9	36.2%	31.2%
FL	0.7	0.4%	0.4%	**NY**	6.3	4.7%	4.5%
GA	0.3	0.1%	0.2%	**OH**	20.6	12.7%	12.9%
IA	15.4	24.0%	23.9%	**OK**	27.2	36.3%	38.2%
ID	4.0	23.0%	22.3%	**OR**	8.9	18.9%	19.7%
IL	11.9	6.5%	6.8%	**PA**	4.8	2.3%	2.1%
IN	5.2	4.2%	6.1%	**RI**	0.1	14.4%	4.3%
KS	16.6	37.3%	54.1%	**SC**	0.1	0.1%	0.1%
KY	0.0	0.0%	0.0%	**SD**	1.8	19.5%	20.4%
LA	0.6	0.8%	0.8%	**TN**	0.2	0.2%	0.2%
MA	7.8	20.2%	23.2%	**TX**	36.9	8.7%	9.3%
MD	3.0	5.9%	6.1%	**UT**	2.4	5.2%	5.2%
ME	0.6	4.0%	3.8%	**VA**	0.1	0.2%	0.1%
MI	9.4	7.6%	8.2%	**VT**	0.5	23.2%	7.1%
MN	9.1	16.0%	15.3%	**WA**	8.7	7.6%	7.7%
MO	6.0	7.0%	7.8%	**WI**	10.1	13.8%	13.4%
MS	0.0	0.0%	0.0%	**WV**	1.7	1.7%	2.6%
MT	2.2	7.8%	15.4%	**WY**	7.0	25.1%	31.2%

	Wind-Solar-Geothermal –Biomass Generation						
St	TWh	$\%_{2020}$	$\%_{2012}$	St	TWh	$\%_{2020}$	$\%_{2012}$
AL	6.4	6.2%	5.5%	**NC**	12.7	10.3%	11.8%
AR	0.1	0.1%	0.1%	**ND**	14.6	31.8%	39.9%
AZ	6.8	7.1%	7.1%	**NE**	1.6	3.8%	3.7%
CA	115.0	42.4%	48.8%	**NH**	1.3	8.6%	5.7%
CO	14.2	26.8%	30.9%	**NJ**	12.4	17.9%	17.8%
CT	6.6	15.8%	18.0%	**NM**	15.4	38.3%	50.9%
DE	0.2	5.0%	5.3%	**NV**	10.9	36.2%	31.3%
FL	4.0	2.0%	2.0%	**NY**	9.0	6.7%	6.4%
GA	4.6	2.6%	3.7%	**OH**	21.0	13.0%	13.1%
IA	15.4	24.1%	24.0%	**OK**	27.2	36.3%	38.2%
ID	4.1	23.8%	23.1%	**OR**	9.5	20.1%	21.0%
IL	12.6	6.9%	7.2%	**PA**	7.8	3.8%	3.3%
IN	5.5	4.4%	6.4%	**RI**	0.2	23.2%	6.9%
KS	16.6	37.4%	54.2%	**SC**	1.6	1.5%	1.7%
KY	0.1	0.1%	0.1%	**SD**	1.8	19.5%	20.4%
LA	1.7	2.1%	2.2%	**TN**	0.2	0.2%	0.3%
MA	9.1	23.3%	26.8%	**TX**	38.7	9.2%	9.7%
MD	3.6	7.0%	7.4%	**UT**	2.5	5.3%	5.3%
ME	3.4	21.5%	20.7%	**VA**	1.7	2.8%	2.3%
MI	11.6	9.4%	10.0%	**VT**	1.0	49.3%	15.1%
MN	11.7	20.5%	19.5%	**WA**	10.0	8.8%	8.9%
MO	6.2	7.3%	8.1%	**WI**	11.9	16.1%	15.7%
MS	0.5	0.7%	0.8%	**WV**	1.7	1.8%	2.6%
MT	2.2	7.8%	15.4%	**WY**	7.0	25.1%	31.2%

TWh *= generation in TWh.* **$\%_{2020}$** *= in-state renewable generation as a percent of total 2020 in-state generation.* **$\%_{2012}$** *= in-state renewable generation as a percent of total 2012 in-state generation.*

Percent generation metrics utilize at-the-generator generation data. 2012 in-state generation is calculated in ReEDS. Transmission and distribution losses are not included in percent calculations, nor are Canadian imports. Variable renewable energy (VRE) curtailments are subtracted from wind and solar outputs to reflect the modelled VRE quantities off-taken to the bulk power sector. Biomass generation consists of the aggregate contributions from dedicated biomass-fueled power plants, landfill gas generation facilities, and biomass co-fired in coal power plants.

2024 State Renewable Generation
'Reduced RE Technology Costs' Scenario

	Wind-Solar-Geothermal Generation						
St	TWh	$\%_{2024}$	$\%_{2012}$	St	TWh	$\%_{2024}$	$\%_{2012}$
AL	0.1	0.1%	0.1%	**NC**	11.5	8.5%	10.8%
AR	0.1	0.1%	0.1%	**ND**	14.7	31.4%	40.1%
AZ	9.7	9.9%	10.1%	**NE**	1.7	4.0%	3.9%
CA	197.2	65.4%	83.7%	**NH**	0.6	3.9%	2.7%
CO	16.1	29.4%	35.1%	**NJ**	13.8	18.6%	19.7%
CT	6.2	14.9%	16.7%	**NM**	17.8	41.8%	58.5%
DE	0.4	7.5%	8.5%	**NV**	12.2	47.3%	35.2%
FL	13.3	6.0%	6.6%	**NY**	7.9	6.0%	5.7%
GA	1.1	0.6%	0.9%	**OH**	23.2	14.2%	14.6%
IA	16.2	25.0%	25.2%	**OK**	30.3	40.1%	42.6%
ID	4.0	24.2%	22.4%	**OR**	10.3	23.5%	22.8%
IL	15.0	8.0%	8.5%	**PA**	6.1	2.9%	2.6%
IN	7.3	5.7%	8.5%	**RI**	0.3	12.1%	13.8%
KS	19.9	40.0%	65.1%	**SC**	1.9	1.7%	2.0%
KY	0.1	0.1%	0.1%	**SD**	1.9	19.3%	21.5%
LA	1.1	1.4%	1.4%	**TN**	0.4	0.4%	0.5%
MA	9.9	22.8%	29.3%	**TX**	58.0	13.3%	14.6%
MD	6.7	12.4%	13.8%	**UT**	13.2	24.6%	28.3%
ME	0.7	4.5%	4.4%	**VA**	0.5	0.8%	0.7%
MI	10.0	8.0%	8.6%	**VT**	0.5	25.2%	7.9%
MN	10.0	17.6%	16.7%	**WA**	9.6	8.3%	8.5%
MO	9.5	10.7%	12.3%	**WI**	10.6	14.2%	13.9%
MS	0.1	0.1%	0.1%	**WV**	1.7	1.8%	2.7%
MT	2.4	8.0%	16.4%	**WY**	7.8	25.9%	34.4%

	Wind-Solar-Geothermal –Biomass Generation						
St	TWh	$\%_{2024}$	$\%_{2012}$	St	TWh	$\%_{2024}$	$\%_{2012}$
AL	8.7	7.8%	7.4%	**NC**	17.4	12.8%	16.3%
AR	0.1	0.2%	0.2%	**ND**	14.7	31.4%	40.1%
AZ	9.9	10.2%	10.3%	**NE**	1.7	4.0%	4.0%
CA	201.6	66.9%	85.6%	**NH**	1.3	8.7%	6.1%
CO	16.2	29.6%	35.3%	**NJ**	14.4	19.5%	20.7%
CT	7.1	17.1%	19.2%	**NM**	17.8	41.9%	58.7%
DE	0.4	8.2%	9.3%	**NV**	12.2	47.4%	35.2%
FL	16.8	7.6%	8.4%	**NY**	10.6	8.1%	7.6%
GA	10.5	6.0%	8.5%	**OH**	23.6	14.4%	14.8%
IA	16.3	25.2%	25.5%	**OK**	30.3	40.1%	42.6%
ID	4.1	25.0%	23.2%	**OR**	10.9	24.8%	24.1%
IL	15.8	8.3%	9.0%	**PA**	9.0	4.3%	3.8%
IN	7.5	5.9%	8.8%	**RI**	0.4	14.4%	16.4%
KS	20.0	40.0%	65.2%	**SC**	3.3	3.1%	3.6%
KY	0.2	0.2%	0.2%	**SD**	1.9	19.3%	21.5%
LA	2.3	2.7%	2.9%	**TN**	0.4	0.5%	0.6%
MA	11.1	25.6%	32.9%	**TX**	59.7	13.7%	15.1%
MD	7.3	13.5%	15.1%	**UT**	13.3	24.7%	28.3%
ME	3.7	22.6%	22.5%	**VA**	2.1	3.5%	2.8%
MI	12.2	9.8%	10.5%	**VT**	1.1	50.5%	15.9%
MN	12.6	22.0%	21.0%	**WA**	11.0	9.5%	9.7%
MO	9.7	11.0%	12.7%	**WI**	12.2	16.4%	16.0%
MS	0.5	0.8%	0.8%	**WV**	1.7	1.8%	2.7%
MT	2.4	8.0%	16.4%	**WY**	7.8	26.0%	34.4%

TWh *= generation in TWh.* **$\%_{2024}$** *= in-state renewable generation as a percent of total 2024 in-state generation.* **$\%_{2012}$** *= in-state renewable generation as a percent of total 2012 in-state generation.*

Percent generation metrics utilize at-the-generator generation data. 2012 in-state generation is calculated in ReEDS. Transmission and distribution losses are not included in percent calculations, nor are Canadian imports. Variable renewable energy (VRE) curtailments are subtracted from wind and solar outputs to reflect the modelled VRE quantities off-taken to the bulk power sector. Biomass generation consists of the aggregate contributions from dedicated biomass-fueled power plants, landfill gas generation facilities, and biomass co-fired in coal power plants.

2030 State Renewable Generation
'Reduced RE Technology Costs' Scenario

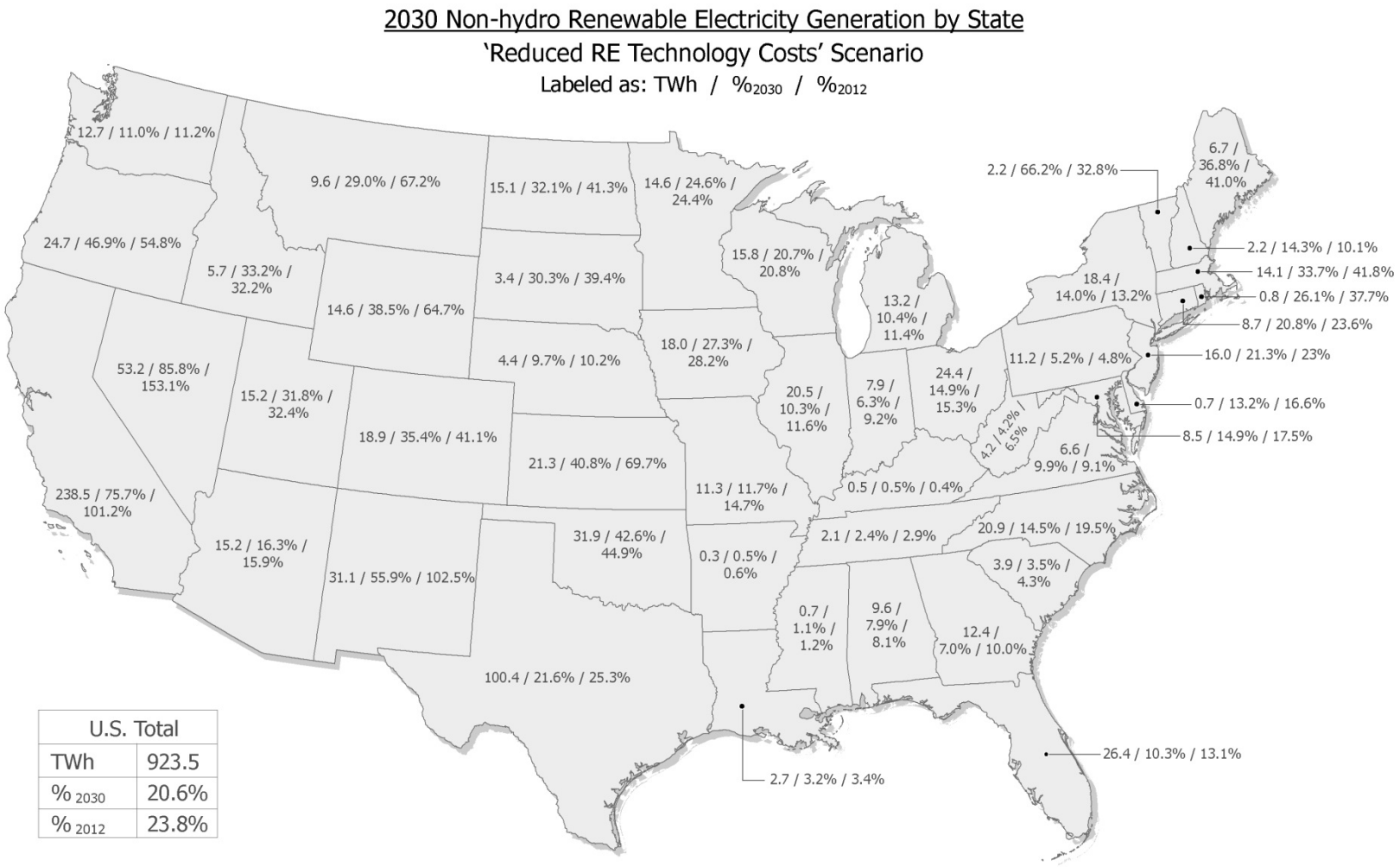
	Wind-Solar-Geothermal Generation						
St	TWh	$\%_{2030}$	$\%_{2012}$	St	TWh	$\%_{2030}$	$\%_{2012}$
AL	0.7	0.5%	0.6%	**NC**	14.4	10.0%	13.5%
AR	0.3	0.5%	0.5%	**ND**	15.1	32.1%	41.4%
AZ	15.0	16.1%	15.7%	**NE**	4.4	9.7%	10.2%
CA	234.2	74.3%	99.3%	**NH**	1.4	9.2%	6.5%
CO	18.8	35.3%	41.0%	**NJ**	15.4	20.5%	22.0%
CT	7.8	18.7%	21.2%	**NM**	31.1	55.9%	102.4%
DE	0.7	12.6%	15.9%	**NV**	53.2	85.8%	153.1%
FL	22.4	8.8%	11.2%	**NY**	15.8	12.0%	11.3%
GA	3.0	1.7%	2.5%	**OH**	24.0	14.7%	15.1%
IA	17.9	27.1%	28.0%	**OK**	32.0	42.6%	44.9%
ID	5.6	32.4%	31.5%	**OR**	24.2	45.9%	53.6%
IL	19.8	10.0%	11.2%	**PA**	8.3	3.8%	3.5%
IN	7.7	6.2%	9.0%	**RI**	0.8	24.3%	35.2%
KS	21.3	40.8%	69.6%	**SC**	2.5	2.2%	2.7%
KY	0.4	0.4%	0.4%	**SD**	3.5	30.4%	39.4%
LA	1.6	1.9%	2.0%	**TN**	2.1	2.4%	2.9%
MA	12.9	30.8%	38.2%	**TX**	97.6	21.1%	24.6%
MD	7.9	13.9%	16.3%	**UT**	15.2	31.8%	32.4%
ME	3.2	17.7%	19.7%	**VA**	5.1	7.6%	7.0%
MI	11.1	8.7%	9.6%	**VT**	1.7	50.5%	25.0%
MN	12.1	20.3%	20.1%	**WA**	11.3	9.8%	10.0%
MO	11.1	11.5%	14.4%	**WI**	14.2	18.6%	18.7%
MS	0.3	0.5%	0.5%	**WV**	4.2	4.3%	6.6%
MT	9.7	29.1%	67.2%	**WY**	14.6	38.6%	64.7%

	Wind-Solar-Geothermal –Biomass Generation						
St	TWh	$\%_{2030}$	$\%_{2012}$	St	TWh	$\%_{2030}$	$\%_{2012}$
AL	9.6	7.9%	8.2%	**NC**	21.0	14.5%	19.6%
AR	0.4	0.6%	0.7%	**ND**	15.1	32.1%	41.4%
AZ	15.3	16.3%	16.0%	**NE**	4.4	9.7%	10.2%
CA	238.5	75.7%	101.2%	**NH**	2.2	14.4%	10.2%
CO	18.9	35.4%	41.2%	**NJ**	16.1	21.4%	23.0%
CT	8.7	20.8%	23.7%	**NM**	31.1	56.0%	102.6%
DE	0.8	13.2%	16.7%	**NV**	53.2	85.9%	153.2%
FL	26.4	10.4%	13.2%	**NY**	18.5	14.1%	13.3%
GA	12.4	7.0%	10.1%	**OH**	24.4	15.0%	15.3%
IA	18.1	27.4%	28.2%	**OK**	32.0	42.6%	44.9%
ID	5.8	33.2%	32.3%	**OR**	24.7	47.0%	54.9%
IL	20.5	10.4%	11.6%	**PA**	11.3	5.2%	4.8%
IN	7.9	6.4%	9.3%	**RI**	0.9	26.1%	37.8%
KS	21.3	40.8%	69.7%	**SC**	4.0	3.5%	4.3%
KY	0.5	0.5%	0.5%	**SD**	3.5	30.4%	39.4%
LA	2.7	3.2%	3.5%	**TN**	2.2	2.4%	2.9%
MA	14.1	33.7%	41.8%	**TX**	100.4	21.7%	25.3%
MD	8.5	15.0%	17.6%	**UT**	15.2	31.9%	32.5%
ME	6.7	36.9%	41.1%	**VA**	6.7	10.0%	9.1%
MI	13.3	10.4%	11.5%	**VT**	2.2	66.2%	32.8%
MN	14.6	24.6%	24.4%	**WA**	12.7	11.0%	11.3%
MO	11.3	11.8%	14.8%	**WI**	15.8	20.7%	20.9%
MS	0.8	1.2%	1.2%	**WV**	4.2	4.3%	6.6%
MT	9.7	29.1%	67.2%	**WY**	14.6	38.6%	64.7%

TWh *= generation in TWh.* **$\%_{2030}$** *= in-state renewable generation as a percent of total 2030 in-state generation.* **$\%_{2012}$** *= in-state renewable generation as a percent of total 2012 in-state generation.*

Percent generation metrics utilize at-the-generator generation data. 2012 in-state generation is calculated in ReEDS. Transmission and distribution losses are not included in percent calculations, nor are Canadian imports. Variable renewable energy (VRE) curtailments are subtracted from wind and solar outputs to reflect the modelled VRE quantities off-taken to the bulk power sector. Biomass generation consists of the aggregate contributions from dedicated biomass-fueled power plants, landfill gas generation facilities, and biomass co-fired in coal power plants.

2030 State Renewable Generation
'Reduced RE Technology Costs' Scenario



U.S. Total	
TWh	923.5
% 2030	20.6%
% 2012	23.8%

TWh = absolute generation in terawatt-hours

$\%_{2030}$ = in-state renewable generation as a percent of total 2030 in-state generation

$\%_{2012}$ = in-state renewable generation as a percent of total 2012 in-state generation

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This map was produced by the National Renewable Energy Laboratory for the Department of Energy.
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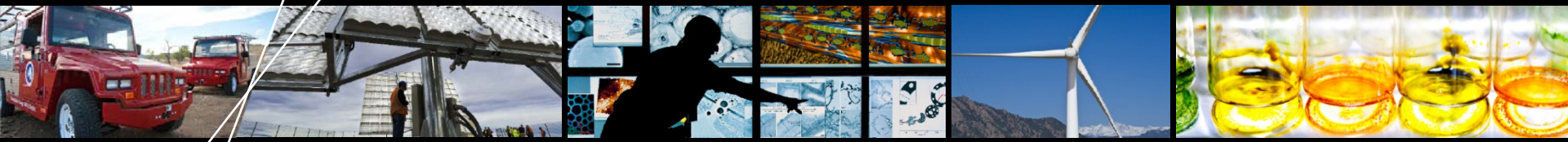

Please direct questions and comments to:

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