Renewable Energy Deployment in Colorado and the West: A Modeling Sensitivity and GIS Analysis

Clayton Barrows, Trieu Mai, Scott Haase, Jennifer Melius, and Meghan Mooney
National Renewable Energy Laboratory

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Foreword

The Bureau of Land Management (BLM) is pleased to present this solar and wind energy analysis for the State of Colorado as completed by the National Renewable Energy Laboratory (NREL). BLM has completed national programmatic studies over the last decade to most effectively allocate public lands in several regions, including Colorado, for the generation of utility-scale solar and wind projects. BLM is aware that there exist complex drivers of solar and wind energy development and renewable energy capacity expansion that encompass both private and public lands, broader energy markets, transmission infrastructure, and such federal and/or state policies as climate change adaptation and renewable energy portfolio standards (RPS), among others. BLM requested an NREL solar and wind energy potential modeling analysis based on varied scenarios and their interpretation at a necessary geographic scale to help the agency and general public understand where in the Colorado landscape solar and wind energy could develop during the next 15-years. The enclosed study provides the framework for a deeper predictive understanding of renewable energy expansion based on business as usual, natural gas prices, increased RPS, and carbon price scenarios with specific focus on the BLM Eastern Colorado Resource Management Planning Area.

List of Acronyms

AEO	Annual Energy Outlook
BA	balancing area
BLM	U.S. Bureau of Land Management
CSP	Concentrating Solar Power
DOE	U.S. Department of Energy
EPA	Environmental Protection Agency
ECRMP	BLM Eastern Colorado Resource Management Plan
GAMS	General Algebraic Modeling System
GIS	Geographic Information System
NERC	North American Electric Reliability Corporation
NG	natural gas
NREL	National Renewable Energy Laboratory
PSCO	Public Service Company of Colorado
PV	photovoltaic
RGFO	Royal Gorge Field Office
RMP	Resource Management Plan
RPM	Resource Planning Model
RPS	Renewable Portfolio Standard
TEPPC	Transmission Expansion Planning Policy Committee
TES	Thermal Energy Storage
VG	variable generation
WACM	Western Area Power Administration, Colorado, and Missouri BA
WECC	Western Electricity Coordinating Council
WWSIS	NREL Western Wind and Solar Integration Study

Glossary

Alternating Current (AC)	The standard for electricity transmission, where the flow of electric charge periodically reverses direction
Balancing Area	Regional grouping of generators, loads and transmission lines whereby aggregate generation and load are balanced (also referred to as Balancing Authority Area)
Balancing Authority	Responsible party for balancing load and generation within a balancing area
Boundary interactions	see Interregional Flows
Buses	see Electrical Buses
Capacity	The maximum generating capability of a generating unit
Capacity Credit	The fraction of a generating unit's nameplate capacity counted towards meeting system reliability reserves
Capacity Expansion Model	Computational tool used to simulate electric system deployment
Combined Cycle (CC, NG-CC)	A power plant where a combustion turbine and steam turbine are combined and fueled by natural gas
Combustion Turbine (CT, NG-CT)	A natural gas fired power plant driven by an internal combustion engine with an upstream rotating compressor and a downstream turbine
Curtailment	Unused energy, usually from variable generation sources
Cycling	An electrical generator's transition between online and offline status
Direct Current (DC)	The unidirectional flow of electric charge. Direct current is produced by photovoltaic and battery devices
Dispatch modeling	see Operations Modeling
Electrical buses	Electric network node, representing transmission line connections, generator connection point, or substation
Electric infrastructure	Physical electric system components (transmission lines, generators, transformers, substations, etc.)
Electric network	The electric grid, composed of transmission lines, transformers, and substations that transport electricity between generators and loads
Fixed tilt photovoltaic	Solar photovoltaic generators mounted on a tilted, non-tracking structure
GIS analysis	Geographic Information System analysis to enhance location-based result description
Grid	see Electric Network

Load	Electricity demand
Megawatt (MW)	The standard unit of measure of power (e.g., for a power plant output)
Operating reserve requirements	Generation scheduling requirements to maintain reliable system operations
Operational constraints	Constraints that govern electric system operation (e.g., generator and transmission line operating parameters, security constraints, physical laws)
Operations modeling	Simulation of generator scheduling for hourly operation to maintain balanced generation and load and system reliability
Photovoltaic (PV)	Semiconductor-based technology that converts solar energy into electricity
Power system	The system, comprised of electrical infrastructure components, that serves to convert and deliver energy in the form of electrical power
Reliability (electric)	The ability of the electric system to continue uninterrupted service
Renewable capacity expansions	Renewable generation capacity deployment
Renewable generation	Electricity generation from resources that are naturally replenished on human timescales
Renewable resources	The location-dependent energy resources that could potentially be utilized to generate electricity through renewable generation technologies
Renewable interconnection cost	The cost associated with connecting a renewable generating facility with existing infrastructure (based on distance between renewable generation site and interconnection bus)
Single-axis tracking photovoltaic	Solar photovoltaic generators mounted on a structure that rotates along one axis designed to track the daily relative motion of the sun and the earth
Transmission congestion	The inability of the electrical grid to facilitate additional electricity transmission due to transmission line flow limits
Utility service territory	The load buses served by an electrical utility or load serving entity
Utility-scale generation	Ground mounted generation connected directly to the electrical transmission system (not connected through a distribution feeder).
Variable generation	Electrical generation that depends upon variable energy sources (e.g. wind and solar generation)
Western Electric Coordinating Council	WECC—the regional entity that exists to assure a reliable electric system for the Western Interconnection power system

Executive Summary

Future renewable power plant development in Colorado will be determined by a combination of market and policy demands as well as the economic competitiveness of renewable technologies relative to other generation options, such as natural gas. However, the amount of renewable generation capacity deployed is driven by the availability and quality of local energy resources and their relative location to transmission infrastructure or metropolitan and other areas with high electricity consumption. An informed outlook of the future electricity system in Colorado will require detailed considerations of these dynamics and constraints. Such an outlook can be useful for utility and land planners in assessing investment and policy decisions over the next two decades.

The Royal Gorge Field Office of the U.S. Department of Interior's Bureau of Land Management (BLM) commissioned the National Renewable Energy Laboratory (NREL) to conduct an assessment of potential trends in future renewable energy technology development within the state of Colorado. BLM requested analysis to help the agency and general public understand the locations of potential solar and wind energy developments over a 15-year horizon in Colorado. This analysis uses a combination of electric system capacity expansion modeling and geographic information system (GIS) tools and is intended to help inform the BLM during the multi-year development of a new Eastern Colorado Resource Management Plan (ECRMP).[1] RPM results highlight trends in Colorado that will help BLM identify areas to consider for renewable energy development allocations in resource management plans.

More specifically, our analysis highlights regions within Colorado where future utility-scale wind and solar generation development might take place based on scenarios developed using NREL's Resource Planning Model (RPM). We use RPM to simulate multiple scenarios of the future power system in Colorado and the U.S. West through 2030. These scenarios include a Reference scenario and scenarios that span a range of potential natural gas price projections developed by the U.S. Energy Information Administration (EIA). On the low end, this range captures a future where delivered natural gas prices remain below $4/MMBtu for all years through 2030 and on the high end, natural gas prices consistently grow after 2015, reaching about $8/MMBtu in 2030.[2] We also model two scenarios that represent proxies for future energy policies that would support a move towards renewable or other low-carbon generation: a scenario wherein CO_2 prices grow to about $32 per metric ton CO_2 by 2030 and a scenario with an effective 50% renewable energy standard in Colorado that would be achieved by 2030. These scenarios do not imply any policy recommendations, but are modeled to assess—as is common in utility portfolio planning—how renewable development might increase given heightened policy support for lower-carbon generation.[3] More generally, none of the scenarios should be interpreted as predictions or forecasts from NREL or the U.S. Department of Energy.

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[1] The ECRMP region consists of land areas in Colorado east of the continental divide.

[2] Unless otherwise noted, we use real 2010 dollars throughout.

[3] The modeling analysis included energy policies and regulations as of January 1, 2015. As such, it does not include the EPA's CPP finalized in August 2015, nor does it include the extended federal renewable energy tax credits passed in December 2015. Future work is needed to assess the impacts of these policies on renewable development in Colorado.

RPM is designed to represent the integrated effects of multiple complex factors (e.g., load growth, plant retirements, policy demands, renewable grid integration, etc.) that will affect electric infrastructure investments. However, it does not consider factors outside the sector such as the impact on local employment, productivity, health, ecological impact, or other more general economic interactions. Additionally, RPM does not capture differences in permitting, siting, and other challenges associated with land ownership types (e.g., public, private, BLM).

We supplement the RPM analysis with a GIS analysis that enables visual inspection of model results and development opportunities on lands categorized under four distinct ownership types: BLM-administered, non-BLM federal, private, and other.[4] To this end we analyze RPM-generated future portfolios in the context of three different land development preference assumptions. These assumptions specify which land types are used for renewable generation capacity development in order of priority:

- Proportional preference. Assumes that new generation capacity simulated in the RPM scenarios is built on each of the four categories of land ownership *proportional* to the distribution of suitable land area of each ownership type within each model region.

- BLM preference. Assumes that development takes place with the following priority order: BLM-administered land, non-BLM federal, other[4], and private land.

- Private preference. Assumes that development takes place with the following priority order: private land, other, non-BLM federal, and BLM-administered lands.

The purpose of these land development preference assumptions is to provide a reasonable range of BLM-administered land areas that could be used for future renewable development. Application of the land development preference assumptions provides bounding estimates of the possible land area requirements for renewable development within each of the four land ownership categories across all modeled scenarios. In addition to the GIS assessment of the RPM scenario results, we also present high-resolution GIS-based data of suitable land areas for wind and solar development and their proximity to existing transmission infrastructure for multiple regions within Colorado.

Key findings:

- In the modeled scenarios, RPM finds that new capacity additions are dominated by renewable technologies across the Western Interconnection and in Colorado:
    - Under a Reference scenario in the Western Interconnection, 35,000 MW of new wind and 48,000 MW of new solar capacity are estimated between 2011 and 2030. Wind and solar are estimated to produce 19% of all generation in 2030.
    - Wind technologies comprise the dominant share of all new Colorado capacity with 4,428 MW of new wind during 2011-2030 (1,558 MW of new solar) in the

[4] "Other" land ownership includes jointly owned, non-governmental organization, regional/local, state, tribal, and unknown.

Reference scenario. In 2030, wind and solar are estimated to contribute 30% of Colorado in-state generation.

- The low gas price sensitivity yields similar results to the Reference scenario; however, under higher gas prices, much greater renewable development is observed. Under the High Gas price scenario, 6,395 MW of new wind and 2,638 MW of new solar is estimated between 2011 and 2030 in Colorado.

- The clean energy policy sensitivities explored show greater renewable technology development. Under the scenario which imposes a CO_2 price, we find 10,002 MW of new wind and 1,635 MW of new solar in Colorado by 2030. With an expanded (50% by 2030) renewable requirement, we estimate 5,758 MW of new wind and 1,572 MW of new solar in Colorado.

- Across all modeled scenarios, the geographic distribution of new renewable capacity additions in Colorado is limited to a relatively few resource regions within the state where the resource quality is high.

  - New utility-scale solar capacity additions are estimated to take place predominantly in the southern part of the state, e.g., in the San Luis Valley. (Rooftop PV installations are more widespread, but are assumed to be somewhat concentrated in the relative population-dense Front Range.)

  - New wind capacity additions are concentrated in the northeast and, to a lesser degree, southeast regions of the state.

- The amount of Colorado land area needed to accommodate new renewable capacity additions through 2030 range from 336,000 to 824,000 acres across all five modeled scenarios.

  - In the ECRMP region (Eastern Colorado), the estimated use of most of the required land area is for wind development. For example, under the highest wind development scenario (CO_2 price scenario), 822,000 acres of land are needed for wind development.

  - Wind development is consistently estimated in and near Huerfano County across all scenarios due to the region's high-quality wind resource potential and proximal location of existing transmission infrastructure.

  - Under most scenarios, a more limited amount of land area is needed for utility-scale solar development (~450 acres in all of Colorado). With high natural gas prices, land area requirements for solar grows to 4,181 acres in the state; however, the vast majority of this area is outside the ECRMP region.

- The greatest opportunities for renewable energy development appear to exist on private lands. BLM-administered lands are not necessarily needed to accommodate new renewable capacity additions across any of the scenarios in any of the regions.

- When prioritizing private lands, no BLM-administered lands will be needed to accommodate future renewable development estimated in the RPM scenarios.
- On the other hand, when applying a BLM preference to land development, we find that the most aggressive RE development scenario (CO_2 price scenario) could use up to 53,600 acres of BLM land in Colorado, of which 52,000 acres are in the ECRMP region, to support new renewable (primarily wind) capacity additions.
- A proportional distribution of land ownership preferences would lower estimated BLM land area for renewable development to up to 1,070 acres in Colorado, virtually all of which is in the ECRMP region.

- The limited *need* for BLM-administered lands to be used for renewable capacity additions can be explained through the relative difference in the amount of renewable-suitable land areas that are BLM-administered and privately owned.
  - BLM-administered, wind-suitable land area within 10 miles of the nearest transmission infrastructure totals 45,000 acres (capable of supporting ~500 MW) in the ECRMP region compared to 9,000,000 acres (capable of supporting 100,000 MW) that are privately owned.
  - BLM-administered, utility-scale, solar-suitable land area within 10 miles of the nearest transmission infrastructure totals 16,000 acres in the ECRMP region compared to 10,000,000 acres of private land.

These findings are derived using the methodologies and assumptions presented in the report. Our methods do not attempt to comprehensively consider the siting or permitting steps undertaken to develop renewable or other power generation capacity. In addition, energy policies and markets often evolve rapidly, and thus uncertainties in the effects of markets and policies on renewable generation deployment exist over the full study horizon. Because of these limitations and uncertainties, as well as other caveats associated with the methods, the local development estimates should not be considered predictive forecasts of renewable energy deployment, but rather scenarios exploring how market and policy conditions will impact future renewable energy deployment. Nonetheless, our analysis identifies some general trends that could help inform electric infrastructure and land planning in and around the state of Colorado.

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1 Introduction

The United States Bureau of Land Management (BLM) is responsible for managing public lands and natural resource values. The BLM develops comprehensive land use plans called Resource Management Plans (RMP) to guide management decisions and actions on BLM-administered public lands. Currently, the Royal Gorge Field Office of the BLM is in the multi-year process of developing a new Eastern Colorado Resource Management Plan (ECRMP). This plan will address the full range of activities that occur on public lands, including off-highway vehicle (OHV) use, wildland fire management, wildlife management, mineral development, and livestock grazing. RMPs also direct management of areas on public lands that require special protection, such as areas of critical environmental concern (ACECs), research natural areas (RNAs), and potential additions to the National Wild and Scenic River (WSR) System. Renewable energy development is one of the aspects that will be analyzed in the RMP and this report will help inform the decisions that are made by highlighting likely trends for renewable energy deployment within Colorado.

Recent and anticipated trends indicate that renewable resources, particularly wind and solar energy, will continue to provide a growing contribution to the Colorado and western United States power systems (Mai et al. 2012; WECC 2011a). These renewable resources are variable and uncertain by nature and their geographical distribution and potential impacts on electric system expansion and operation need to be properly accounted for in electric system planning models.

The National Renewable Energy Laboratory's (NREL's) Resource Planning Model (RPM) has high spatial and temporal resolution that can be used for mid- and long-term scenario planning of regional power systems across broad geographic regions. RPM simulates the addition of new generation and transmission to meet projected future electricity demand reliably and at the least cost, subject to a set of constraints and assumptions that define the future scenario being modeled. A detailed description of RPM is provided by Mai et al. (2015) and the modeling assumptions used in this study can be found in Section 2.

As a part of the multi-year BLM RMP process, this study was requested by the ECRMP planning staff to analyze a suite of issues around renewable energy deployment in Colorado, including:

- Potential demand for renewable energy[5] in Colorado between 2015 and 2030, and the geographic regions of the state where future renewable energy and transmission corridor enhancement is likely to take place based on a number of factors including resource potential, access to load, access to existing transmission and corridors, and overall costs of production.

[5] RPM simulations and analysis focus on utility-scale renewable energy deployment. For the analysis presented here, the model simulates deployment of land-based wind, and utility-scale solar. While geothermal, hydropower, biopower and other renewable technology deployment are all possible; they have not received the same level of deployment in recent years and their expansion is not modeled in RPM. For rooftop solar power, we use an exogenously-defined deployment projection from a separate model (Sigrin et al. forthcoming).

- The suitability and potential likelihood that some of those future renewable energy and/or transmission projects might be sited on BLM surface lands within Colorado in general and the ECRMP planning region in particular.

- How future changes in state or federal policies, or fuel prices (e.g., Colorado's Renewable Portfolio Standard increases to 40%, a range of environmental policies, a range of natural gas prices) impact the potential need for renewables and transmission.

We model two balancing areas (BAs) that maintain electricity supply-demand balance in and around Colorado (see Table 1): Public Service Company of Colorado (PSC), and Western Area Colorado Missouri (WACM).[6] A description of the model, including the structure and definition of the geographic regions, key assumptions used, and detail on how the optimizes expansion and operation of the electricity system is presented in Section 2. A description of the scenarios exploring a range of future natural gas prices and energy and environmental policies is presented in Section 3. The analysis, summarized in Section 4, focuses on 2015-2030 planning scenarios for renewable technology deployment on BLM lands within Colorado. Additional regional detail is provided in the Appendix. We conclude in Section 5.

[6] The WACM and PSC balancing areas include regions and infrastructure from rural electric cooperatives and other load-serving entities in Colorado and neighboring states.

2 Resource Planning Model (RPM) Description

The NREL's Resource Planning Model (RPM) simulates the evolution of regional electric power systems. The model represents the capitol and operational costs associated with building and operating electrical infrastructure. RPM draws from a variety of datasets to represent existing electricity generation and transmission infrastructure, land use and availability, weather patterns, demand and cost projections, and energy and environmental policies and regulations. Model results can be used to analyze the effects of policy, technology advancement, and economic futures in terms of the type and location of electricity production and new infrastructure. Descriptions of RPM structure, scope, inputs, and assumptions are included in the remainder of this section.

2.1 General Model Framework

The NREL's Resource Planning Model (RPM) is a capacity expansion model designed for a regional power system, such as a utility service territory, state, or balancing authority. It includes an optimization model that finds the least-cost investment and dispatch solution over a 20-year horizon. The model investment decisions are made for multiple conventional and renewable generation technologies, storage technologies, and transmission. The model uses a highly spatially disaggregated representation of grid infrastructure and generation resources (down to the individual unit and line) and multiple solar and wind spatial resource regions. Dispatch modeling within RPM is conducted using hourly time-steps sampled throughout a year, and the model considers energy balance, reserves, and many generator performance and operational constraints. Transmission constraints are represented with a transport (pipe-flow) model. RPM is designed for analysis that focuses on a specific region while maintaining a representation of inter-regional transactions. A simplified representation of the rest of the interconnection in which the region of interest resides is included in the model to account for boundary interactions. We designed RPM specifically to consider the characteristics of wind and solar technology resources—that is, location-dependence, variability, and uncertainty—in its investment decisions; it accounts for renewable interconnections, endogenously-estimated capacity credits, increased operating reserve requirements, curtailment, transmission congestion, and cycling costs.

RPM formulates an optimization problem that minimizes overall system cost, including capital costs, fixed and variable operation and maintenance (O&M) costs, fuel costs, and start-up costs. All costs in the objective function, including operating costs (e.g., fuel and variable O&M costs) and fixed costs (e.g., amortized capital and fixed O&M costs), are annualized. Several constraints are designed to characterize power plant operation, transmission dispatch, grid reliability, and capacity expansion. Sections 2.2, 2.3, and 2.4 summarize the key features of the model and highlight those that differ from the version described in (Mai et al. 2013).

2.2 Model Structure and Initial Conditions

RPM models the Western Interconnection electricity system, which includes all or parts of 13 western states in the United States, two western provinces in Canada, and a small northern region of Mexico. Data from modeling in the Western Wind and Solar Integration Study (WWSIS)

Phase 2 study (Lew et al. 2013)[7] comprise the underlying data for the existing (2010) infrastructure modeled in RPM.[8] These data include 17,521 nodes, 4,300 generation units, and 21,086 transmission lines.[9] While the spatial extent of RPM covers a wide geographic area, the model is designed for a particular "focus region," with all other regions treated in a simplified manner; that is, RPM is a combined nodal (for nodes within the focus region) and zonal model (for zones outside the focus region). For this analysis, we use a Colorado-centric focus region that includes PSC and WACM balancing areas. Figure 1 shows the zonal structure of BAs outside the focus region along with the nodal structure within the Colorado-centric focus region. Nodes represent electrical buses connected to individual generators and loads, or buses that serve as connection points between transmission elements, e.g., transmission lines and transformers. There are 36 model BAs throughout the Western Interconnection (see Table 1). For this study, we aggregate nodes within the 34 BAs outside of the Colorado-centric focus region to form the zones.[10]

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[7] The WWSIS Phase 2 study relied on data from the Western Electricity Coordinating Council (WECC) Transmission Expansion Planning Policy Committee (TEPPC) 2020 Common Case (WECC 2011b) with updates from the TEPPC 2022 Common Case (WECC 2013) along with other revisions as described by (Lew et al. 2013).
[8] While the model start year begins in 2010, the data for the 2015 solve year includes many recent capacity additions and retirements. In addition, our analysis is primarily focused on 2015-2030.
[9] Only transmission lines greater than 69 kV are included in the database.
[10] In addition to zonal transmission treatment, generators are aggregated for most technology types for each BA zone to further simplify the model outside of the focus region.

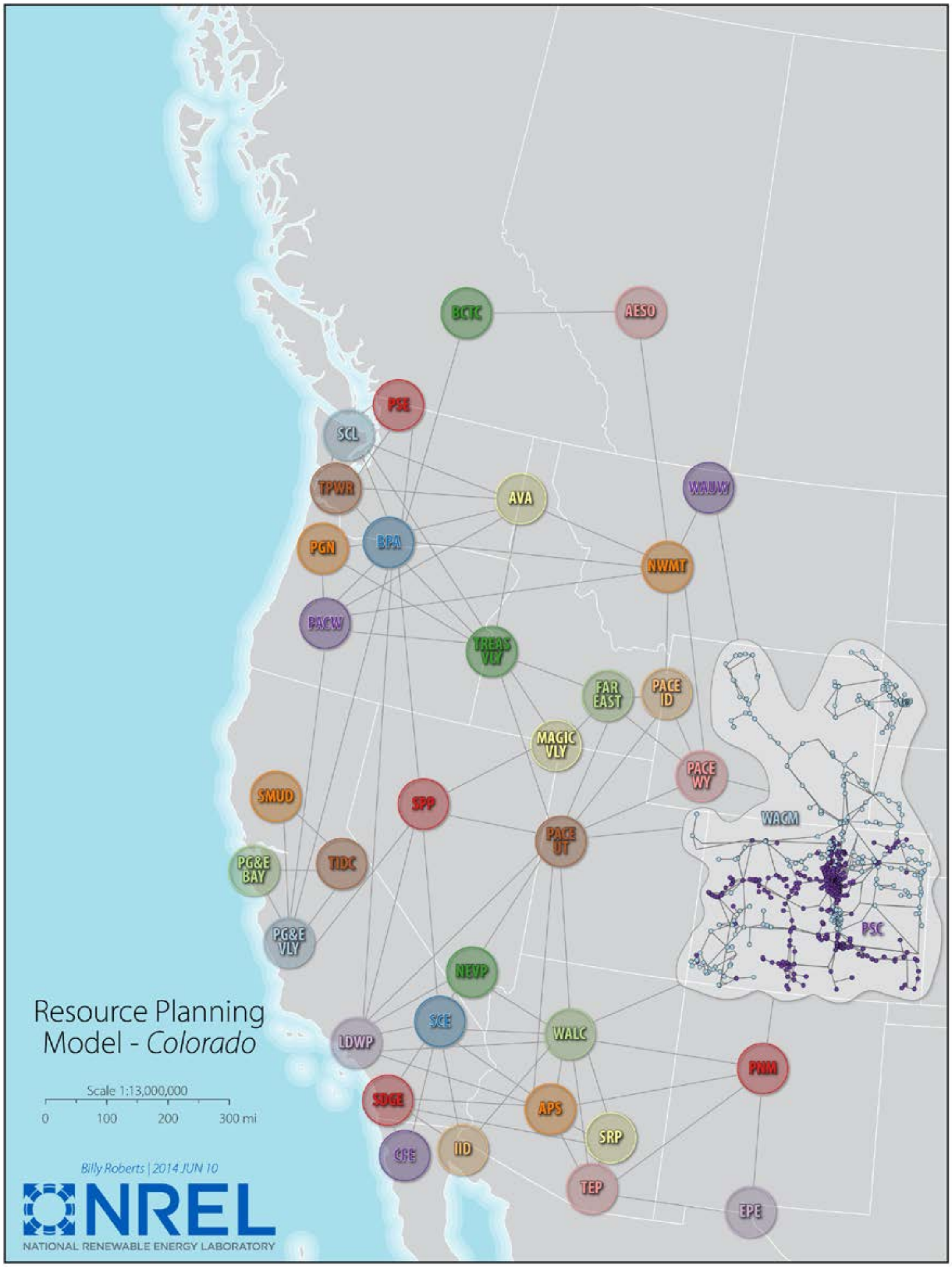

Figure 1. Combined zonal/nodal structure used for the CO-centric version of RPM

Table 1. Balancing Areas (BAs) Modeled in the Resource Planning Model

Focus Region BAs		Other BAs			
PSC	Public Service Company of Colorado	AESO	Alberta Electric System Operator	PG&E_BAY	Pacific Gas & Electric Bay Area
WACM	Western Area Power Administration Colorado/Missouri	APS	Arizona Public Service	PG&E_VLY	Pacific Gas & Electric Valley Area
		AVA	Avista	PGN	Portland General Electric
		BCTC	British Columbia Transmission Corporation	PNM	Public Service New Mexico
		BPA	Bonneville Power Administration	PSE	Puget Sound Energy
		CFE	Comisión Federal de Electricidad	SCE	Southern California Edison
		EPE	El Paso Electric Company	SCL	Seattle City Light
		FAR_EAST	Far East	SDGE	San Diego Gas & Electric
		IID	Imperial Irrigation District	SMUD	Sacramento Municipal District
		LDWP	Los Angeles Department of Water and Power	SPP	Sierra Pacific Power
		MAGIC_VLY	Magic Valley	SRP	Salt River Project
		NEVP	Nevada Power	TEP	Tucson Electric Power
		NWMT	Northwestern Montana	TIDC	Turlock Irrigation District
		PACE_ID	Pacificorp East – Idaho	TPWR	Tacoma Power
		PACE_UT	Pacificorp East Utah	TREAS_VLY	Treasure Valley
		PACE_WY	Pacificorp East Wyoming	WALC	Western Area Power Administration Lower Colorado
		PACW	Pacificorp West	WAUW	Western Area Power Administration Upper Missouri

For our analysis, the focus region includes the PSC and WACM BAs. Throughout the report, we refer to this region as the CO-centric focus region, because these two balancing authorities primarily serve loads in Colorado (CO).[11] The CO-centric focus region includes 1,406 nodes and 1,840 transmission lines, and includes 376 individual generators representing a total of 16,805 MW of installed capacity during the model start year (2010). Outside the focus region, 34 model BAs are represented zonally. The entire Western Interconnection system includes 224,244 MW of generating capacity for the model start year. Interactions between BAs are constrained by interface limits assumed by (Lew et al. 2013). Interactions between nodes within the focus region consider nodal transmission constraints defined by the thermal power flow limits on transmission lines. Figure 1 shows the combined zonal and nodal structure of RPM and the Colorado-centric focus region analyzed here.

Table 2 shows the capacity mix by technology category as represented in RPM for the 2010 start year for the focus region and the entire Western Interconnection. Note that while the technology categories are generalized in Table 2, individual unit characteristics (e.g., ramp rates, heat rates, and maximum generation points) from (Lew et al. 2013) are used in RPM explicitly for the focus region and averaged by technology category for the BAs in the rest of the Western Interconnection.

[11] The PSCO and WACM BAs also include nodes in Wyoming, Montana, Nebraska, South Dakota, and Utah.

Table 2. Start Year (2010) Capacity in RPM[12]

Generator Type	PSCO and WACM Focus Region (MW)	Entire Western Interconnection (MW)
Coal	7,331	38,529
Coal Cogeneration	0	289
Natural Gas Combined Cycle (NG-CC)	2,778	45,505
Natural Gas Combustion Turbine (NG-CT)	3,223	16,659
Gas Cogeneration	0	3,821
Gas Steam	222	19,601
Nuclear	0	9,681
Biomass	0	1,559
Geothermal	0	3,054
Hydropower – Fixed	1,188	17,395
Hydropower – Flexible	87	52,593
Pumped Hydropower Storage	560	3,787
Solar Photovoltaic (PV) – Fixed-Tilt	8	74
Solar PV – Single-Axis Tracking	0	0
Solar PV – Rooftop	3	1,098
Concentrating Solar Power (CSP) without Thermal Energy Storage (TES)	0	428
CSP with TES	0	0
Wind	1,405	10,171
Total	16,805	224,244

In addition to nodes and model BAs, RPM includes additional spatial layers to represent the resource potential and electricity production capability of solar and wind technologies. These renewable generation resources are considered by RPM as options to meet future electrical load, subject to capital, interconnection, and operations costs. To apply greater resolution to the CO-centric focus region, the focus region contains 40 solar and 40 wind resource regions (see Figure 2) while the remaining 60 solar and 60 wind regions reside in the rest of the Western Interconnection. Renewable resource potential (in acres of land area), performance (annual and hourly capacity factors), and grid interconnection distances are used to characterize the solar or wind resources available for capacity expansion in each renewable region.[13] A detailed description of the clustering methods used to generate wind and solar resource regions is provided in (Getman et al. 2015).

[12] The system simulated in 2010 represents existing infrastructure only. Capacity expansions are not allowed until the next simulated year (2015).

[13] Multiple interconnection points (buses) are available to connect any individual wind or solar resource region. The specific interconnection point or points used is a model decision.

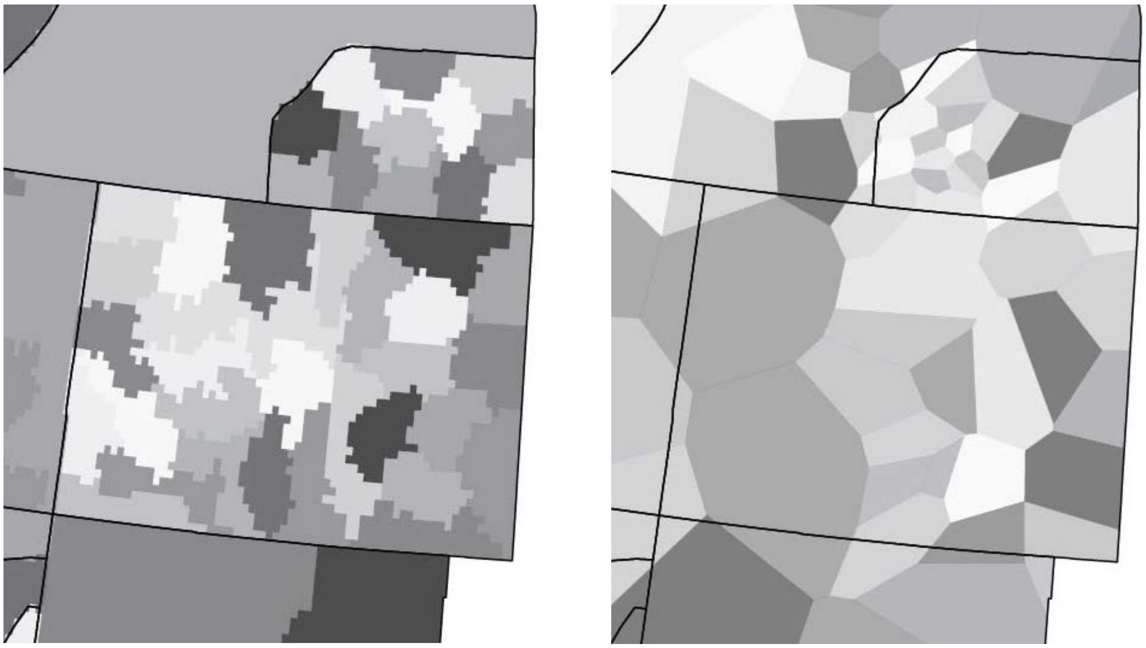

Figure 2. Solar (left) and wind (right) resource regions modeled in the CO-centric version of RPM

RPM is a sequential optimization model that starts in 2010 and ends in 2030, advancing in 5-year increments. Thus, RPM simulates the electric system in 2010, 2015, 2020, 2025, and 2030. For the 2010 simulation, the optimal solution is based solely on simulating existing system operations and excludes any investment decisions.[14] In other words, the 2010 installed capacity reflects the infrastructure as represented in the model database from (Lew et al. 2013), and we allow RPM to dispatch that capacity subject to dispatch constraints. A detailed description of constraints and a comparison with actual 2010 generation data are provided in (Mai et al. 2015). For all future solve years (2015, 2020, 2025, and 2030), new capacity investment decisions are considered in the model (see Section 2.4).

2.3 Investment Decision Assumptions and Drivers

Investment decisions in RPM are made simultaneously with the dispatch modeling. In this section, we briefly describe the model treatment of certain topics that directly influence investment decisions, and we provide the key assumptions used in our analysis for the key technologies relevant to our analysis, including natural gas-fired, wind, and solar PV technologies.[15] The restriction to this small set of technologies are motivated by deployment trends in recent years and to accommodate computational tractability. We acknowledge that this is a model limitation and that deployment of new capacity from other technologies is expected, at least to limited amounts.

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[14] For projects that either have been installed since 2010 or are in later stages of development, we exogenously include them in RPM. Similarly, retirements and announced retirements are exogenously considered as well.
[15] RPM includes many other technologies as shown in Table 2, some of which may play important roles in the future. Nonetheless, our analysis is restricted to new natural gas-fired, wind, and solar PV technologies.

Table 3 shows the assumed technology costs and performance used in our analysis. Data for natural gas-fired technologies are consistent with those found in the National Renewable Energy Laboratory's Annual Technology Baseline (Blair et al. 2015), which relies on data from the Annual Energy Outlook 2015 Reference scenario (EIA 2015) for natural gas-fired technologies, DOE reports (Margolis, Coggeshall, and Zuboy 2012) for solar technologies, and the DOE Wind Vision Study (DOE 2015) for wind technologies. The overnight capital costs shown in Table 3 include costs of all equipment up to the plant gate and do not include the spur line and financing costs, which are included separately in the model.[16] Spur line or interconnection costs for new renewable capacity vary between resource regions and depend on the distance between the centroid of the wind or solar resource region and the connected bus. RPM also includes financing costs (Sullivan et al. 2015) that vary between technologies to account for differences in construction periods, accelerated tax depreciation rules, and investment tax credits.[17]

Other plant parameters, particularly for NG plants, are also used in RPM and are described in (Mai et al. 2015). Reference scenario assumed fuel costs are shown in Figure 3 and are based on national fuel projections from the Annual Energy Outlook 2015 Reference scenario (EIA 2015). Additional fuel cost trajectories for scenario analysis are described in Section 3. Fuel costs are assumed to be uniform across regions and without seasonal or diurnal variations within each solve year. While volatility and uncertainty exists for fuel prices, particularly for natural gas, fuel sensitivities are not included in our analysis. We do not include foresight, such as for fuel price forecasts, in RPM.

[16] Real 2010 dollars are used throughout this report unless otherwise noted.

[17] RPM uses technology-specific fixed charge rates. Fixed charge rates for NG-CC, NG-CT, wind, and solar PV are 0.117, 0.111, 0.098, and 0.084, respectively, for all years with the exception of a fixed charge rate of 0.062 for solar PV in 2015 to represent the 30% investment tax credit available before 2017 (the analysis was completed before tax credit extensions were passed in December 2015). These fixed charge rates are used to calculate amortized capital over 20 years using a nominal weighted average cost of capital of 8.1%.

Table 3. Technology Cost and Performance Assumptions for New Generation Capacity

	2015	2020	2025	2030
Overnight Capital Costs (2010$/kW)				
Natural Gas-Combined Cycle	900	890	880	860
Natural Gas-Combustion Turbine	770	750	740	720
Wind (resource class dependent)	1,530-1,650	1,480-1,630	1,440-1,620	1,430-1,620
PV Fixed-Tilt	1,740	1,410	1,160	910
PV Single-Axis Tracking	1,830	1,510	1,260	1,010
Fixed O&M (2010$/kW-yr)				
Natural Gas-Combined Cycle	13	13	13	13
Natural Gas-Combustion Turbine	7	7	7	7
Wind (all)	47	46	45	44
PV (all)	15	8	8	8
Variable O&M (2010$/MWh)				
Natural Gas-Combined Cycle	3	3	3	3
Natural Gas-Combustion Turbine	12	12	12	12
Wind (all)	0	0	0	0
PV (all)	0	0	0	0
Heat Rate (MMBtu/MWh)				
Natural Gas-Combined Cycle	6.68	6.62	6.57	6.57
Natural Gas-Combustion Turbine	10.0	9.76	9.50	9.50
Fuel Cost (2010$/MMBtu)				
Natural Gas	4.38	5.43	6.91	8.20
Capacity Factor (%)				
Wind (resource class dependent)	52%-33%	54%-35%	55%-36%	56%-37%
PV Fixed-Tilt	12–22%	12–22%	12–22%	12–22%
PV Single-Axis Tracking	14–28%	14–28%	14–28%	14–28%

Note: PV capacity is represented in DC terms and PV costs are represented in AC terms. PV capacity factor reflects AC output over DC capacity. AC capacity and output are used for all other technologies. In the table, PV refers to utility PV only; rooftop PV trajectories and performance characteristics are from the dSolar model (Sigrin et al., forthcoming).

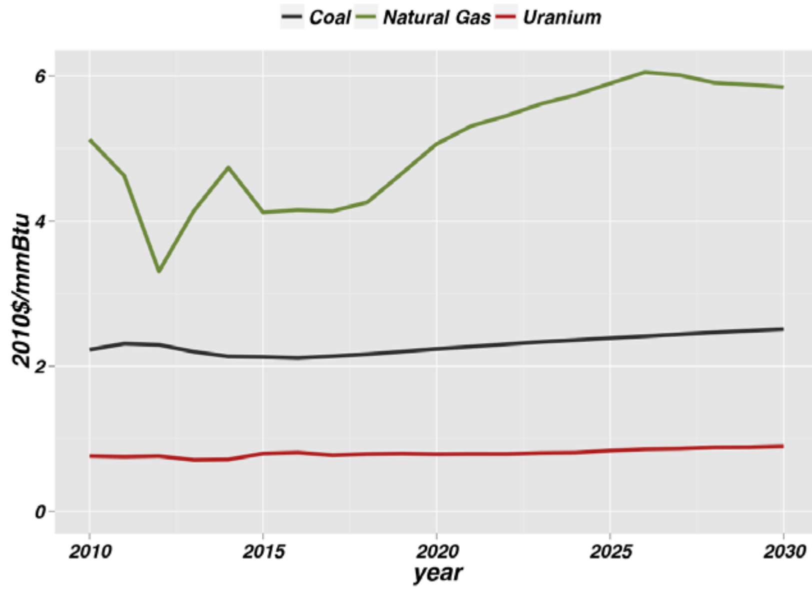

Figure 3. Assumed delivered natural gas, coal, and uranium AEO 2015 price trajectories from 2010 to 2030 (EIA 2015)

With the exception of rooftop PV capacity, new solar capacity deployment is restricted by the technical potential of the resource in each resource region and is driven by the economic potential of particular resources. The technical potential assessment uses the same methodology and exclusions as in (Lopez et al. 2012). Wind and solar suitable land exclusions include: slopes greater than 3% (solar) and 20% (wind), contiguous areas less than 1 km^2 (solar), lands within 1 km distance to other exclusions (wind), water, wetlands, urban areas, BLM areas of critical environmental concern, National Parks, Fish and Wildlife lands, Federal Parks, wilderness, National Monuments, National Battlefields, Federal Wildlife Areas and other federally identified protected lands. Rooftop PV capacity adoption is defined exogenously and updated after each solve year using NRELs dSolar model (Sigrin et al., forthcoming). The primary factors, beyond fuel and technology costs, that drive RPM's investment decisions relate to demand growth, planning reserves, and state renewable portfolio standard (RPS) requirements. Planning reserve constraints are applied to ensure North American Electric Reliability Corporation (NERC) resource adequacy reference margins (NERC 2013) are met. We set a planning reserve requirement for each of four NERC sub-regions[18] in the Western Interconnection to be the peak demand in that region plus a reserve margin (NERC 2013).[19] All non-variable generators are assumed to contribute their full nameplate capacity to the planning reserve requirement; a capacity credit of one is assumed for all thermal capacity, hydropower, CSP with thermal energy storage (TES), and storage. For variable generation, including wind, solar PV, and CSP without TES, we endogenously estimate the capacity credit using a capacity factor-based approximation

[18] The regions are WECC-CAMX, WECC-NWPP, WECC-RMRG, and WECC-SRSG.

[19] For the WECC-CAMX region, we assume 11,000 MW and 5,000 MW of capacity are available from the NWPP and SRSG sub-regions, respectively, to meet planning reserve requirements for all years. We assume that the deductions from NWPP and SRSG are not available to supply capacity reserves in their respective regions. This representation follows the Maximum Import Capacity considered by the California Independent System Operator. Planning reserve requirements are met by local resources only for the other three sub-regions.

The modeling analysis was completed using data and assumptions available in early 2015. For energy policies, this includes state renewable portfolio standards (RPSs) at that time and as reflected in DSIRE.[20] However, we note that further work is needed to more rigorously apply RPS rules and incentives in the model, including trading rules and existing contracts from out-of-state projects that qualify for RPS compliance. The results reflect a simplified representation of RPS policies. We also include the federal tax incentives for wind and solar that were in effect at the time this analysis was conducted: an investment tax credit for commercial and utility-scale solar equivalent to 30% of eligible capital costs, declining to 10% of total eligible costs after 2016, and a wind production tax credit of $23/MWh for facilities under construction prior to 2015. However, the tax credit extensions included in the Consolidated Appropriations Act of 2016 are not included in the analysis[21]. In addition, the present version of RPM does not include a representation of state carbon cap and trade systems (e.g. California Assembly Bill 32) or the recent 50% RPS by 2030 policy in California.[22] We do not include the Environmental Protection Agency's (EPA) Clean Power Plan (CPP) in any of the modeled scenarios. Finally, we do not model any changes to policies surrounding public land administration. While these omitted policies are expected to significantly alter results from our Reference scenario, we model a suite of policy sensitivity scenarios, including expanded RPS policies and a carbon price scenario which can lead to similar investment and deployment behavior as recently implemented legislation and regulations (see Section 3). Future work will explore additional policy sensitivities including the CPP.

Due to the optimization problem formulated in RPM, simulation results are particularly sensitive to capital cost assumptions, and as our modeling results show, the large majority of capacity additions in the west are comprised of renewable generation and natural gas combined cycle generation. As a result, the cost and performance assumptions used for these technologies have significant implications on results. Recently, the solar generation technologies have experienced significant cost reductions and improvements in performance (Barbose and Darghouth 2015; Bolinger and Seel 2015) and while there is uncertainty on how these cost reductions might continue into the future, DOE goals (Margolis, Coggeshall, and Zuboy 2012) indicate significantly greater reductions are possible, relative to the cost reductions modeled. Additionally, RPM does not endogenously consider residential rooftop PV development due to the difficulty in representing homeowner PV adoption behavior. As such, deployment results (see Section 1) may underestimate future solar deployment in Colorado and potentially the Western Interconnection. Future sensitivities, including those with lower relative RE development costs, are needed to broaden the range of potential expected outcomes and a forthcoming study to analyze these and other sensitivities is planed.

[20] See www.dsireusa.org/.
[21] Model simulations for the analysis presented here were completed in the fall of 2015. Due to uncertainties surrounding policy extensions at the time of simulation, tax credit extensions included in congressional bills in December 2015 are excluded from this analysis.
[22] Emissions or renewable policies such as California Assembly Bill 32, primarily affect capacity expansion and operations results near the policy location and locations where contracted imports are likely. Therefore, omissions of these policies are unlikely to significantly affect the results of this analysis.

Recent (2010-2014) and expected new transmission and generation capacity additions and retirements are exogenously included in RPM based on data from Ventyx (2010) and SolarPaces (2014)[23]. The optimization in RPM does not explicitly consider any other retirements, such as economic retirements.

[23] In particular, two solar generation developments totaling 206 MW in Colorado have recently been announced that are not included in RPM ("Broomfield Firm to Build Colorado's Largest Solar Farm near Pueblo" 2016; "Xcel Energy Flips the Switch on Colorado Solar Power Plant" 2016)

3 Scenario Framework

We modeled long-term capacity expansion and electricity system operations under a core reference scenario (REF) and four sensitivity scenarios designed to highlight a range of possible policy and economic futures. To address the uncertainties of future natural gas prices, we use natural gas price projections (see Figure 4) from the Energy Information Administration Annual Energy Outlook to inform high (HI-NG) (EIA 2014) and low (LO-NG) (EIA 2015) model scenarios. In addition, we model a CO_2 price sensitivity where the investment and dispatch decisions in RPM are influenced by an effective price on combustion-related CO_2 emissions of the various generator types modeled. We calculate a median non-zero CO_2 price trajectory (see Figure 5) based upon data collected for the Resource Planning Portal ("RPP" 2015) [24]. The CO_2 price sensitivity is not intended to directly represent any particular policy. Rather, it is included to represent the effect of how the Western Interconnection might evolve under a clean energy legislation or regulations aimed at curbing greenhouse gas emissions, such as EPA's CPP (US EPA 2015).[25] Finally, we model a variant of the reference scenario where the state of Colorado amends its current RPS that mandates the provision of load with at least 30% renewable generation by 2020, with an additional RPS policy that raises that level to 50% by 2030.

With the following exceptions, all scenarios use a common set of input assumptions documented in Section 2, including zero CO_2 price, currently in-place RPS policies, and the reference case natural gas price trajectory shown in Figure 3:

- The high natural gas price scenario (HI-NG) follows the high natural gas price trajectory in Figure 4
- The low natural gas price scenario (LO-NG) follows the low natural gas price trajectory in Figure 4
- The CO_2 price scenario (CO2) applies the median non-zero CO_2 price trajectory to carbon emissions from electricity generators starting in 2017
- The high renewable portfolio standard scenario (HI-RPS) assumes that the State of Colorado adopts a more aggressive RPS standard that mandates 50% renewable generation in 2030.

None of these scenarios represent a forecast or prediction. The scenarios do not reflect a policy or other recommendation pertaining to the formation of BLM resource management plans, but instead aim to capture a range of possible futures. These scenarios are intended to simulate the

[24] CO_2 prices are based on integrated resource plans created between 2010 and 2013 by 14 load serving entities in the western United States as collected for Lawrence Berkeley National Laboratory's Resource Planning Portal (http://resourceplanning.lbl.gov). The median trajectory shown here was calculated from the IRP scenarios with non-zero CO_2 prices.

[25] At the time model simulations were executed, the CPP was proposed, but not finalized. Therefore, the greenhouse gas emissions limits required by the CPP are not included in the results presented here. Ongoing RPM development will enable explicit representation of CPP legislation in future simulations.

broader trends in the future western electricity system, with the results quantifying potential demands on various lands owned by the BLM, other federal agencies, private and other entities.

Figure 4. Assumed reference, low, and high AEO 2015 delivered natural gas price trajectories (EIA 2015)

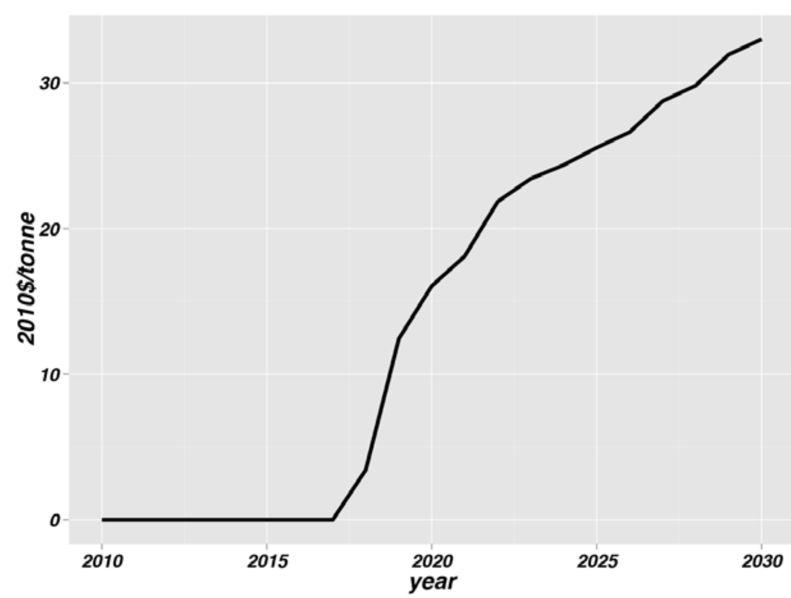

Figure 5. Assumed median CO_2 price

4 Results and Discussion

RPM Scenario Results

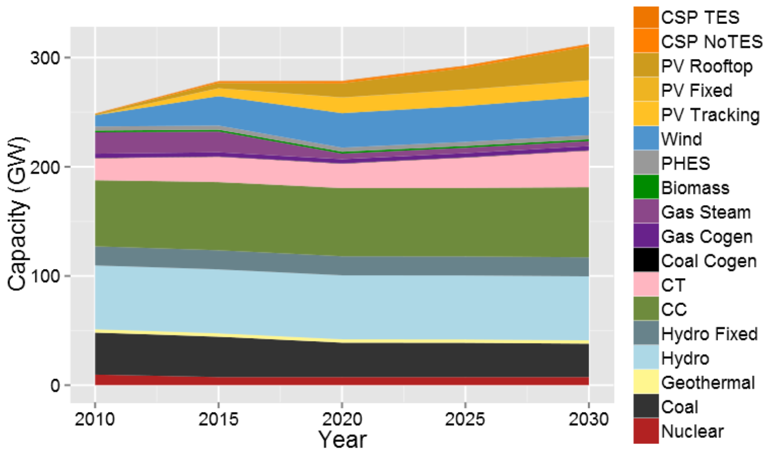

Figure 6. Installed generation capacity in the Western Interconnection for the reference scenario

The simulated scenarios represent a range of modeled outcomes under a variety of policy and future economic assumptions. The results demonstrate that the magnitudes and distributions of renewable energy development in Colorado are sensitive to various policy and economic drivers. Figure 6 shows the Wester Interconnection-wide capacity mix over time from the reference scenario; Figure 7 shows the capacity mix through time for the Colorado-centric focus region. Changes in capacity under the reference scenario are largely driven by load growth assumptions and existing RPS policies. Under the reference scenario 35,000 MW of new wind, 15,000 MW of new utility-scale solar, and 33,000 MW of new rooftop solar capacity are added between 2011 and 2030 in the Western Interconnection. With this new capacity, wind and solar are estimated to comprise 19% of all generation in 2030.

Figure 7 shows that wind technologies comprise the dominant share of all new capacity in the Colorado-centric focus region - wind additions total 4,428 MW, while new rooftop solar totals 1,440 MW and only new utility-scale solar, 118 MW during 2011-2030. As a result of these capacity additions, by 2030 wind and solar make up 30% of Colorado in-state generation under the reference scenario.

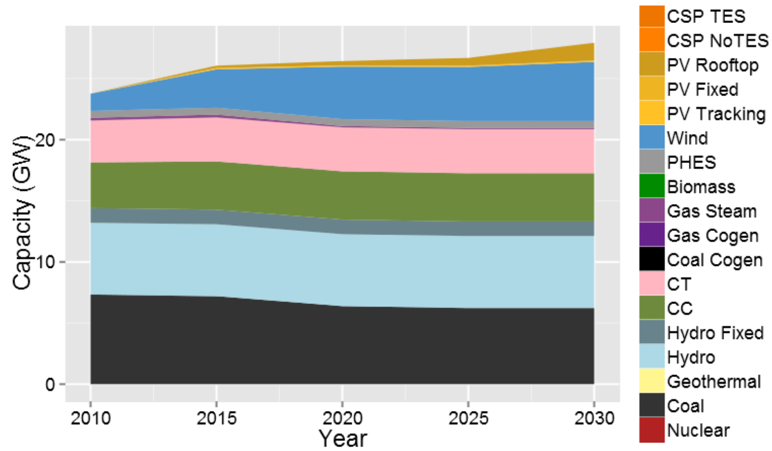

Figure 7. Installed generation capacity in the Colorado-centric focus region for the reference scenario

Differences in the capacity mix between the reference scenario and the four sensitivity scenarios are shown for the Western Interconnect in Figure 8 and for the Colorado-centric focus region in Figure 9. Figure 8 demonstrates that both the high natural gas prices and a CO_2 price in the HI-NG and CO2 scenarios, respectively, create some additional incentive for wind and PV capacity in the Western United States, and therefore lead to higher penetrations of wind and solar capacity. Similarly, Figure 9 shows that the HI-NG, CO2, and HI-RPS [26] scenarios lead to greater wind capacity builds in the focus region (CO) than in the reference scenario. Total 2030 wind capacity additions in Colorado (excluding the Wyoming portions of the focus region) are 6,395 MW, 10,002 MW, and 5,758 MW, for the HI-NG, CO2, and HI-RPS scenarios, respectively. The additional Colorado solar capacity observed under the HI-NG scenario creates a total of 1,198 MW of new utility-scale solar, and 1,440 MW of new rooftop solar by 2030.

[26] Figure 9 only shows a marginal increase in focus region wind capacity over the reference scenario despite the significant increase in annual generation required to meet the 50% RPS in Colorado in the HI-RPS scenario in 2030. The increased annual renewable generation is achieved in the HI-RPS scenario by building more wind in Colorado and less wind in Wyoming. Thus the Colorado-centric focus region, which includes Colorado and much of Wyoming, has minimal net renewable capacity increase.

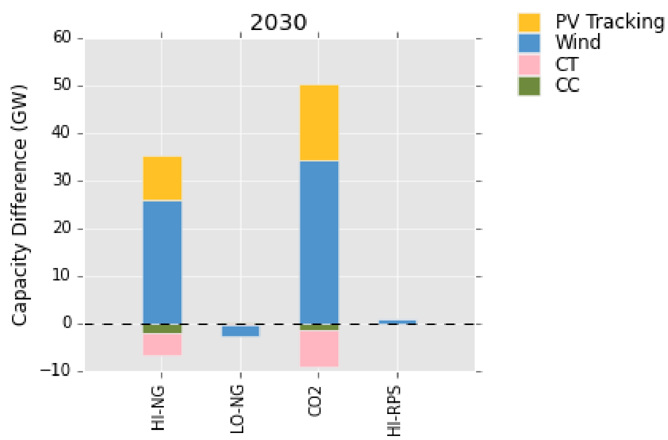

Figure 8. Differences in 2030 capacity in the Western Interconnection with respect to the reference scenario

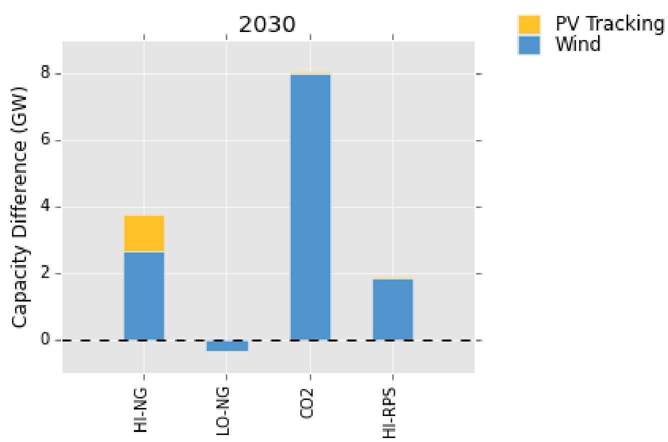

Figure 9. Differences in 2030 capacity in the Colorado-centric focus region with respect to the reference scenario

Cross-scenario differences in the focus region capacity mix can be attributed to the different input assumptions and policies represented in each scenario. For instance, the HI-NG scenario assumes that natural gas prices follow a higher price trajectory than in the reference scenario. This places a premium on operating natural gas fired generation, such as NG-CC and NG-CT generators. Increased operating costs for natural gas fired generation make wind and PV generation more cost competitive, thus increasing simulated capacity additions. Similarly, the CO2 scenario simulates an additional cost to operating carbon dioxide emitting generating resources. The non-zero CO_2 price primarily affects coal-fired, and to a lesser extent NG-fired generators. The results of the CO2 scenario shown in Figure 9 suggests that additional wind capacity makes up the majority of reduced coal-fired generation in the Colorado-centric focus region. Figure 7 shows that the reference scenario results in significant wind and solar capacity expansions in Colorado and parts of Wyoming. Figure 9 shows that, when compared to the reference scenario, the HI-RPS scenario only needs an additional 2 GW of focus region wind capacity to achieve the 50% renewable generation requirement.

GIS Post-Processing and Resource Potential Analysis

Statewide and ECRMP Results

Despite the fact that significant wind and solar capacity additions are occur across the range of scenarios explored, suitable land availability within Colorado remains abundant through 2030. The amount of Colorado land area needed to accommodate modeled renewable capacity additions through 2030 range from 336,000 to 824,000 acres across all five modeled scenarios. Figure 10 and Figure 11 show Colorado lands suitable for wind and solar energy development, respectively. Suitable land availability is analyzed by land ownership within four 'Distance to Transmission' bins, summarized in Table 4 and Table 5. Transmission distances are calculated between each suitable land grid cell (10 km^2) and the closest transmission bus.[27] Suitable land area, in acres, is calculated after applying exclusions described in Lopez et al. (2012) and the MW capacity potential is calculated by applying technology specific land use intensities found in Denholm et al. (2009).

[27] Transmission buses considered in this analysis include existing and WECC planned infrastructure at or above 69 kV nominal voltage ratings.

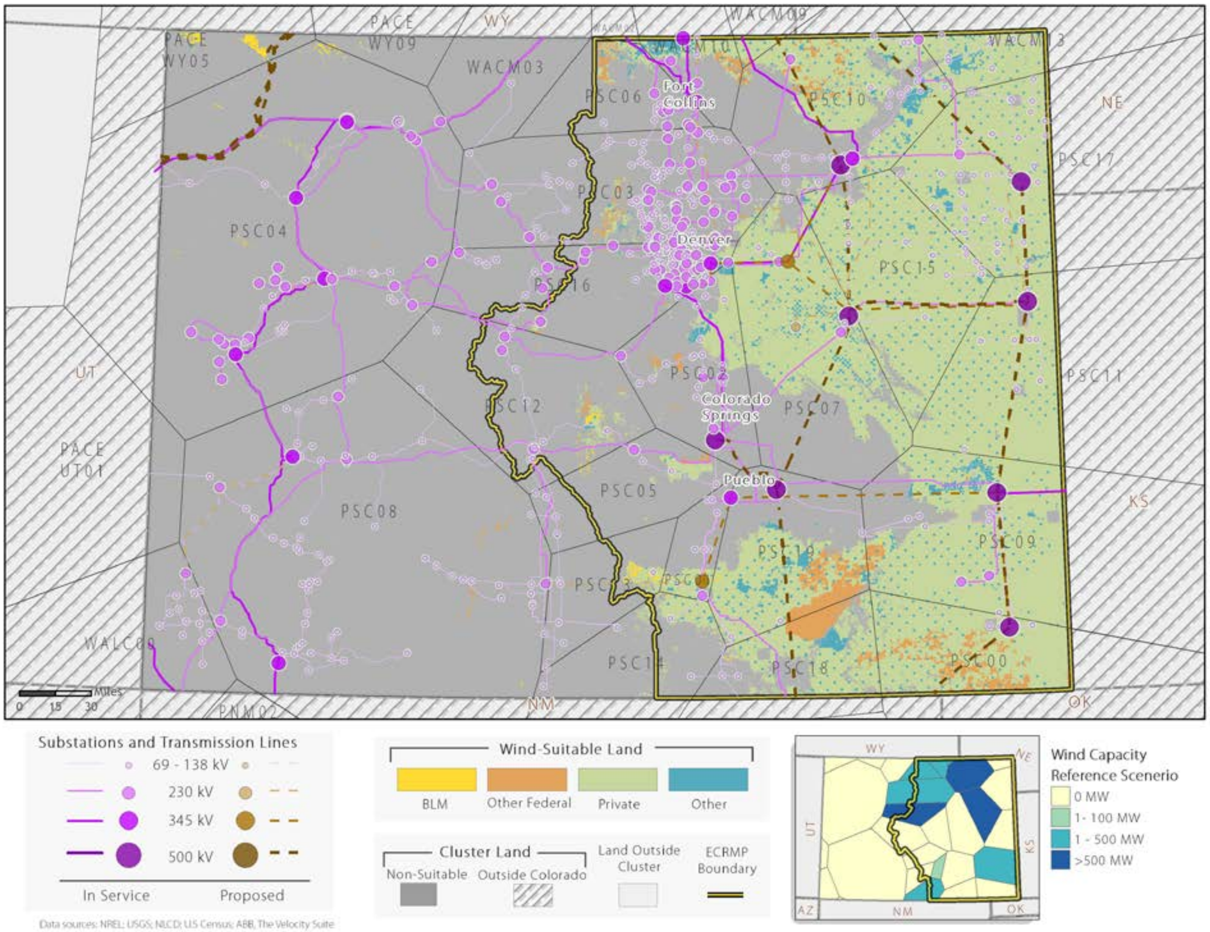

Figure 10. Colorado wind-suitable land

Table 4. Colorado–Wind-Suitable Land: Area and MW Potential

Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	676	8	10,742	130	35,485	431	85,689	1,040
Federal	286	3	35,028	425	152,692	1,854	747,768	9,078
Other	14,855	180	286,770	3,482	403,691	4,901	630,510	7,655
Private	170,090	2,065	3,482,771	42,283	5,609,683	68,105	8,660,317	105,141

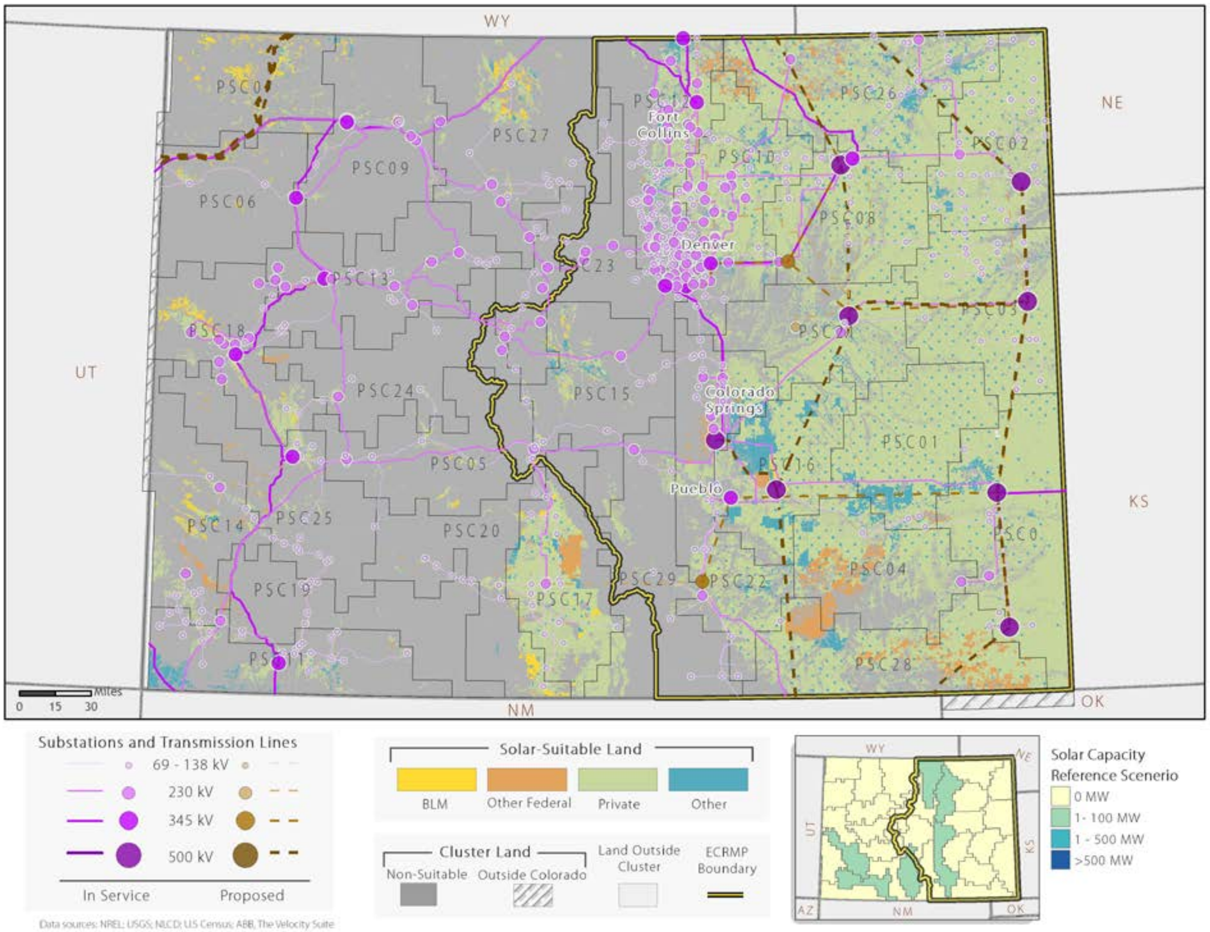

Figure 11. Colorado utility-scale solar-suitable land

Table 5. Colorado–Solar-Suitable Land: Area and MW Potential

Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	542	155	53,225	15,251	111,854	32,050	259,125	74,248
Federal	936	268	65,781	18,848	212,993	61,030	605,166	173,400
Other	18,784	5,382	321,219	92,040	489,051	140,129	1,050,674	301,053
Private	311,631	89,293	5,025,581	1,439,995	5,892,545	1,688,408	9,035,090	2,588,851

Table 6. Colorado–Modeled Wind and Solar Capacity (MW)

	Ref	HI-NG	LO-NG	C02	HI-RPS
Wind	4,428	6,395	4,080	10,002	5,758
Solar	118	1,198	112	195	132

The solar and wind capacity additions modeled through 2030 for each scenario are described in Table 6. The results demonstrated that wind capacity additions largely outpace solar capacity additions in Colorado. With the exception of the HI-NG scenario, utility-scale solar developments across all other scenarios use only about 450 acres in all of Colorado. Depending on the scenarios, statewide land usage for wind development ranges from about 365,000 to 824,000 acres. A comparison of the results presented in Table 6 and the availability of suitable land by ownership in Table 4 demonstrates a statewide abundance of wind-suitable private land and solar-suitable lands of all ownership types. These results suggest that Colorado could accommodate significantly more RE development than is simulated across the range of scenarios, even if development was prohibited on some lands

The ECRMP region is comprised of the eastern portion of the state and is bounded by the continental divide on the west and state borders on the north, east, and south (see yellow border in Figure 10). Table 7 and Table 8 show the wind and solar-suitable land availability in the ECRMP. Comparison of the ECRMP-suitable land availability with the Colorado land availability demonstrates that the majority of wind-suitable land in Colorado exists within the ECRMP boundary. Table 9 shows that all of the RPM simulated wind capacity, except 16 MW in the CO2 scenario, are allocated inside the ECRMP boundary. Despite an abundance of solar-suitable land in the ECRMP, RPM simulates the majority of Colorado solar capacity expansions in the western portion of the state.

Table 7. ECRMP–Wind-suitable Land: Area and MW Potential

Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	660	8	10,262	125	33,696	409	22,132	269
Federal	276	3	33,679	409	148,468	1,802	732,313	8,891
Other	14,855	180	286,284	3,476	403,365	4,897	624,398	7,581
Private	169,934	2,063	3,479,603	42,244	5,595,939	67,938	8,625,066	104,713

Table 8. ECRMP–Solar-suitable Land: Area and MW Potential

Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	43	12	3,296	945	12,376	3,546	24,173	6,926
Federal	731	209	47,607	13,641	117,043	33,537	549,218	157,369
Other	17,180	4,923	289,844	83,050	425,478	121,914	877,034	251,299
Private	264,183	75,697	4,292,574	1,229,964	5,237,288	1,500,655	8,428,131	2,414,937

Table 9. ECRMP–Modeled Wind and Solar Capacity (MW)

	Ref	HI-NG	LO-NG	C02	HI-RPS
Wind	4,428	6,395	4,080	9,986	5,758
Solar	17	107	17	29	28

Resource Region Specific Results

To provide additional detail on wind and solar resource availability and the locations of RPM simulated RE developments, the following figures and tables present information on specific wind and solar resource regions within Colorado. The maps are designed to portray the location of lands suitable for wind and solar development, while the bar charts are designed to portray the results of RPM scenarios within three possible land development preferences. The figures also demonstrate the proximity of lands to existing and planned transmission infrastructure to give a sense of the relative costs that might be incurred for RE development on various lands. Here, we present the analysis for two Colorado resource regions within the ECRMP boundary, one wind and one solar. Other resource regions where RPM simulates wind or utility-scale solar capacity additions are presented in the Appendix.

Figure 12 highlights lands with wind energy development potential within the PSC06 wind region. Additionally, Table 10 summarizes the wind-suitable land area and MW potential in the PSC06 wind resource region by land ownership type. Table 10 also describes the distance to transmission infrastructure for lands with wind energy development potential. Transmission distances are calculated between each suitable land grid cell (10 km^2) and the closest transmission bus, regardless of whether or not the bus resides within the resource region boundary. Figure 12 and Table 10 demonstrate that the majority of wind energy development opportunities in the PSC06 region exist on private lands and that wind-suitable land is primarily located at distances greater than 10 miles away from existing transmission infrastructure.

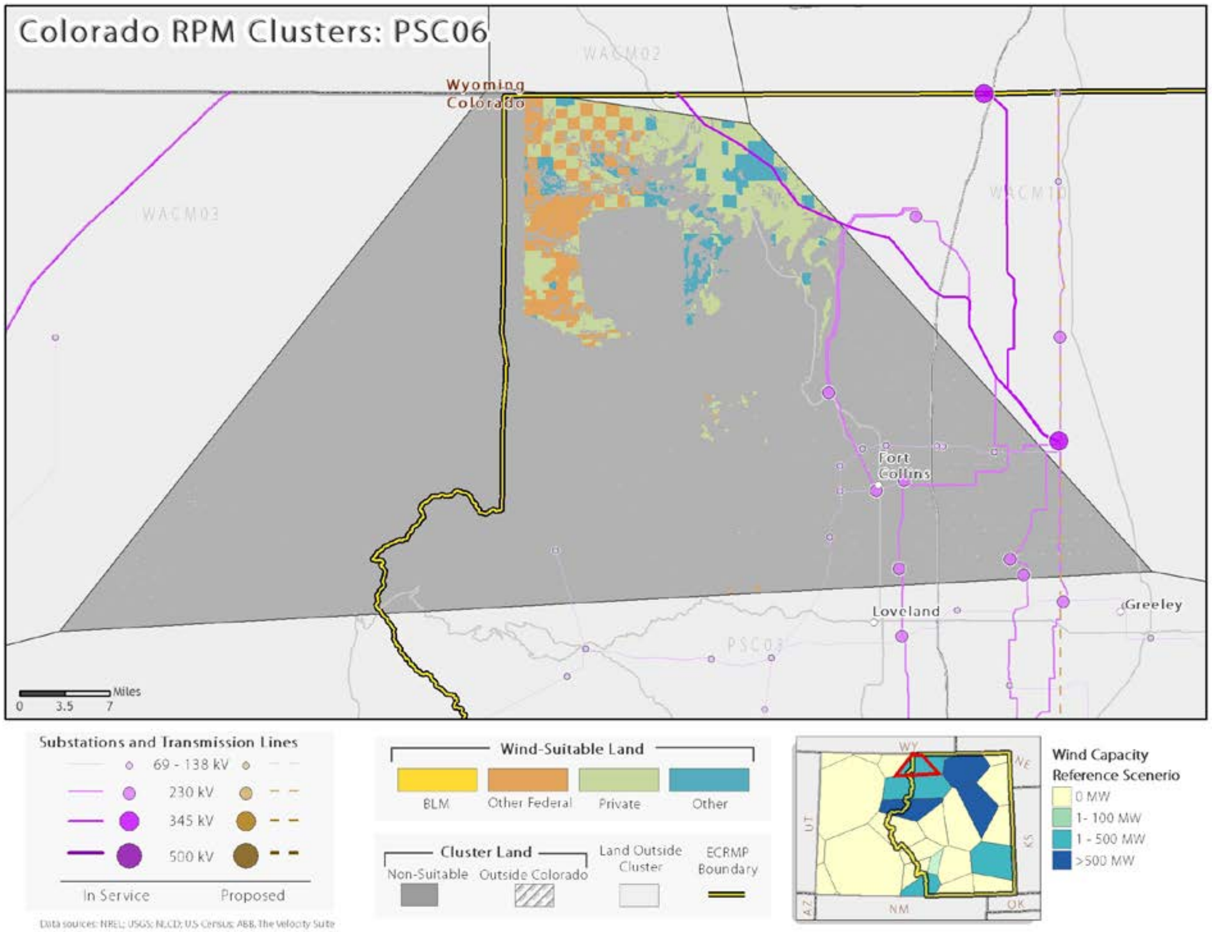

Figure 12. PSC06 wind resource region[28]

Table 10. PSC06–Wind-suitable Land Area and MW Potential

Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	0	0	16	0	0	0
Federal	0	0	0	0	283	3	34,608	420
Other	0	0	0	0	1,184	14	19,870	241
Private	0	0	183	2	8,824	107	58,789	714

Table 11. PSC06–Modeled Wind Capacity (MW)

Ref	HI-NG	LO-NG	C02	HI-RPS
277	965	224	1,171	670

[28] For a complete description of the various information displayed, refer to the text at the beginning of the Appendix.

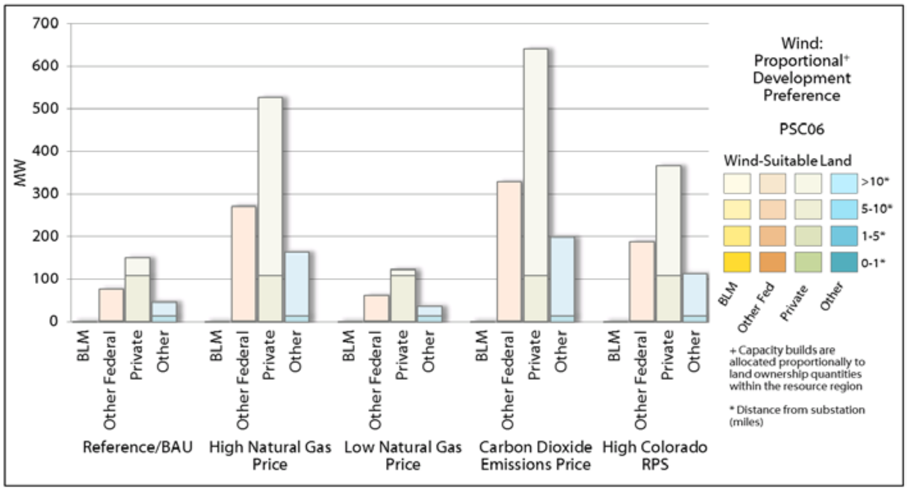

Figure 13. Wind: PSC06—proportional development preference

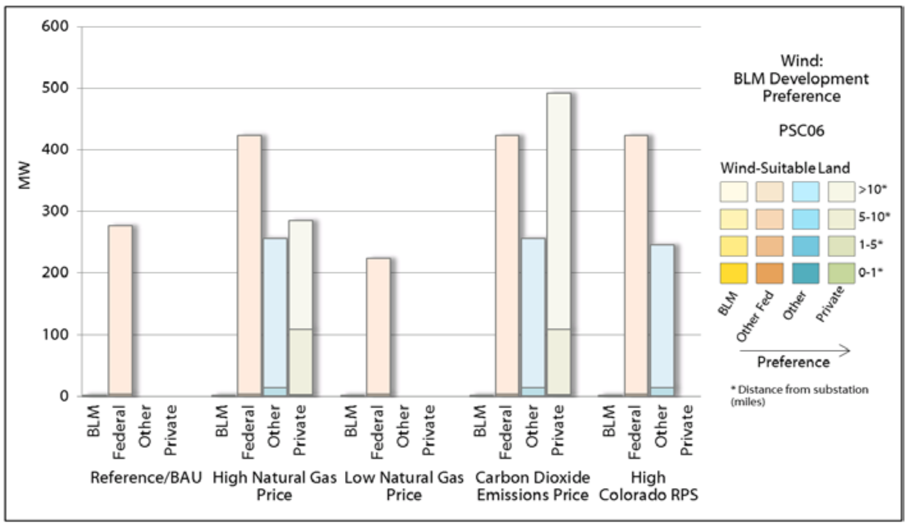

Figure 14. Wind: PSC06—BLM development preference

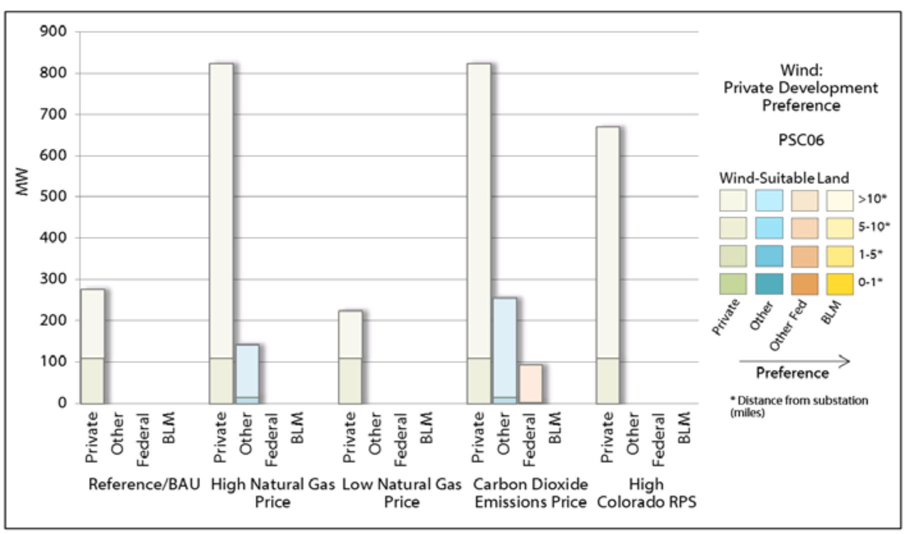

Figure 15. Wind: PSC06—private development preference

Despite the relatively long transmission connection distances of wind-suitable lands in PSC06, Table 11 shows significant wind capacity additions in PSC06 across the full suite of scenarios explored. By comparing the results presented in Table 11 and the availability of suitable land by ownership, we describe three potential wind development pathways in Figure 13, Figure 14, and Figure 15. Figure 13 shows the land allocation of RPM wind capacity additions for each scenario assuming that development takes place proportionally to the amount of wind-suitable land available within the PSC06 wind resource region. Figure 14 shows the allocation of wind capacity additions to different land ownership types assuming development takes place with the following priority order: BLM-administered land gets developed first, and other federal lands, other and private land, get developed second, third and last. Conversely, Figure 15 describes the allocation of wind capacity additions assuming the opposite development preference order where private land gets developed with greatest priority. Figure 15 shows that private land in PSC06 could accommodate all of the RPM-simulated capacity additions in each scenario without utilizing any BLM, other federal, or other land for wind development.

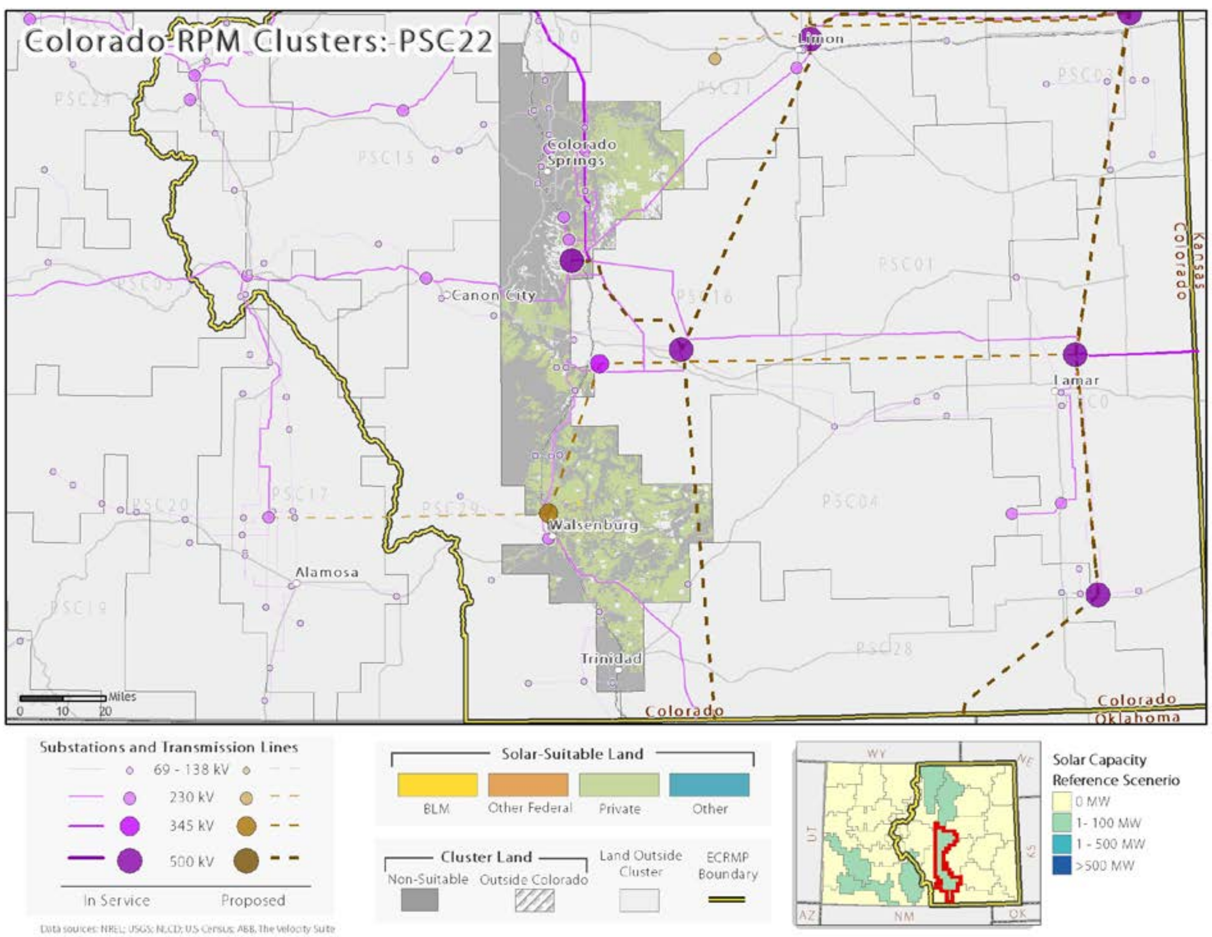

Figure 16. PSC22 solar resource region[28]

Table 12. PSC22—Solar-suitable Land: Area and MW Potential

Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	506	145	1,651	473	718	206
Federal	14	4	17,372	4,978	12,380	3,547	2,879	825
Other	613	176	17,010	4,874	26,880	7,702	55,287	15,842
Private	15,939	4,567	209,334	59,981	301,807	86,478	311,033	89,121

Table 13. PSC22—Modeled Solar Capacity (MW)

Ref	HI-NG	LO-NG	C02	HI-RPS
8	8	8	8	8

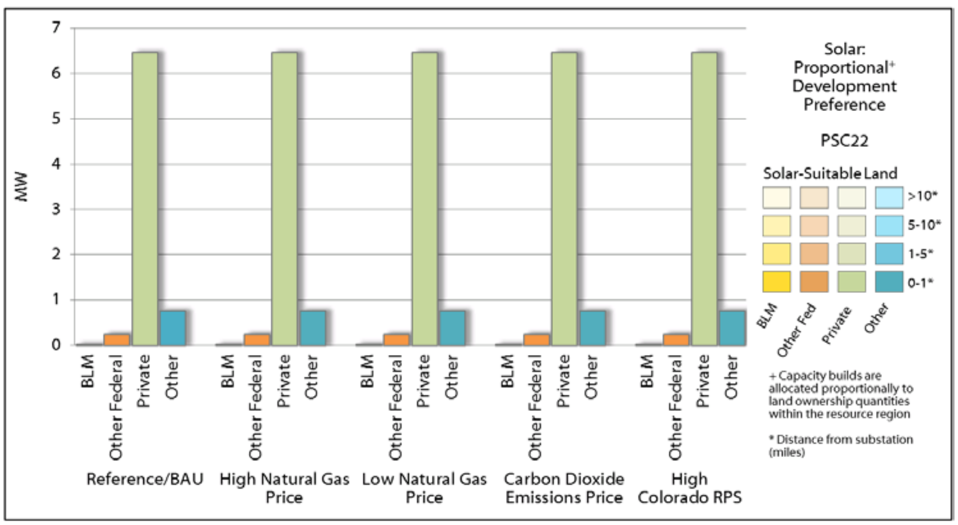

Figure 17. Solar: PSC22—proportional development preference

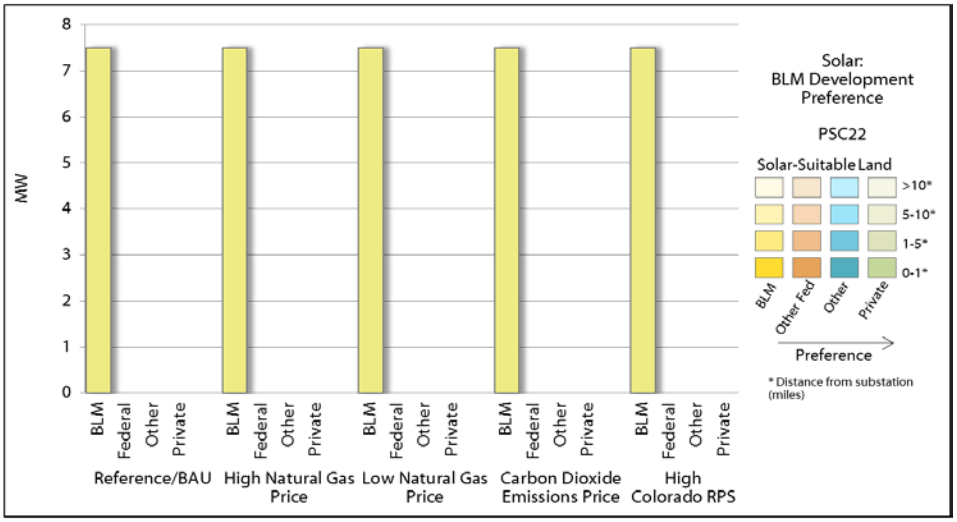

Figure 18. Solar: PSC22—BLM development preference

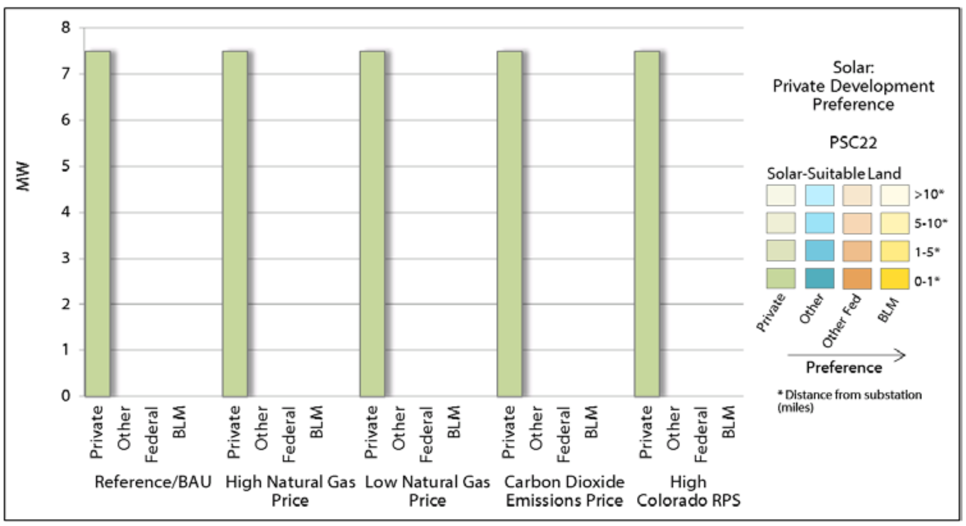

Figure 19. Solar: PSC22—private development preference

Figure 16 through Figure 19, and Table 12 and Table 13 present the same resource potential and GIS post-processing analysis on the PSC22 solar resource region. Table 12 shows that the majority of solar-suitable land is located at distances greater than 5 mi from existing and planned transmission infrastructure. Table 13 shows that RPM simulates a relatively modest 8 MW of solar capacity expansion in PSC22 in all scenarios. At this modest development level, both "Other" and private lands could accommodate the RPM simulated solar capacity additions on land within a mile of existing and planned transmission infrastructure. Due to the private ownership of the majority of solar-suitable lands, the proportional development preference chart in Figure 17 allocates most solar development in PSC22 to private lands. However, Figure 18 shows that if a BLM solar development preference existed, BLM-administered lands could accommodate the entire RPM simulated solar capacity expansion in PSC22.

The Appendix contains similar figures and tables for each resource region within Colorado where RPM results indicate wind or solar development is likely.

Implications for BLM Resource Management Planning in Colorado

Overall, BLM-administered lands within 10 miles of the nearest transmission substation in Colorado total 47,000 wind-suitable acres, and 166,000 utility-scale solar-suitable acres. Within the ECRMP boundary BLM administers roughly 45,000 wind-suitable and 16,000 utility-scale solar-suitable acres. The RPM scenario simulation results highlight potential opportunities for BLM to allocate lands for renewable energy development in locations where BLM lands with high quality wind or solar resources are located near existing or planned transmission infrastructure. In particular, BLM-administered lands in Huerfano County have strong wind resource potential and are located close to transmission infrastructure. Additionally, new wind capacity is developed in regions PSC01 and PSC14 (see Appendix: Wind Resource Regions), which primarily represent lands in Huerfano County, across the full range of scenarios explored. This result suggests that wind development on BLM lands in the PSC01 and PSC14 wind resource regions, although modest, is particularly attractive.

The RPM simulation results suggest a limited amount of utility-scale solar PV development in Colorado. Furthermore, BLM-administered lands with solar resource potential tend to be located further from transmission infrastructure than other land ownerships. The resource potential of non-BLM-administered lands is more than sufficient to accommodate simulated solar capacity expansions in Colorado. Overall, attractive solar PV development opportunities on BLM lands are minimal, especially in the ECRMP region. The most attractive areas for solar PV development on BLM-administered lands exist along the Rocky Mountain Front Range in the PSC10 and PSC22 solar resource regions (see Appendix). These resource regions represent some of the most populated land area in Colorado along the I-25 corridor, stretching from Ft. Collins to Walsenburg. The heavily populated nature of these regions enhances the value of solar development since the need to transport energy long distances is alleviated, however lands available for development are fragmented and limited.

5 Conclusions

The analysis presented here combines results obtained from RPM simulations and an additional GIS analysis applied to enhance the location specificity of RPM simulated capacity additions. The RPM scenarios were selected to give a range of likely future system development trajectories. GIS analysis has been applied to the wind and solar resource availability model inputs to generate the maps in the Appendix. The maps highlight suitable land for renewable development to provide a visual assessment of the proximity of various land ownerships to transmission infrastructure. Generally, larger generation developments will require access to higher voltage infrastructure to facilitate efficient long distance power transfer. For the purposes of this analysis, we provide a quantitative analysis of the total resource potential within various distances to transmission. Finally, within each wind and solar resource region, we analyze three potential development preferences. The development preference bar charts for each resource region in the Appendix describe the land usage allocations according a proportional, BLM, and private land development preferences.[29] The analysis highlights the following broad trends for renewable development within Colorado:

- RPM scenario simulations find that new capacity additions are dominated by renewable technologies across the Western Interconnection and in Colorado.
- Across all modeled scenarios, the geographic distribution of new renewable capacity additions in Colorado is highly correlated to the resource quality and are limited to a relatively few resource regions within the state.
- Wind and solar-suitable land in Colorado far exceeds the land area needed to accommodate new renewable capacity additions through 2030 across all five modeled scenarios.
- This analysis suggests that the greatest opportunities for renewable energy development appear to exist on private lands, and BLM-administered lands are not necessarily needed to accommodate new renewable capacity additions across any of the scenarios in any of the regions.
- The limited *need* for BLM-administered lands to be used for RPM simulated renewable capacity additions can be explained through the relative difference in the amount and transmission proximity of renewable-suitable land areas that are BLM-administered and privately owned.

If the RPM results presented here are any indication of the trends of renewable energy development in the state of Colorado, there are likely many opportunities for partnerships between developers and various landowners. Opportunities for renewable energy development on lands managed by the BLM and other federal agencies will ultimately depend upon land management plans developed by these agencies in addition to the specific location, quality, and system interaction of available resources.

[29] For a more complete description of the three development preferences, refer to the text in the Appendix.

The results presented in this report do not represent forecasts or predictions. The land development preferences and conclusions do not reflect any existing policy or other recommendation pertaining to the formation of BLM resource management plans. Instead, the results and conclusions presented here aim to capture a range of possible futures and the corresponding development opportunities on various lands, including BLM-administered lands.

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Appendix

The following figures and tables show the renewable resource regions within Colorado in which any RPM simulation scenario results in wind or utility-scale solar photovoltaic capacity expansions. Each resource region section contains several figures and tables of information designed to communicate the resource availability, land ownership, transmission proximity, and RPM simulation results. Each section is structured with the following information:

- **Resource region maps:**
    - The thumbnail map in the bottom right shows the location of the highlighted resource region with the red outline. The map displays the Reference scenario simulated wind or solar capacity expansion as shaded resource regions. The map also contains the yellow border outlining the area covered by the ECRMP.
    - The main "Colorado RPM Clusters" map featured in the figure focuses in on an individual resource region. Land area shaded in dark grey is unsuitable for resource development, while the land area highlighted in color is suitable for resource development following the exclusion rules outlined in (Lopez et al. 2012). The different colors of the shaded land area represent the different land ownerships (BLM, Other Federal[30], Private, and Other[31]). In service and proposed transmission lines and substations are displayed in shades of purple and brown, respectively. The voltage rating of transmission infrastructure follows the legend in the bottom left of the figure. Finally, geographic information such as town names and road networks are displayed in light grey.
- **Suitable land area and MW potential tables:**
    - Tables display the available land in acres and the corresponding resource potential in MW for lands of each ownership type within distances of 0-1 mi, 1-5 mi, 5-10 mi, and >10 mi from the nearest in-service or proposed substation.
- **Modeled capacity tables:**
    - The modeled capacity tables display the MW capacity expansion of each resource by 2030 in each RPM simulation scenario.
- **Proportional development preference grouped bar chart:**
    - The proportional preference grouped bar chart describes a possible distribution of capacity sighting across land ownership types for each RPM simulation scenario. The distribution assumes that capacity expansion simulated in RPM scenarios is

[30] Other Federal: Bureau of Reclamation (BOR), Department of Defense (DOD), Department of Energy (DOE), Fish and Wildlife Service (FWS), National Parks Service (NPS), US Forest Service (USFS), Other/Unknown Federal

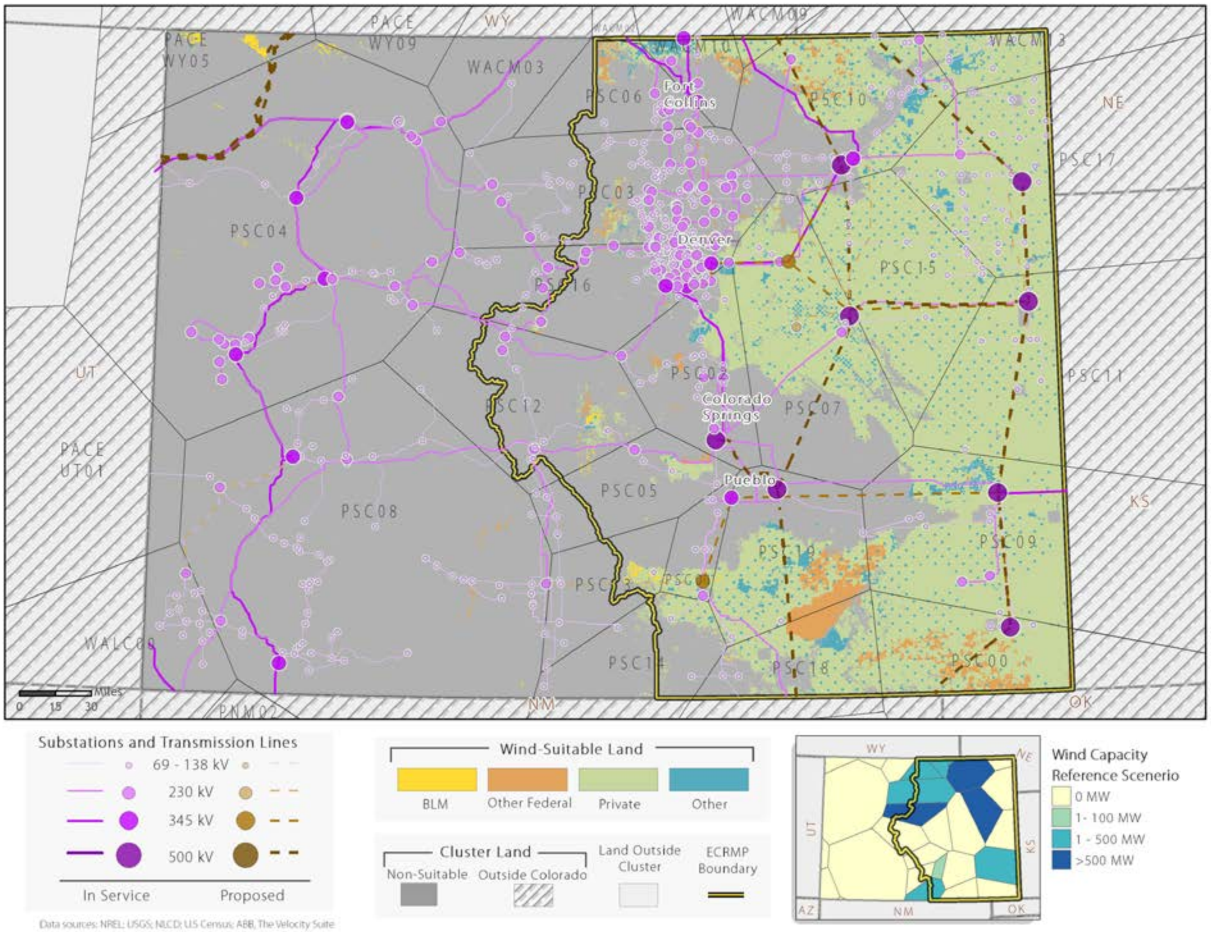
[31] Other: Jointly Owned, Non-Governmental Organization, Regional/Local, State, Tribal, Unknown

built on each category of land ownership proportional to the distribution of suitable land area of each ownership type within the resource region. Each capacity bar is also shaded by the amount of suitable land within the various distances to transmission substations.

- **BLM development preference grouped bar chart:**
    - The BLM preference grouped bar chart describes a possible distribution of capacity sighting across land ownership types assuming development takes place with the following priority order: BLM-administered land gets developed first, and other federal, "other", and private lands get developed second, third, and last. For example, consider a situation where RPM simulates a 30MW capacity expansion within a particular resource region. If BLM only administers enough land to accommodate 20MW of capacity within the resource region, the 20MW of capacity is allocated to BLM lands, and the remainder of the simulated capacity expansion is allocated first to other federal, then "other", and finally to private lands if necessary.
- **Private development preference grouped bar chart:**
    - The private preference grouped bar chart describes a possible distribution of capacity sighting across land ownership types assuming development takes place with the following priority order: private land gets developed first, and "other", other federal, and BLM lands get developed second, third, and last. For example, consider a situation where RPM simulates a 30MW capacity expansion within a particular resource region. If private lands only account for enough land to accommodate 20MW of capacity within the resource region, the 20MW of capacity is allocated to private lands, and the remainder of the simulated capacity expansion is allocated first to "other", then other federal, and finally to BLM lands if necessary.

Wind Resource Regions

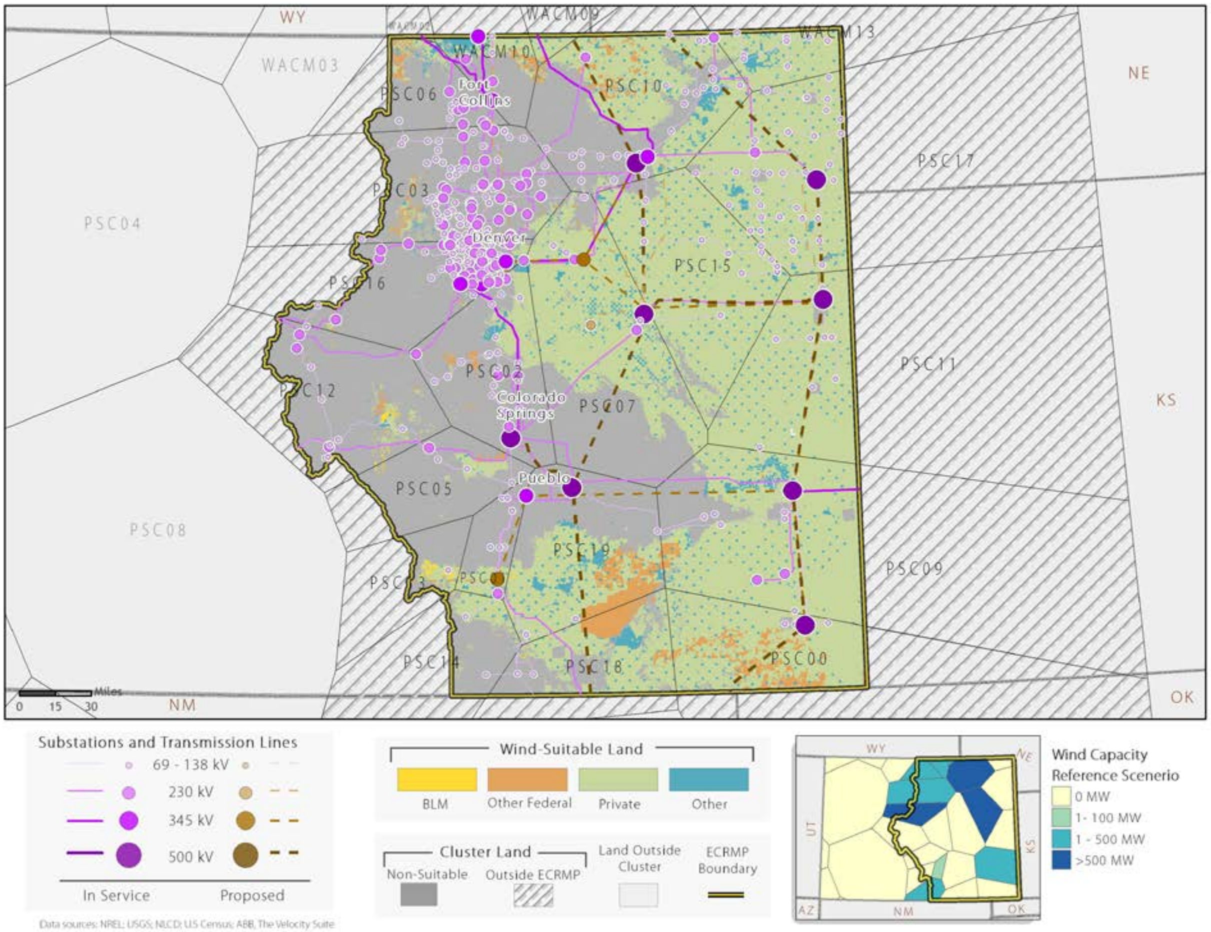
Colorado Wind Resource Regions



Colorado—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	676	8	10,742	130	35,485	431	85,689	1,040
Federal	286	3	35,028	425	152,692	1,854	747,768	9,078
Other	14,855	180	286,770	3,482	403,691	4,901	630,510	7,655
Private	170,090	2,065	3,482,771	42,283	5,609,683	68,105	8,660,317	105,141

Colorado—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
4,428	6,395	4,080	10,002	5,758

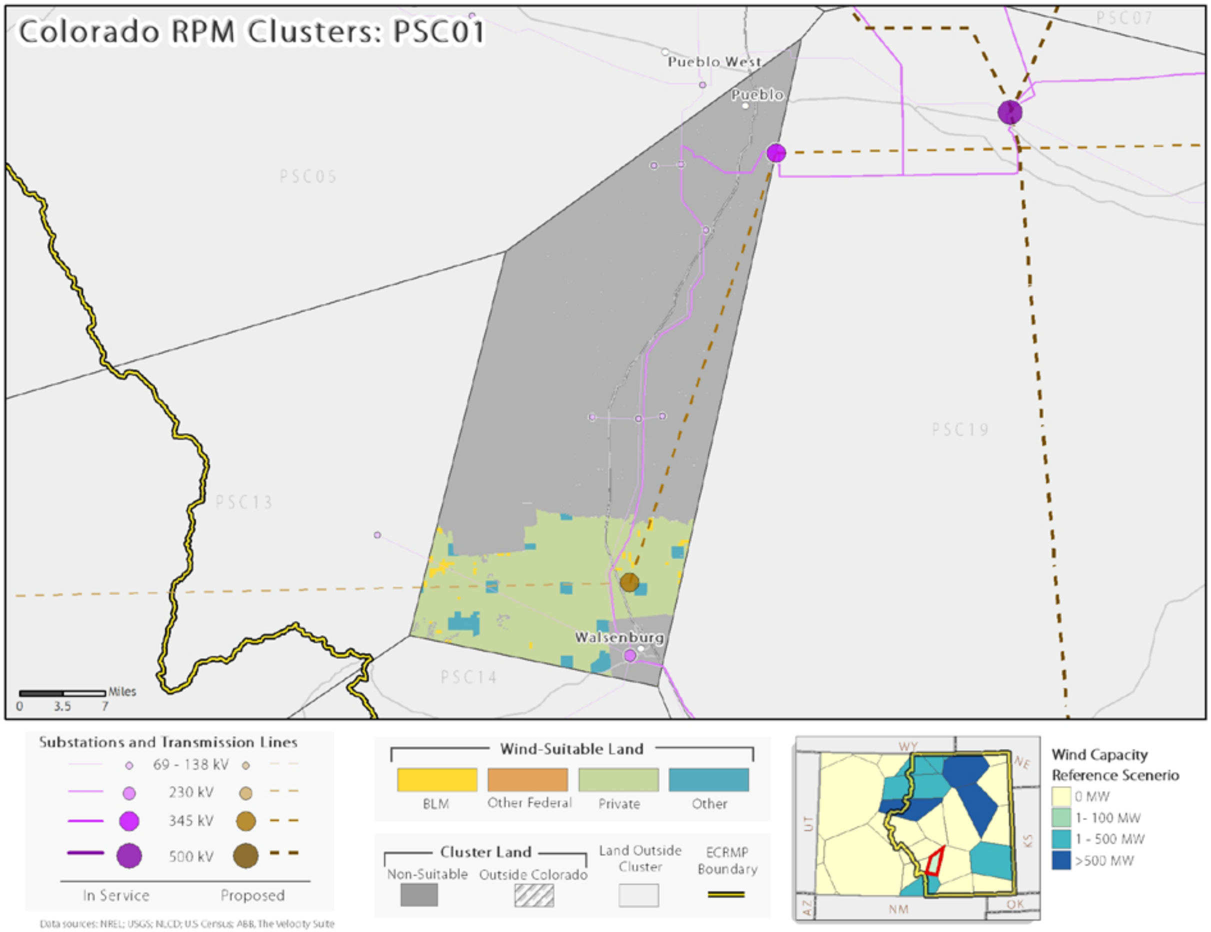
ECRMP Wind Resource Regions



ECRMP—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	660	8	10,262	125	33,696	409	22,132	269
Federal	276	3	33,679	409	148,468	1,802	732,313	8,891
Other	14,855	180	286,284	3,476	403,365	4,897	624,398	7,581
Private	169,934	2,063	3,479,603	42,244	5,595,939	67,938	8,625,066	104,713

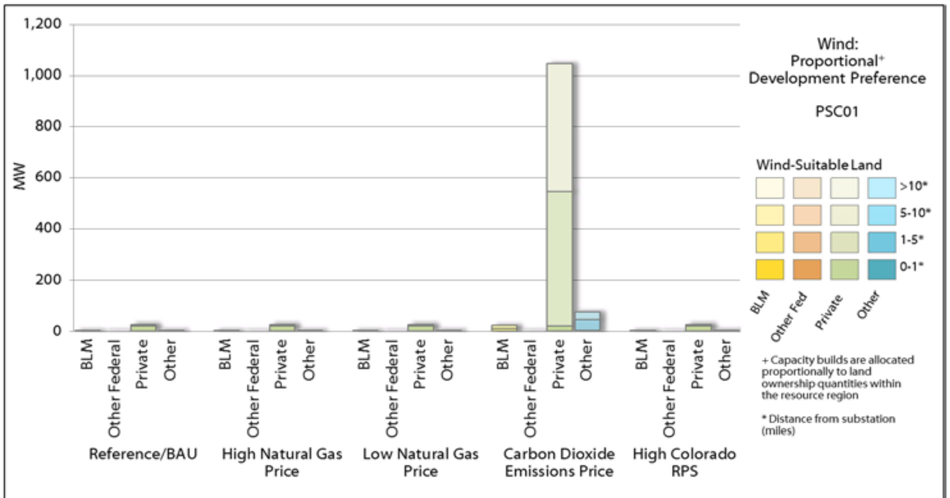
ECRMP—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
4,428	6,395	4,080	9,986	5,758

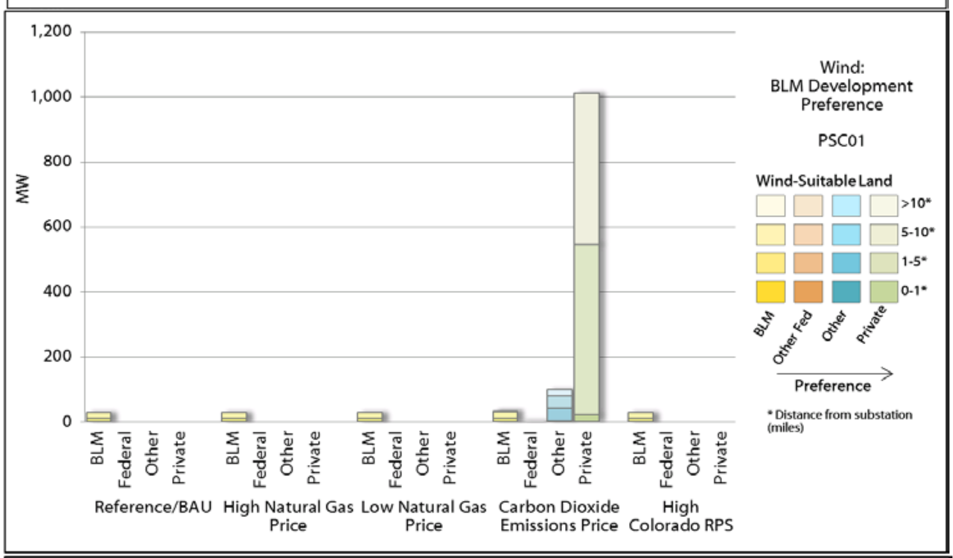
PSC01 Wind Resource Region

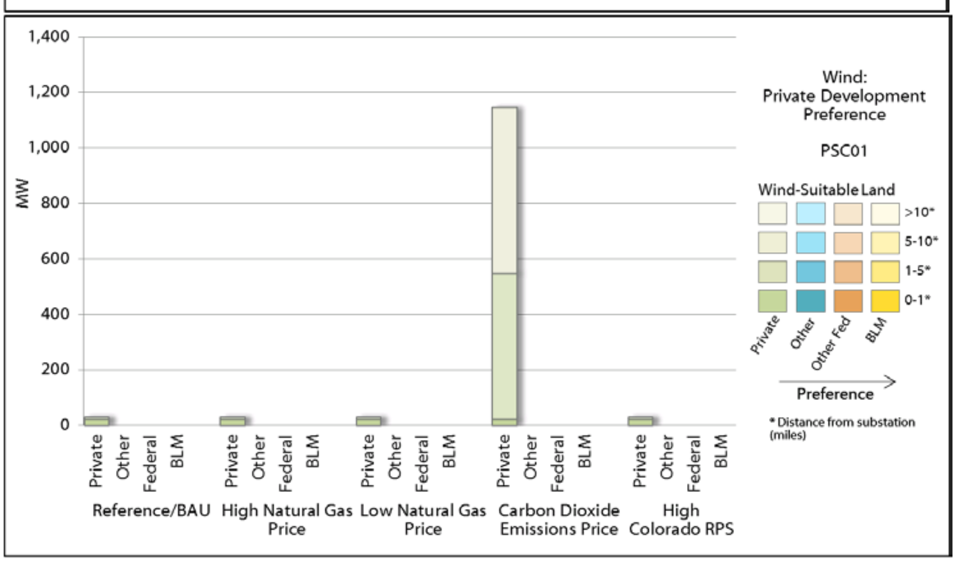


PSC01—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	926	11	1,626	20	160	2
Federal	0	0	0	0	0	0	0	0
Other	228	3	3,311	40	2,947	36	1,764	21
Private	1,781	22	43,220	525	61,155	742	11,224	136

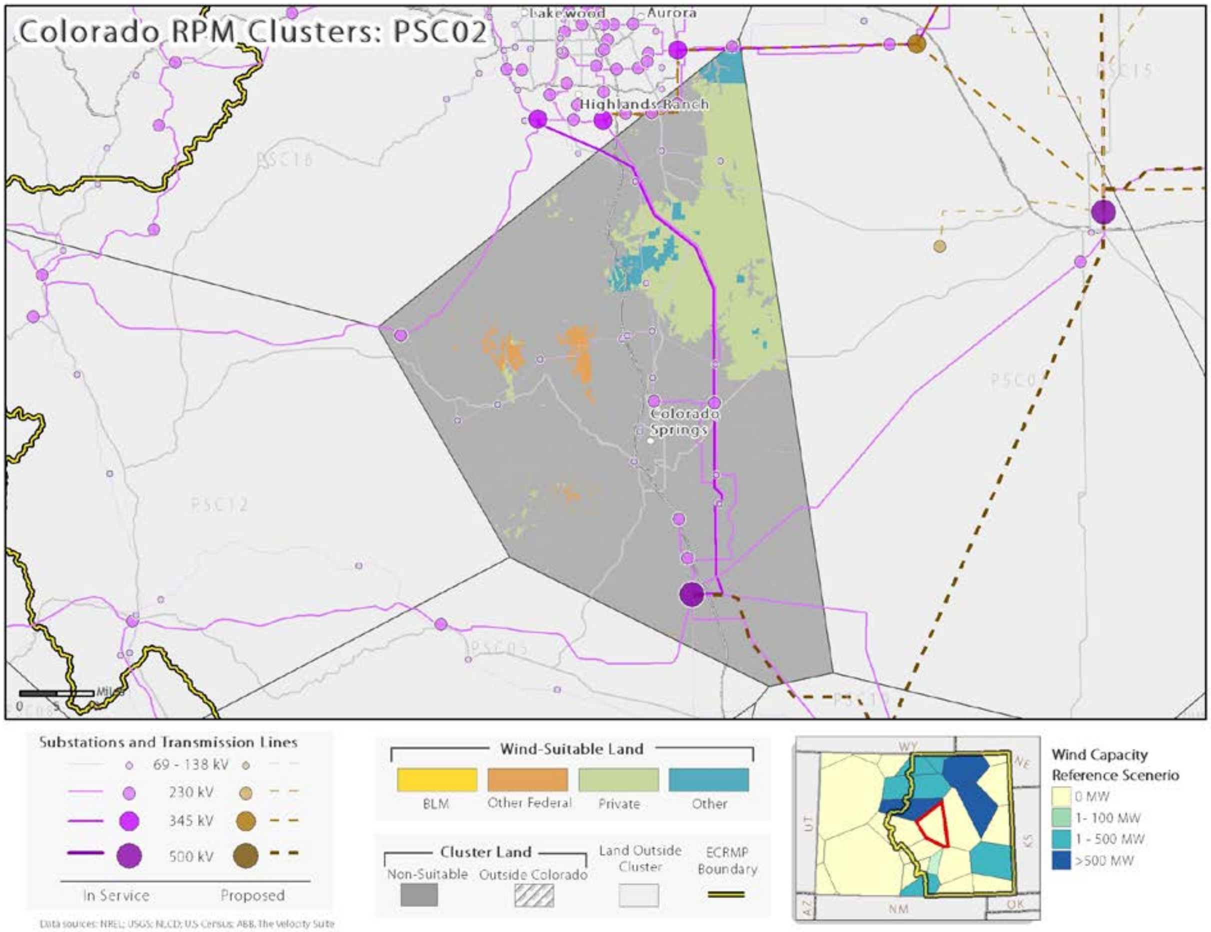
PSC01—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
29	29	29	1,145	29


Wind:
Proportional+
Development Preference
PSC01
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
1,200
1,000
800
600
400
200
0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Wind:
BLM Development Preference
PSC01
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
1,200
1,000
800
600
400
200
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

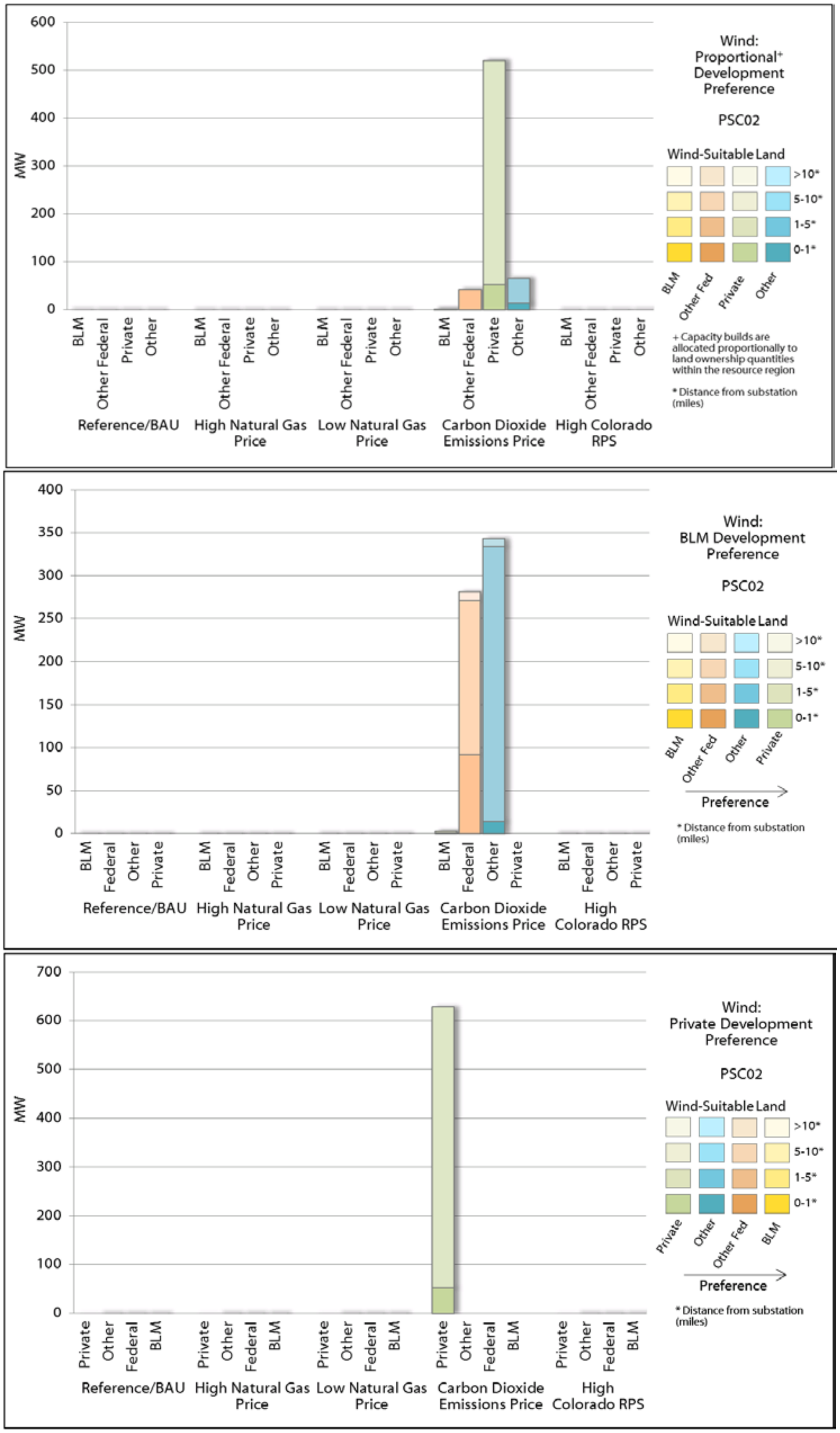

Wind:
Private Development Preference
PSC01
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
1,400
1,200
1,000
800
600
400
200
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

PSC02 Wind Resource Region

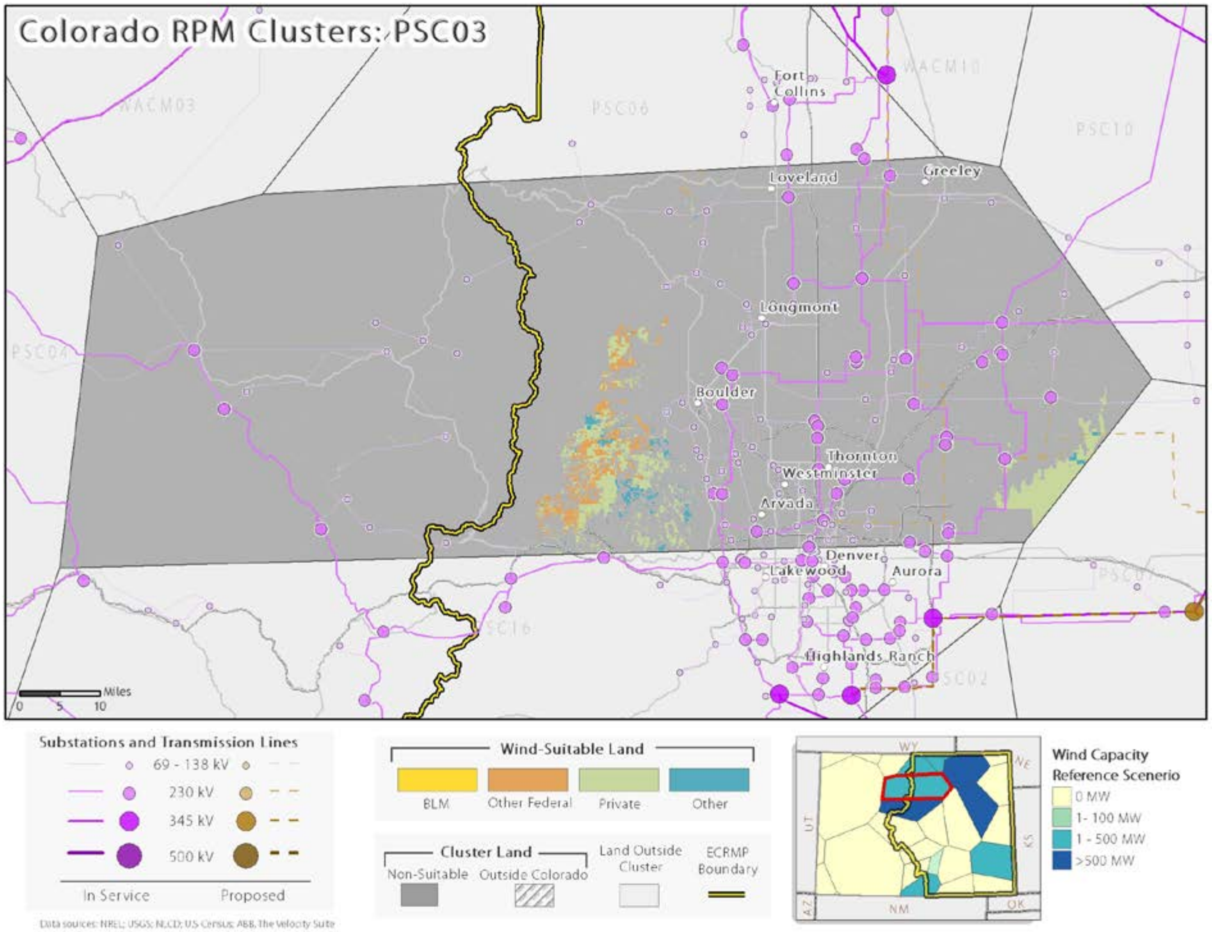


PSC02—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	27	0	10	0	197	2
Federal	0	0	7,562	91	14,777	179	867	10
Other	1,103	13	26,424	321	8,264	100	684	8
Private	4,274	51	87,237	1,060	153,080	1,860	45,535	553

PSC02—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
0	0	0	628	0


Wind: Proportional+ Development Preference
PSC02
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Wind: BLM Development Preference
PSC02
Wind-Suitable Land
Preference
* Distance from substation (miles)
Wind: Private Development Preference
PSC02
Wind-Suitable Land
Preference
* Distance from substation (miles)

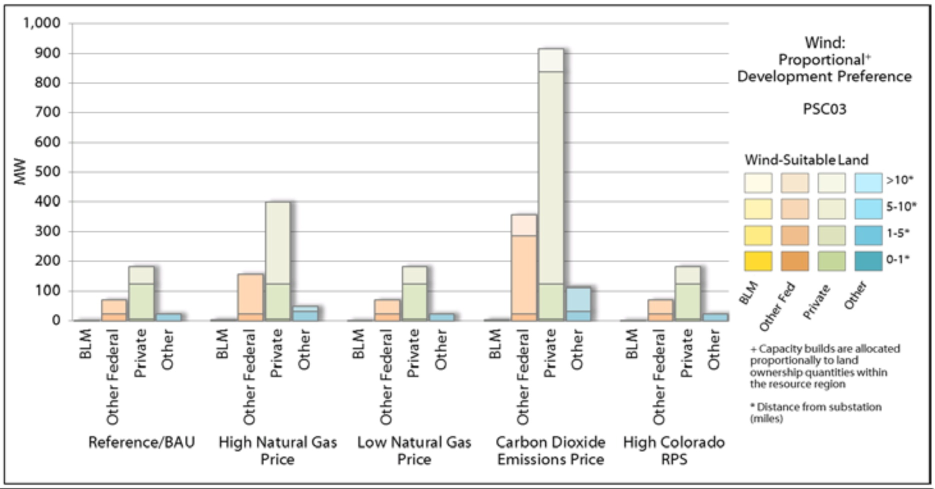
PSC03 Wind Resource Region

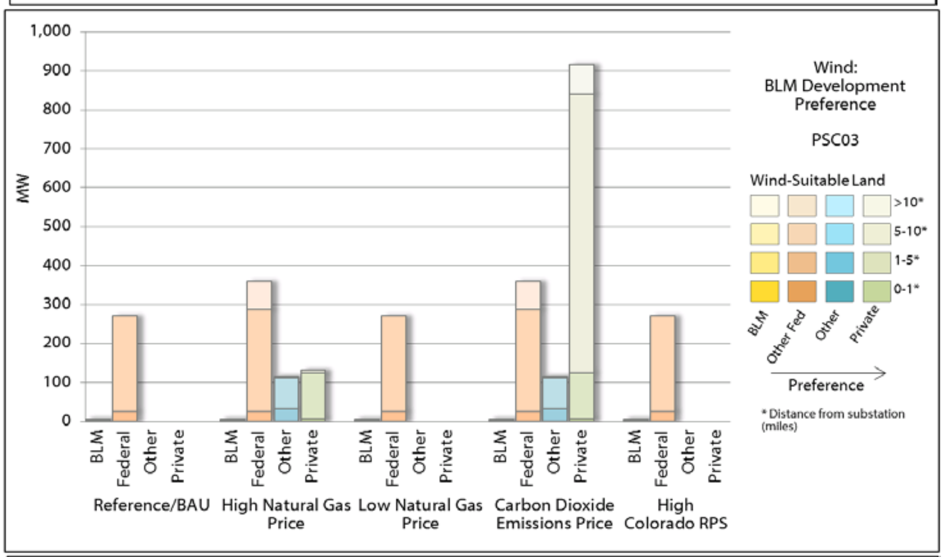


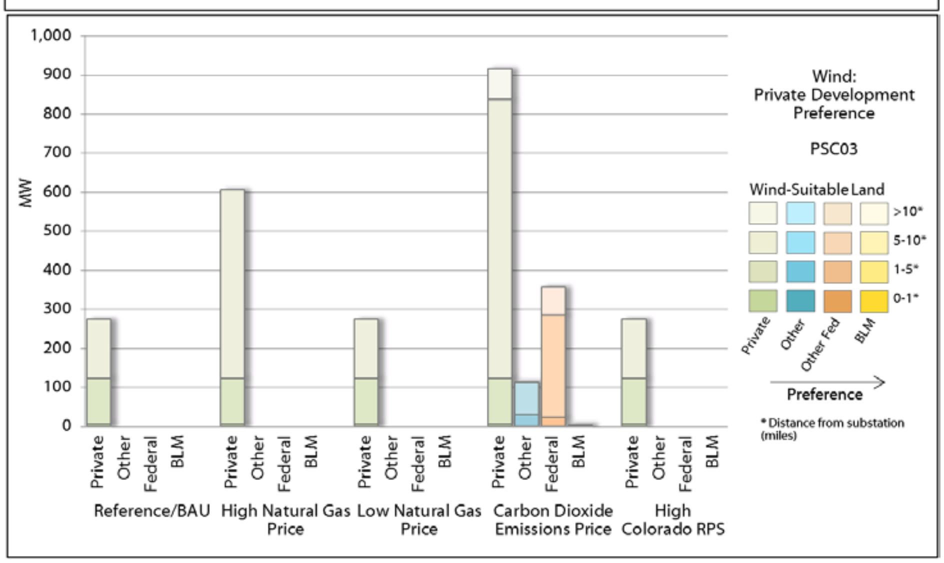
PSC03—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	90	1	238	2	0	0
Federal	0	0	1,960	23	21,570	262	5,964	72
Other	0	0	2,579	31	6,627	80	216	2
Private	499	6	9,675	117	58,891	715	6,394	77

PSC03—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
275	607	275	1,821[32]	275

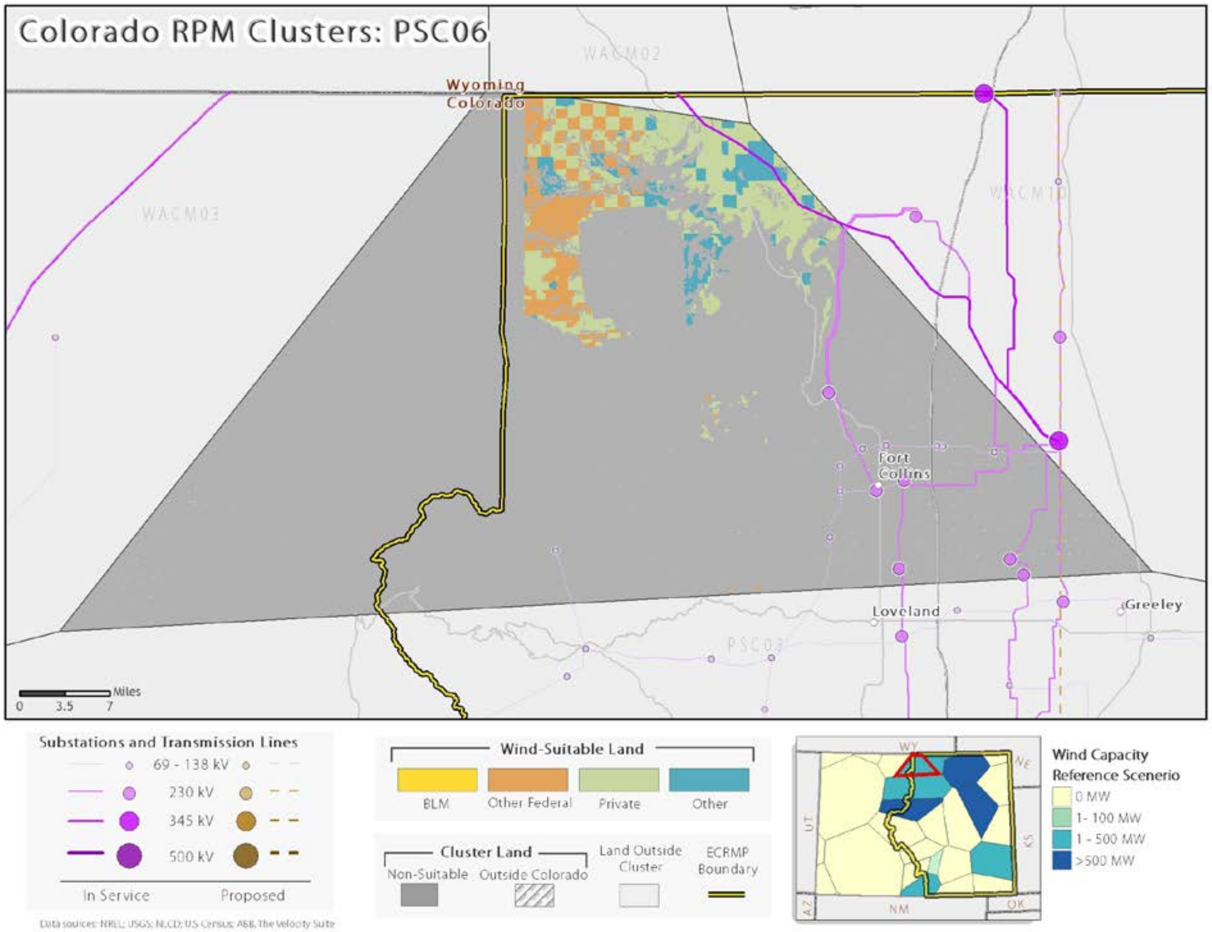
32 The total MW potential for wind-suitable lands in PSC03 is 1,388 MW while RPM capacity expansion in the CO_2 scenario exceeds this number by 433 MW. Excess capacity expansion results in certain regions are due to non-coterminous resource availability and prescribed capacity expansion data sets.


Wind:
Proportional+
Development Preference
PSC03
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Other Federal


Wind:
BLM Development
Preference
PSC03
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Federal

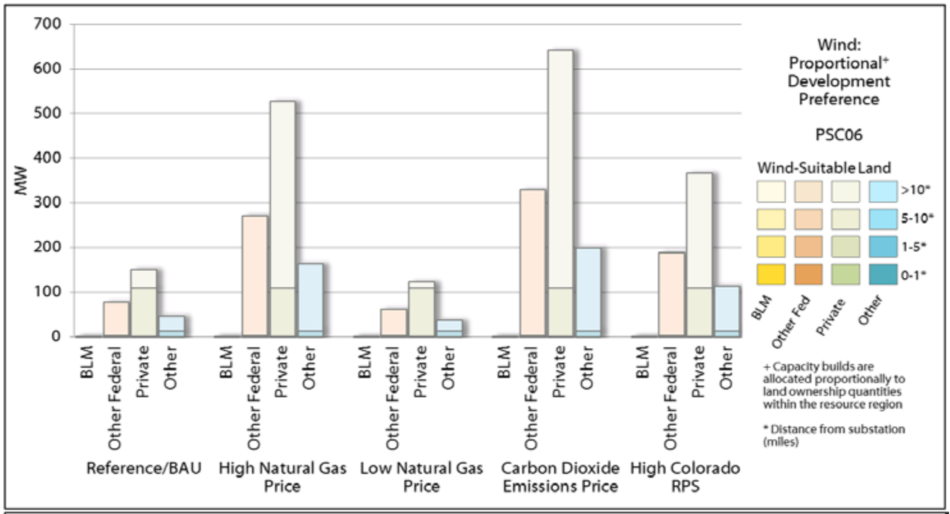

Wind:
Private Development
Preference
PSC03
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Federal

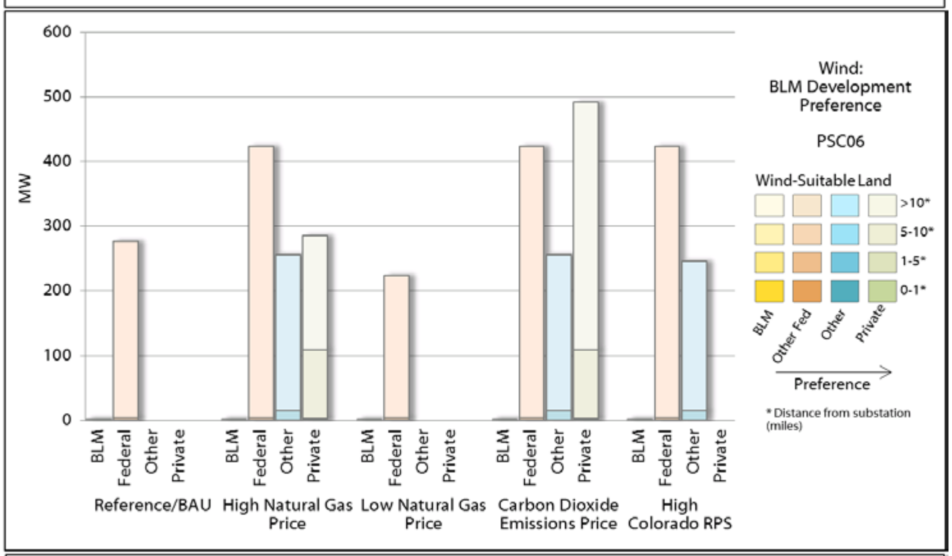
PSC06 Wind Resource Region

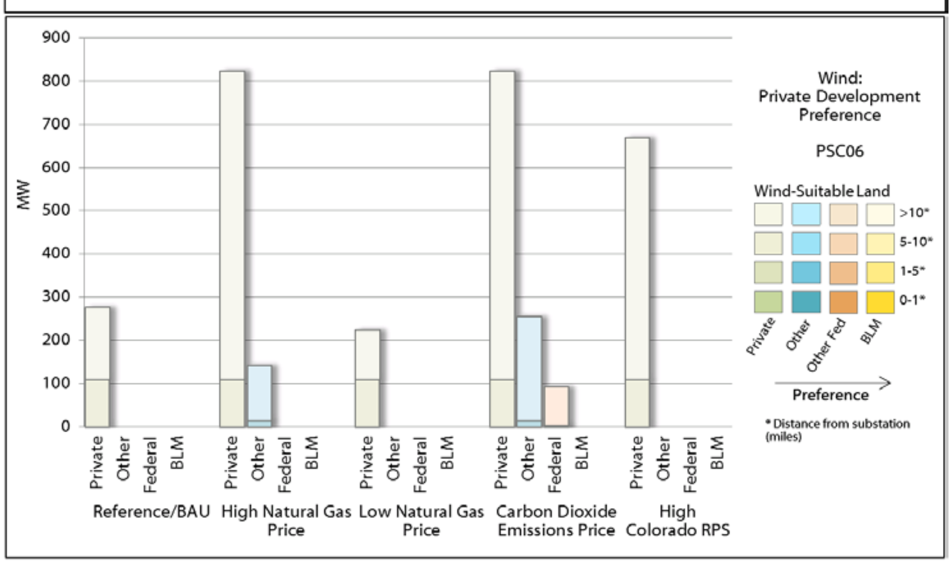


PSC06 — Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	0	0	16	0	0	0
Federal	0	0	0	0	283	3	34,608	420
Other	0	0	0	0	1,184	14	19,870	241
Private	0	0	183	2	8,824	107	58,789	714

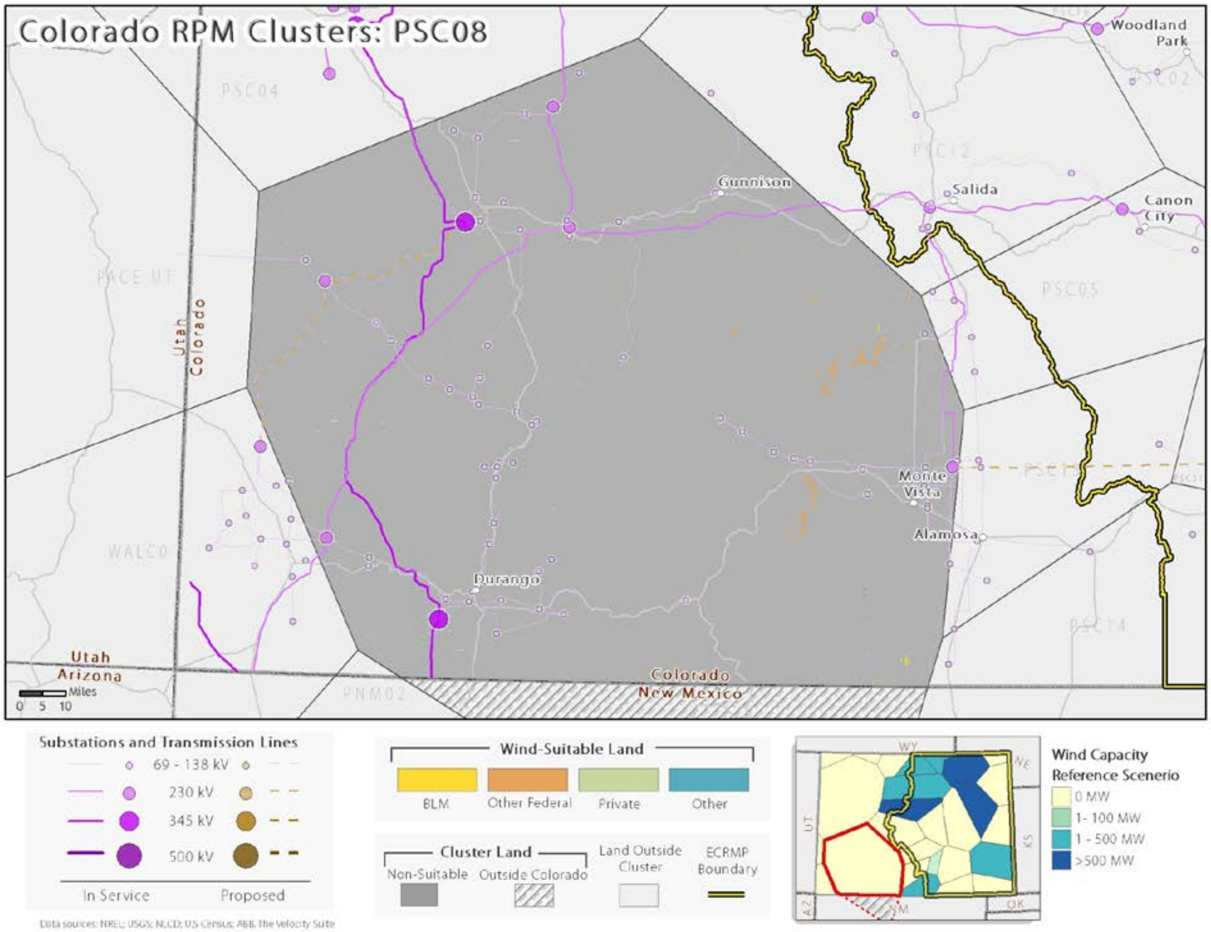
PSC06— Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
277	965	224	1,171	670


Wind:
Proportional+
Development
Preference
PSC06
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
700
600
500
400
300
200
100
0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Wind:
BLM Development
Preference
PSC06
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
600
500
400
300
200
100
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

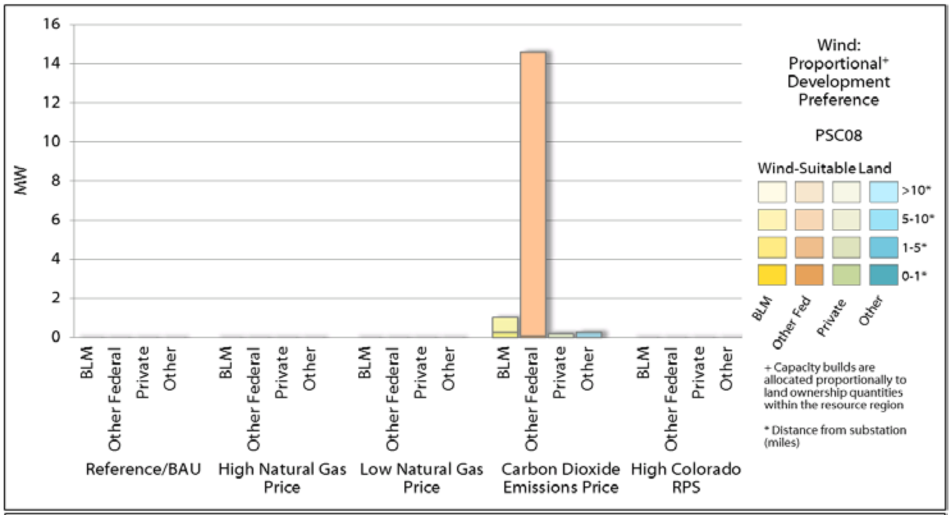

Wind:
Private Development
Preference
PSC06
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
900
800
700
600
500
400
300
200
100
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

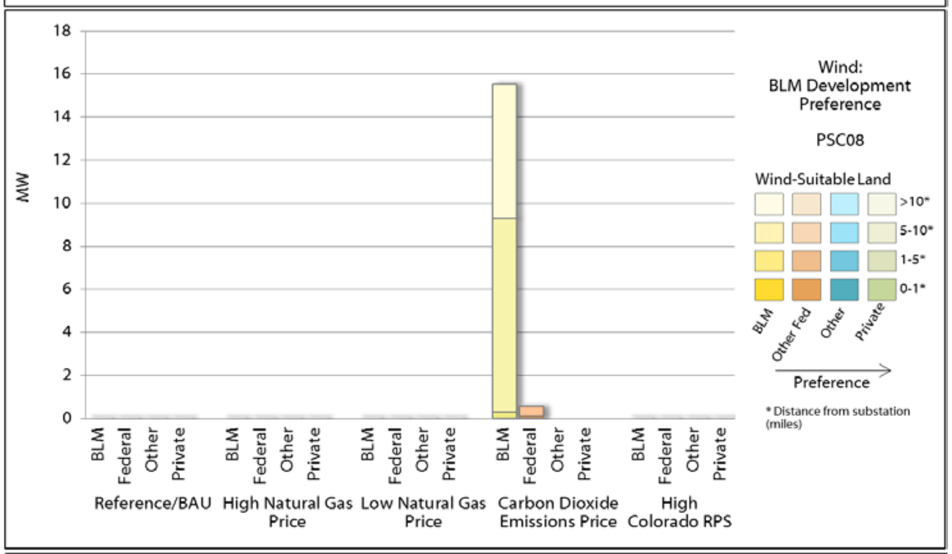
PSC08 Wind Resource Region

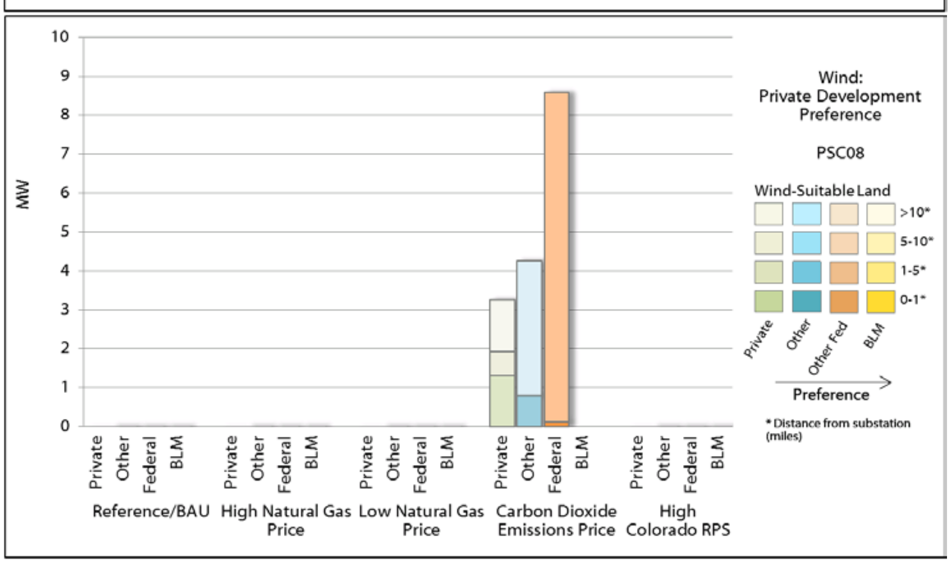


PSC08—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	25	0	741	9	514	6
Federal	10	0	1,278	15	3,487	42	13,518	164
Other	0	0	65	0	0	0	287	3
Private	0	0	107	1	52	0	109	1

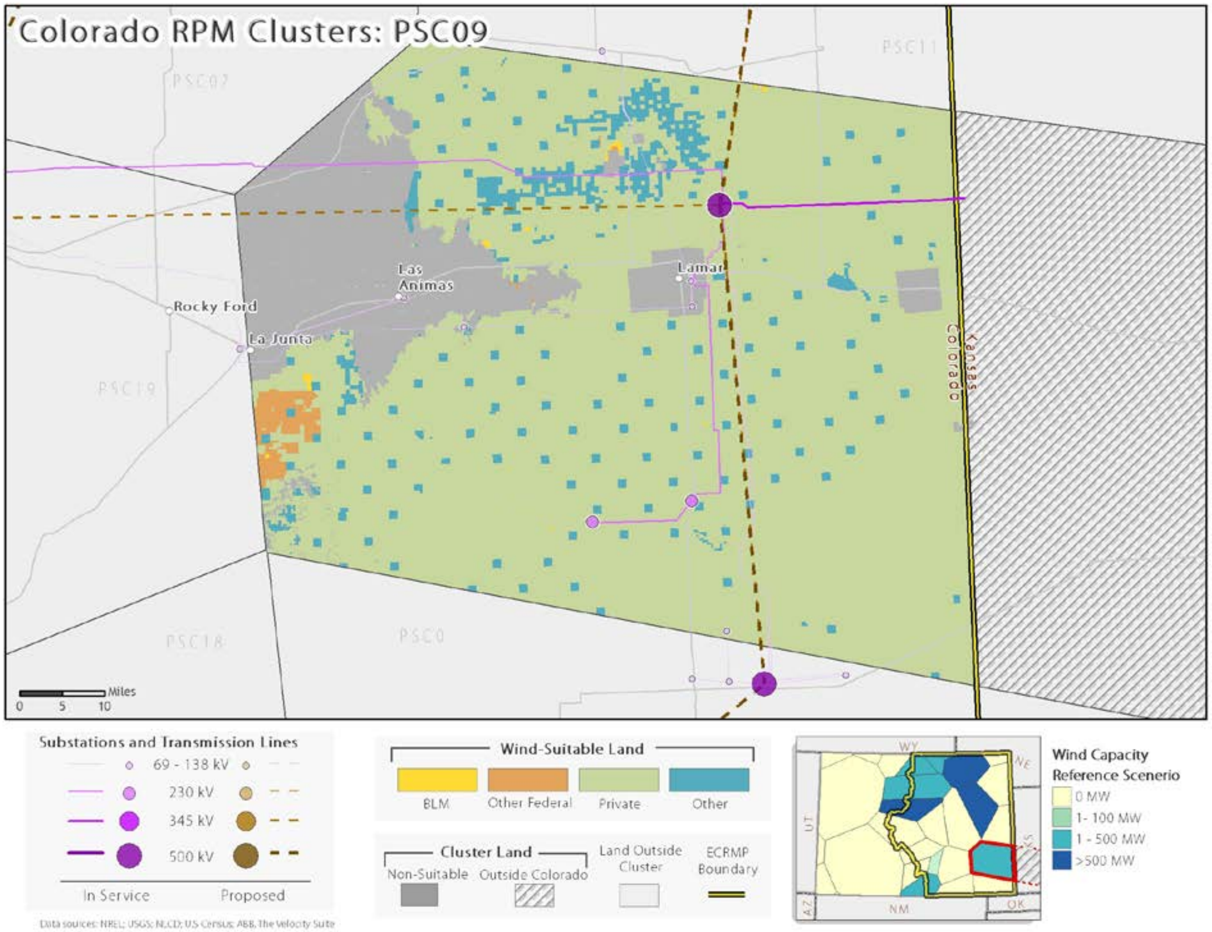
PSC08—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
0	0	0	16	0


Wind:
Proportional+
Development
Preference
PSC08
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
BLM
Other Federal
Private
Other


Wind:
BLM Development
Preference
PSC08
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
BLM
Federal
Other
Private

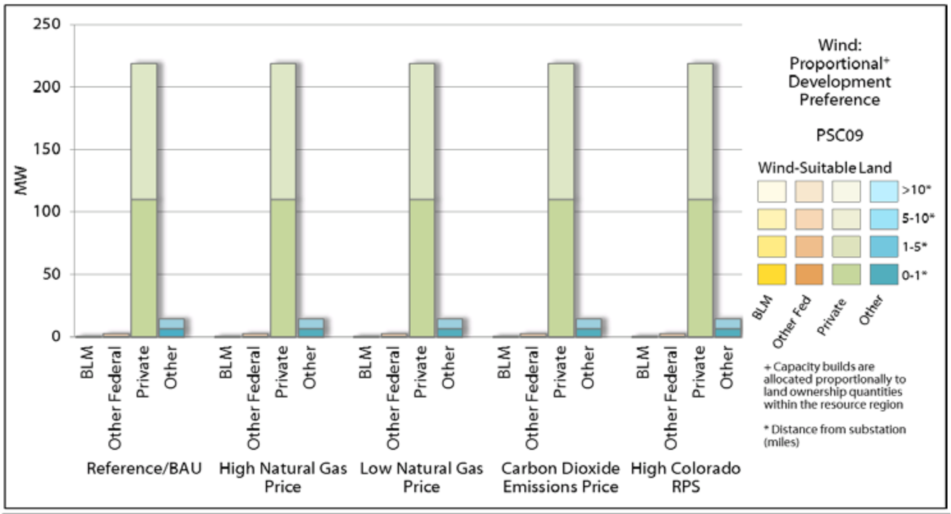

Wind:
Private Development
Preference
PSC08
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Private
Other
Federal
BLM

PSC09 Wind Resource Region

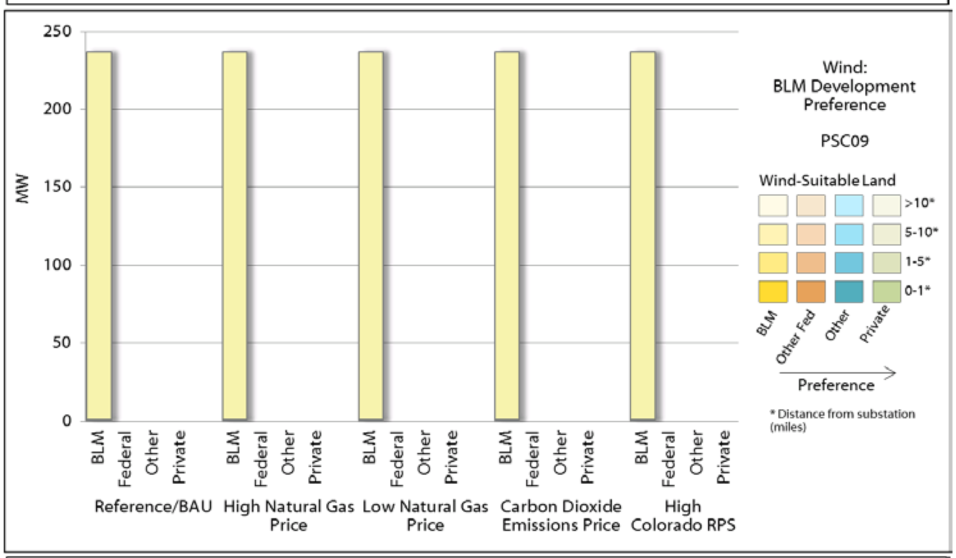


PSC09—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	90	1	1,809	21	1,882	22
Federal	0	0	33	0	13,469	163	18,803	228
Other	533	6	12,491	151	57,470	698	106,279	1,291
Private	9,041	109	262,287	3,187	720,178	8,752	1,698,638	20,643

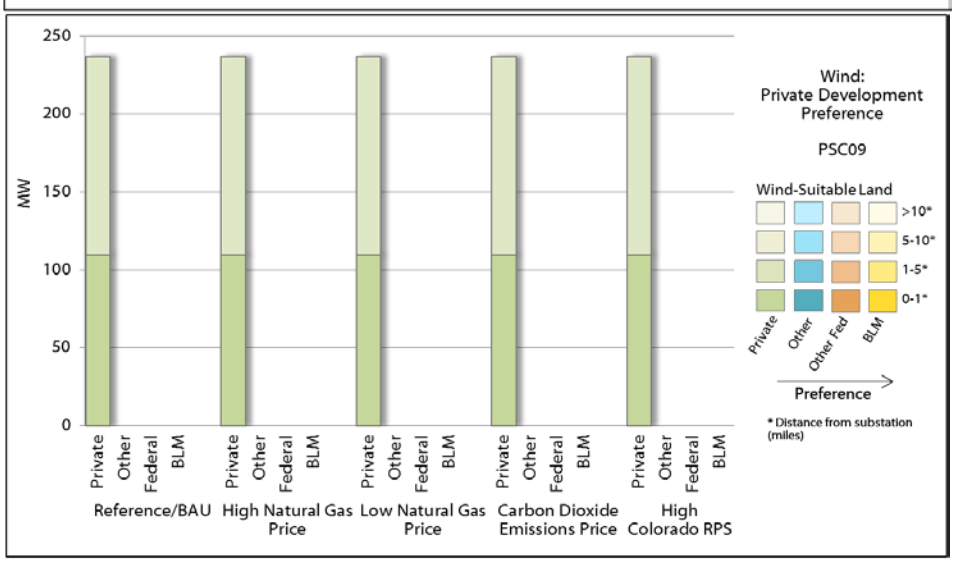
PSC09—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
237	237	237	237	237



Wind:
Proportional+
Development
Preference
PSC09
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
250
200
150
100
50
0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

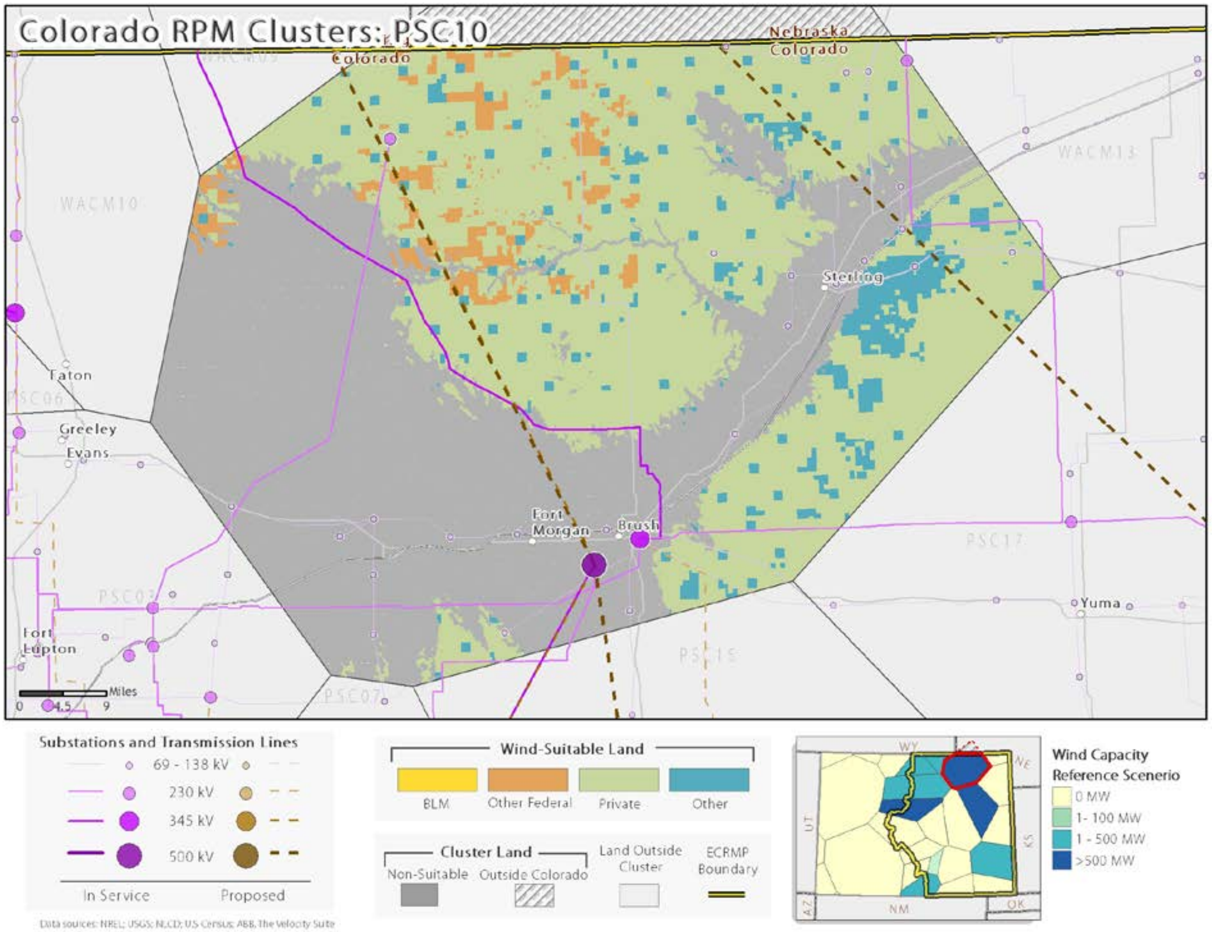


Wind:
BLM Development
Preference
PSC09
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
250
200
150
100
50
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS



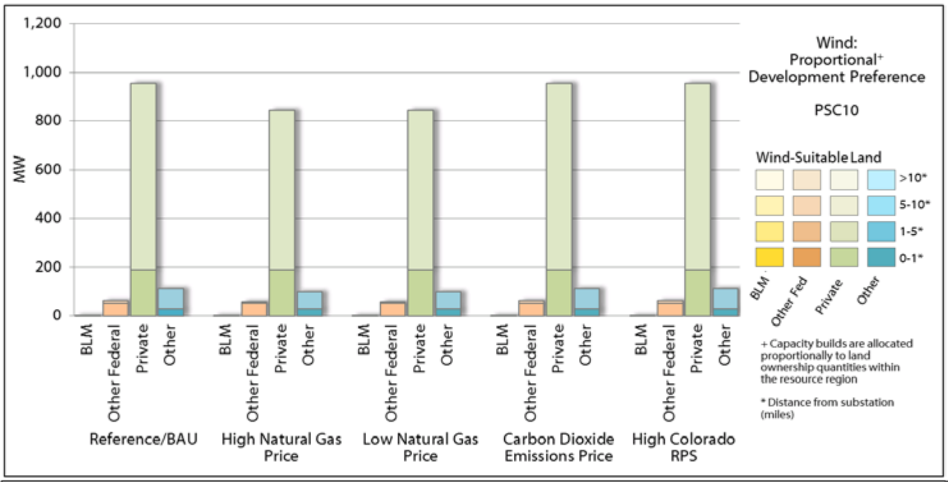
Wind:
Private Development
Preference
PSC09
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
250
200
150
100
50
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

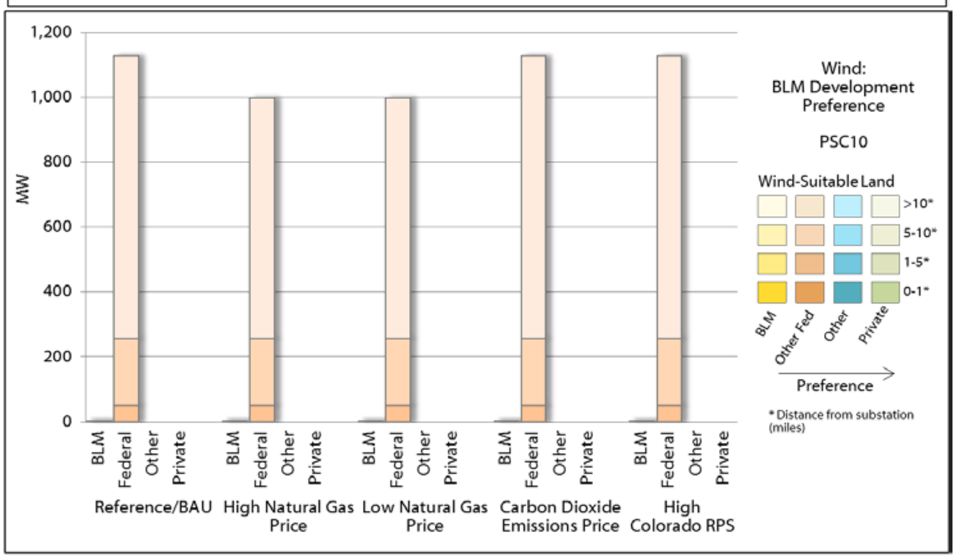
PSC10 Wind Resource Region

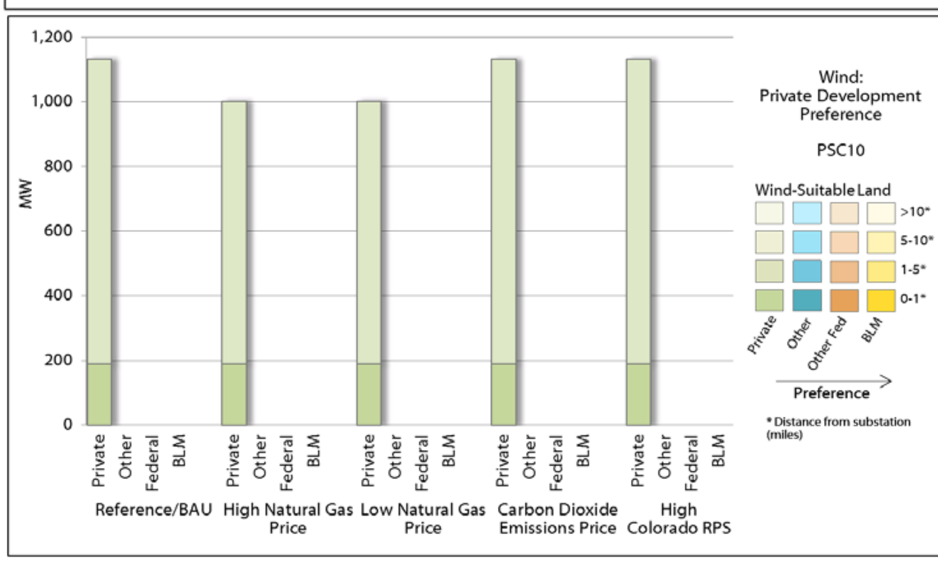


PSC10—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	0	0	105	1	56	0
Federal	0	0	4,289	52	16,839	204	70,446	856
Other	2,283	27	54,102	657	58,238	707	43,326	526
Private	15,575	189	275,559	3,348	524,775	6,377	537,298	6,529

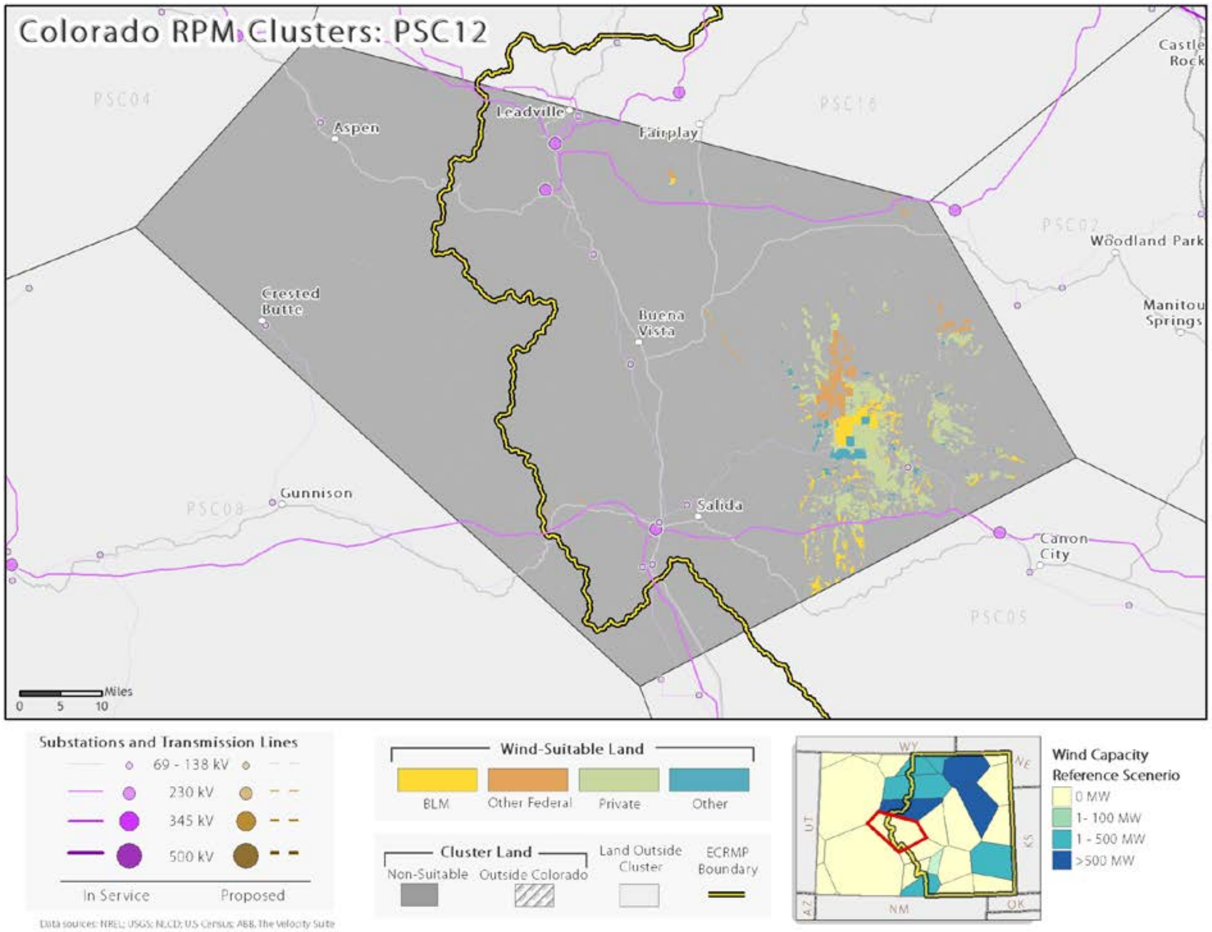
PSC10—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
1,131	1,001	1,001	1,131	1,131


Wind:
Proportional+
Development Preference
PSC10
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
1,200
1,000
800
600
400
200
0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Wind:
BLM Development Preference
PSC10
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
1,200
1,000
800
600
400
200
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

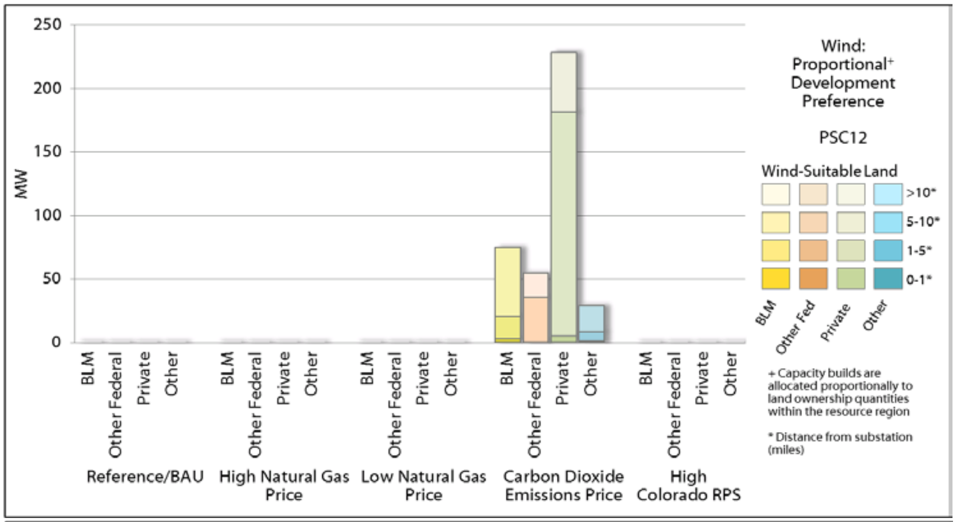

Wind:
Private Development Preference
PSC10
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
1,200
1,000
800
600
400
200
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

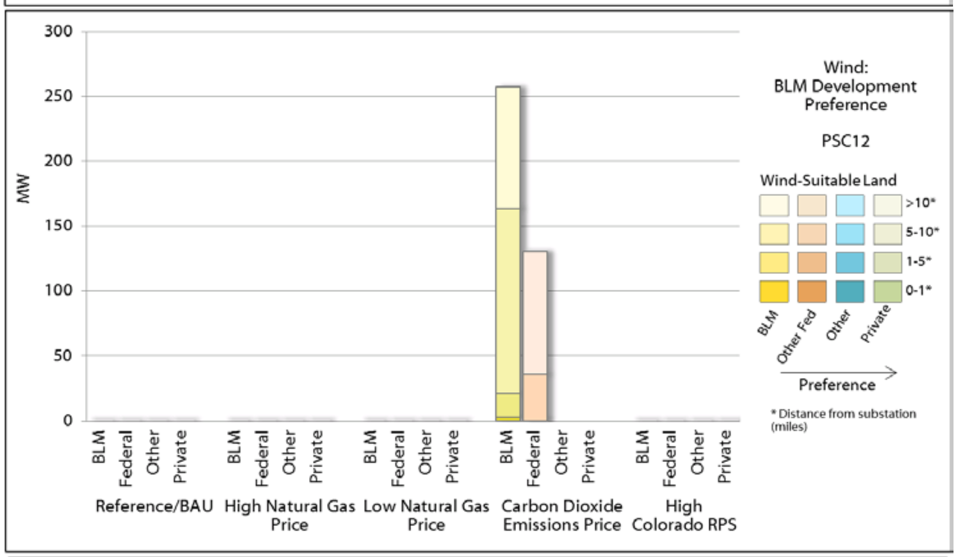
PSC12 Wind Resource Region

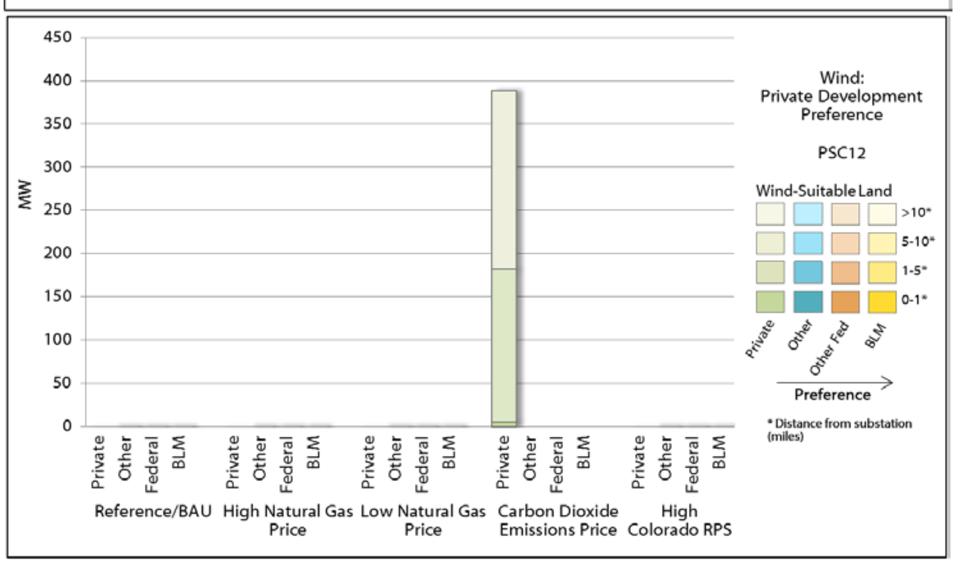


PSC12—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	230	2	1,506	18	11,751	142	7,706	93
Federal	0	0	1	0	2,946	35	12,587	152
Other	91	1	608	7	5,288	64	2,227	27
Private	414	5	14,534	176	31,796	386	17,677	214

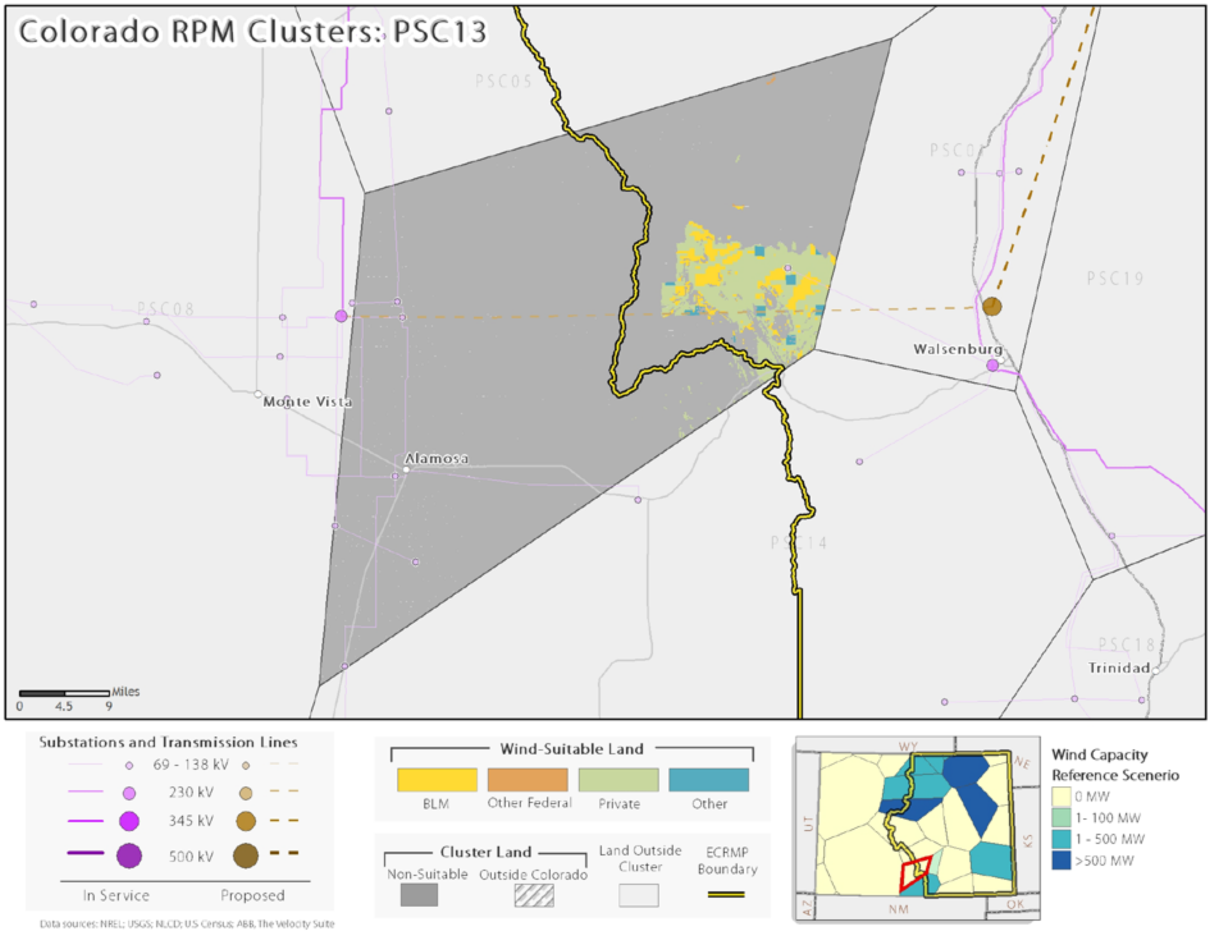
PSC12—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
0	0	0	388	0


Wind:
Proportional+
Development
Preference
PSC12
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
250
200
150
100
50
0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Wind:
BLM Development
Preference
PSC12
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
300
250
200
150
100
50
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

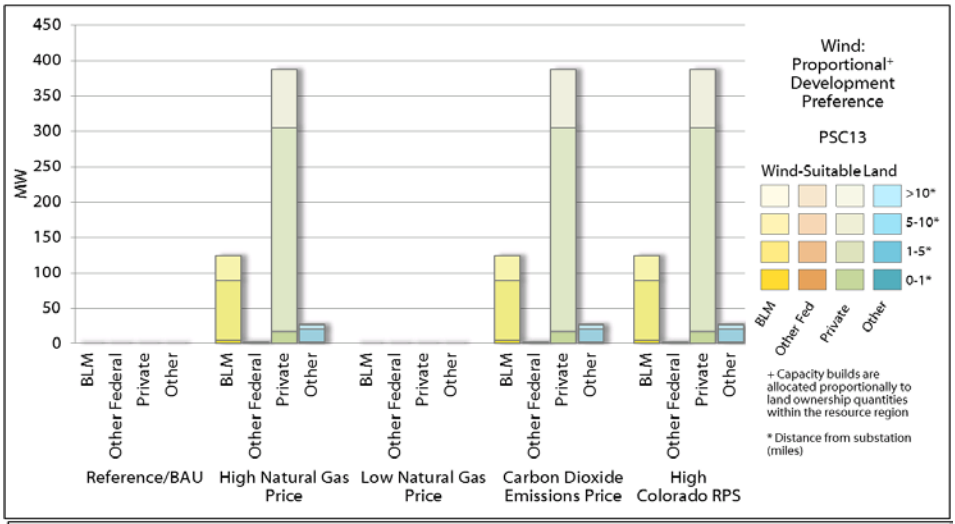

Wind:
Private Development
Preference
PSC12
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
450
400
350
300
250
200
150
100
50
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

PSC13 Wind Resource Region

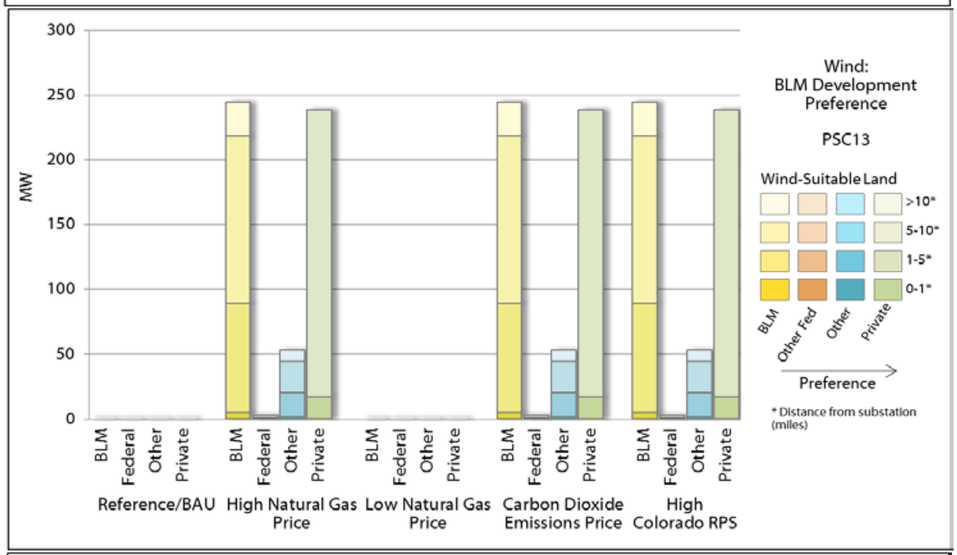


PSC13—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	430	5	6,933	84	10,654	129	2,168	26
Federal	0	0	0	0	92	1	165	2
Other	148	1	1,517	18	2,027	24	696	8
Private	1,432	17	23,758	288	27,619	335	10,253	124

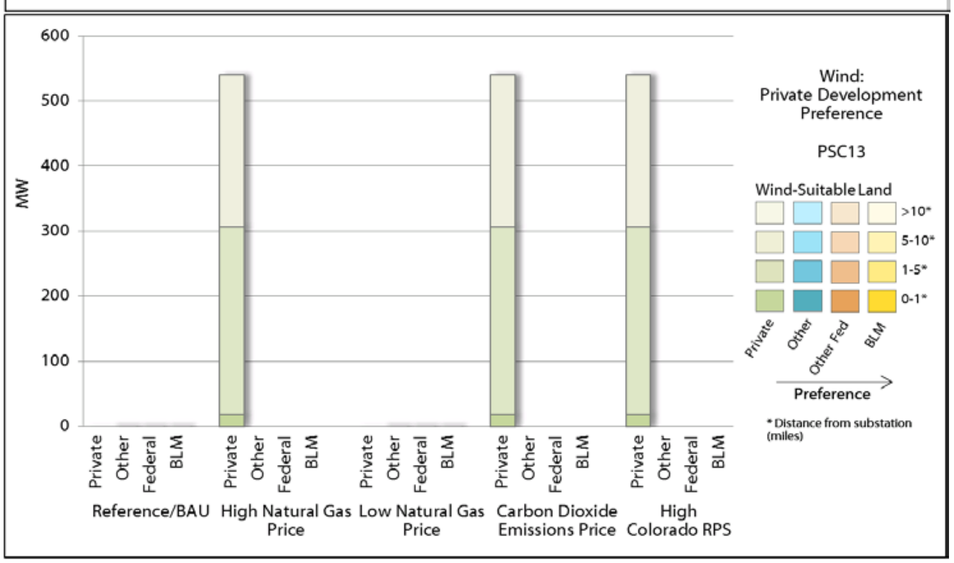
PSC13—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
0	540	0	540	540



Wind: Proportional+ Development Preference
PSC13
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
450
400
350
300
250
200
150
100
50
0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

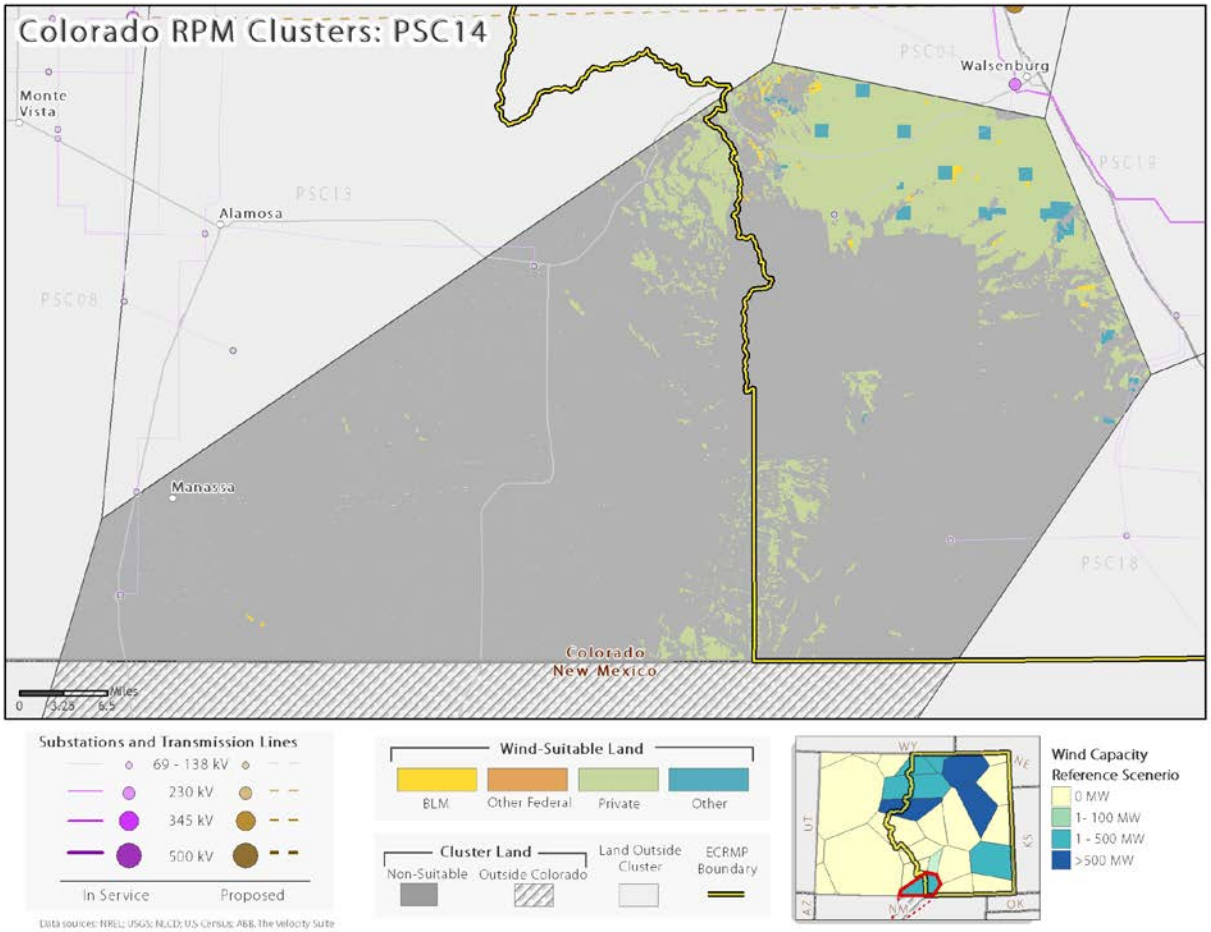


Wind: BLM Development Preference
PSC13
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
300
250
200
150
100
50
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS



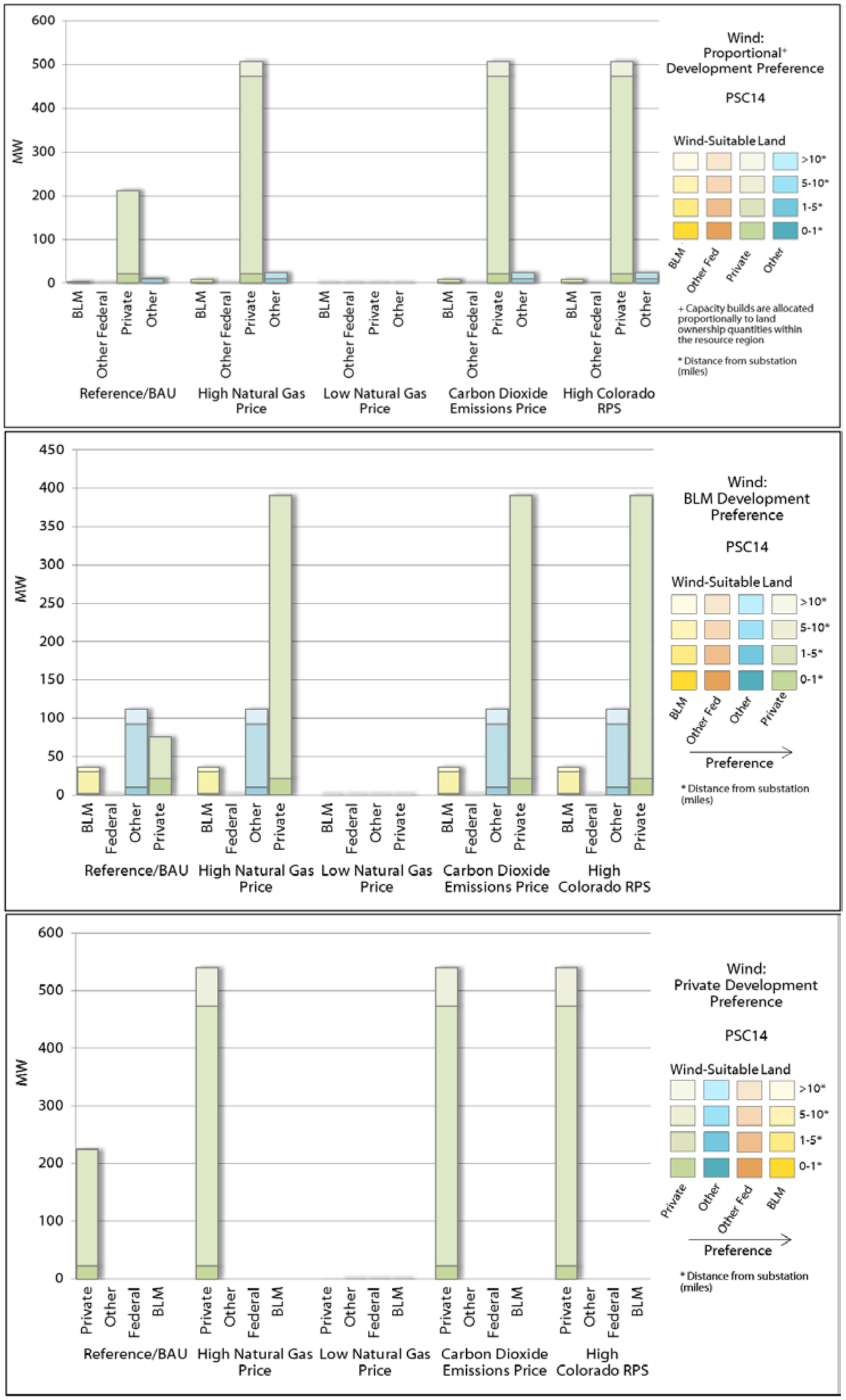
Wind: Private Development Preference
PSC13
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
600
500
400
300
200
100
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

PSC14 Wind Resource Region

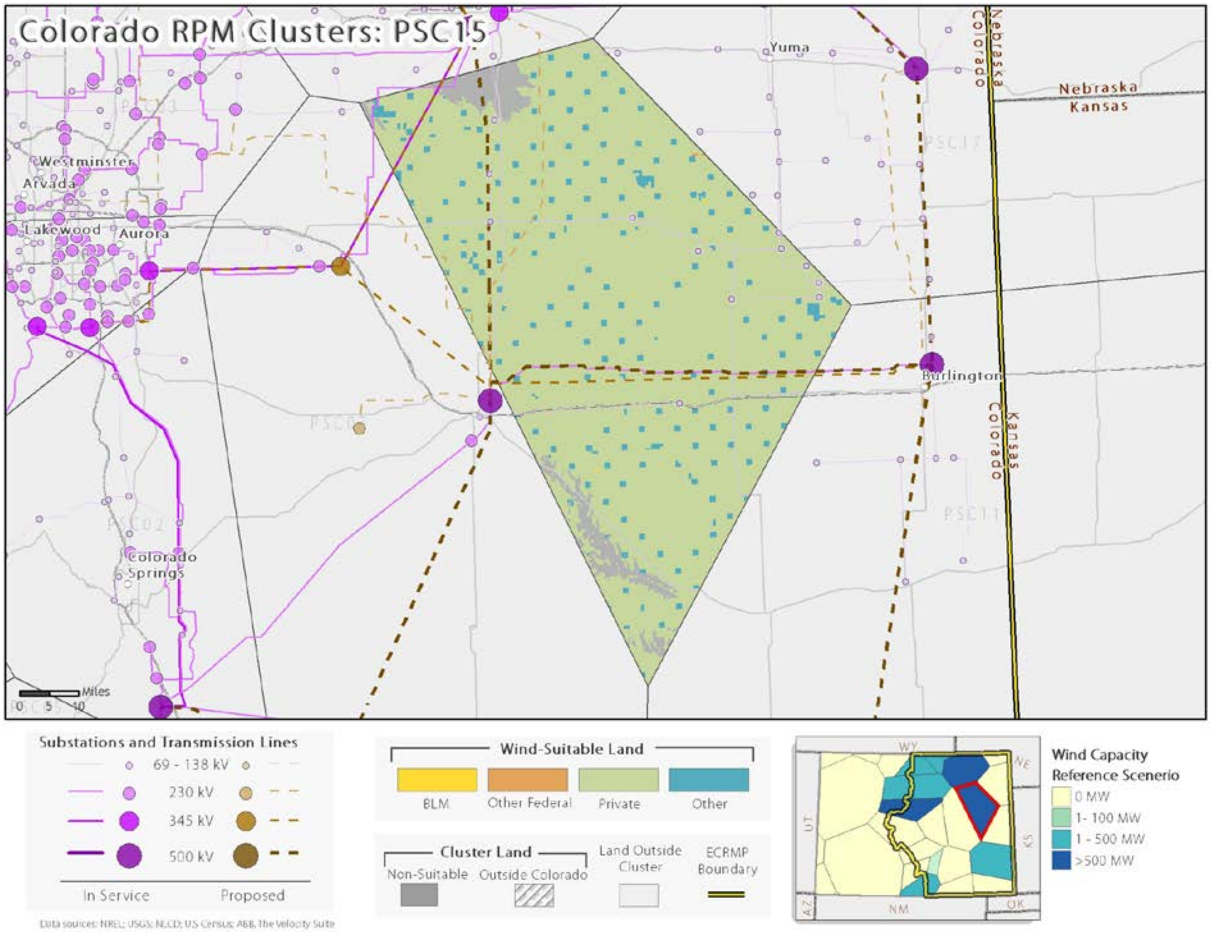


PSC14—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	174	2	2,331	28	534	6
Federal	0	0	0	0	0	0	0	0
Other	0	0	811	9	6,825	82	1,585	19
Private	1,789	21	37,196	452	103,813	1,261	51,224	622

PSC14—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
225	540	0	540	540

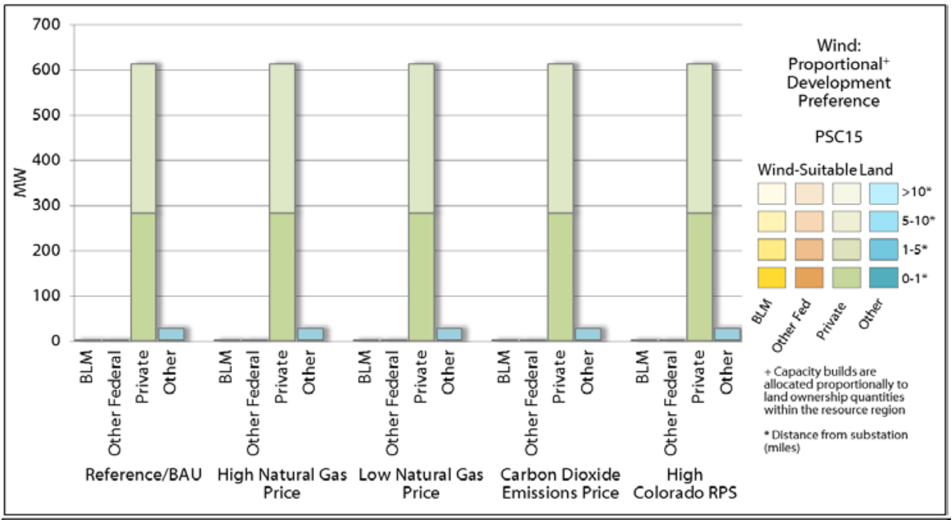

Wind: Proportional+ Development Preference
PSC14
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
600
500
400
300
200
100
0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Wind: BLM Development Preference
PSC14
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
450
400
350
300
250
200
150
100
50
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Wind: Private Development Preference
PSC14
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
600
500
400
300
200
100
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

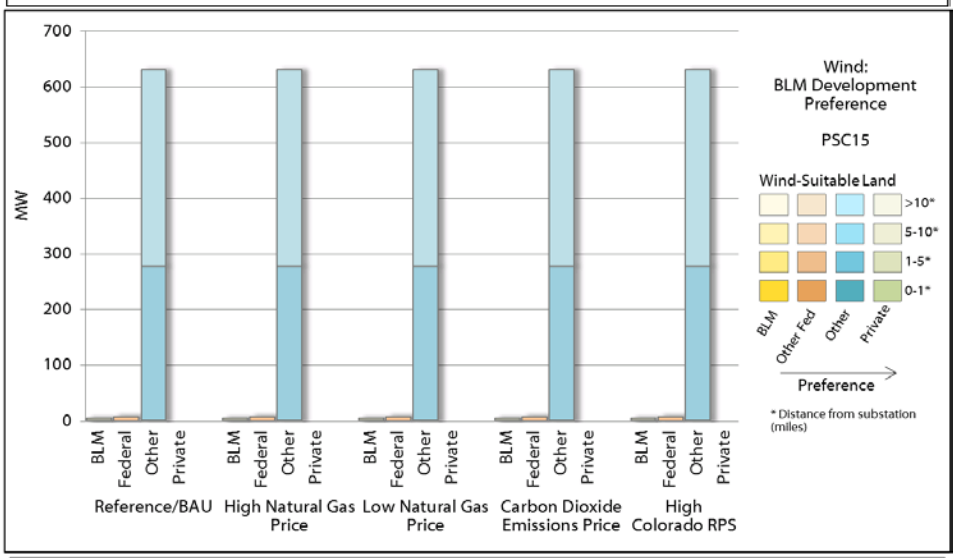
PSC15 Wind Resource Region

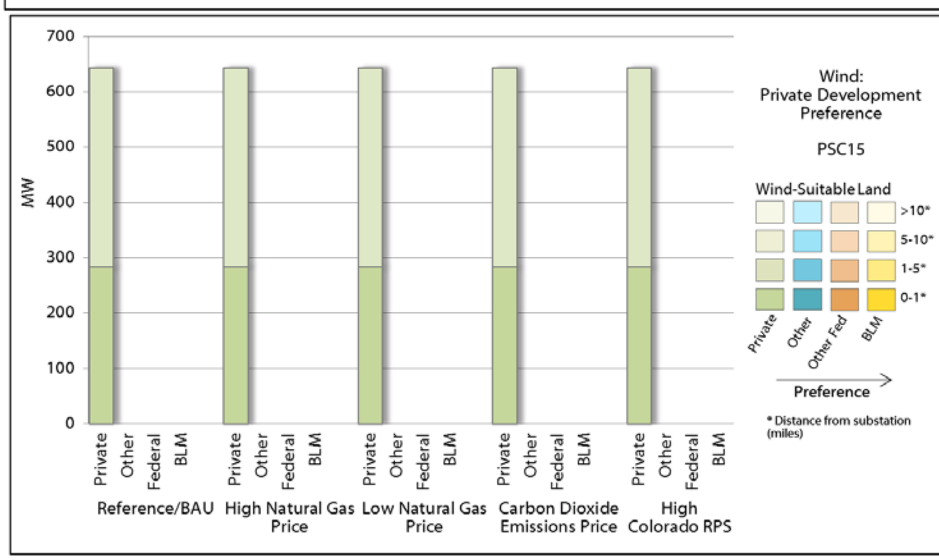


PSC15—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	0	0	157	1	240	2
Federal	0	0	613	7	0	0	0	0
Other	135	1	22,795	277	45,961	558	52,738	640
Private	23,295	283	434,978	5,286	908,865	11,045	1,205,957	14,655

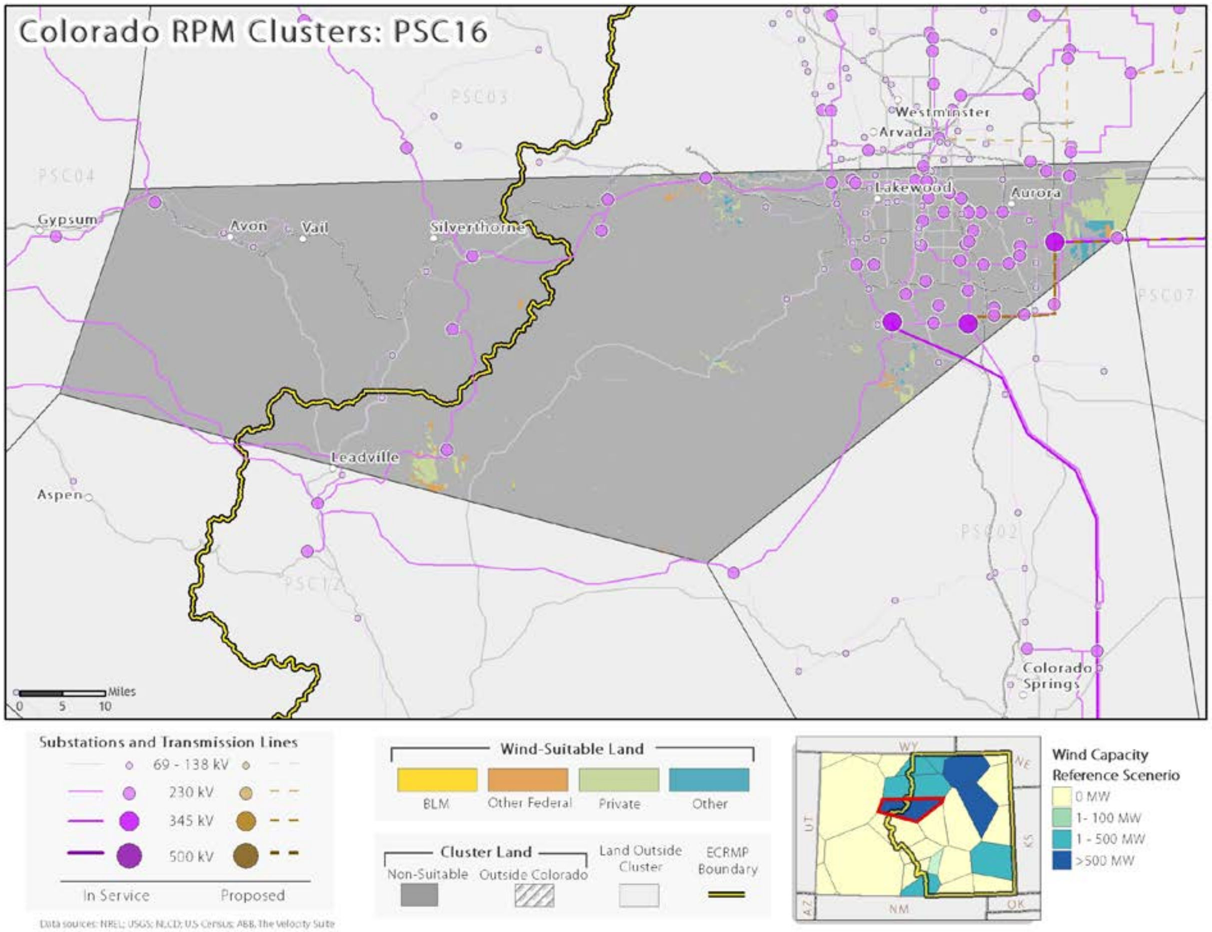
PSC15—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
643	643	643	643	643


700
600
500
400
300
200
100
0
MW
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Wind: Proportional+ Development Preference
PSC15
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)


700
600
500
400
300
200
100
0
MW
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Wind: BLM Development Preference
PSC15
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)


700
600
500
400
300
200
100
0
MW
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Wind: Private Development Preference
PSC15
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)

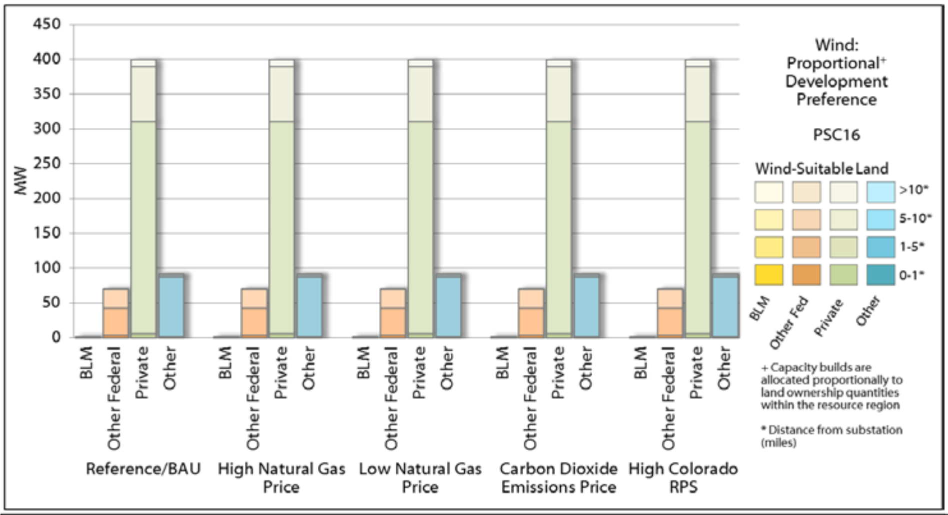
PSC16 Wind Resource Region

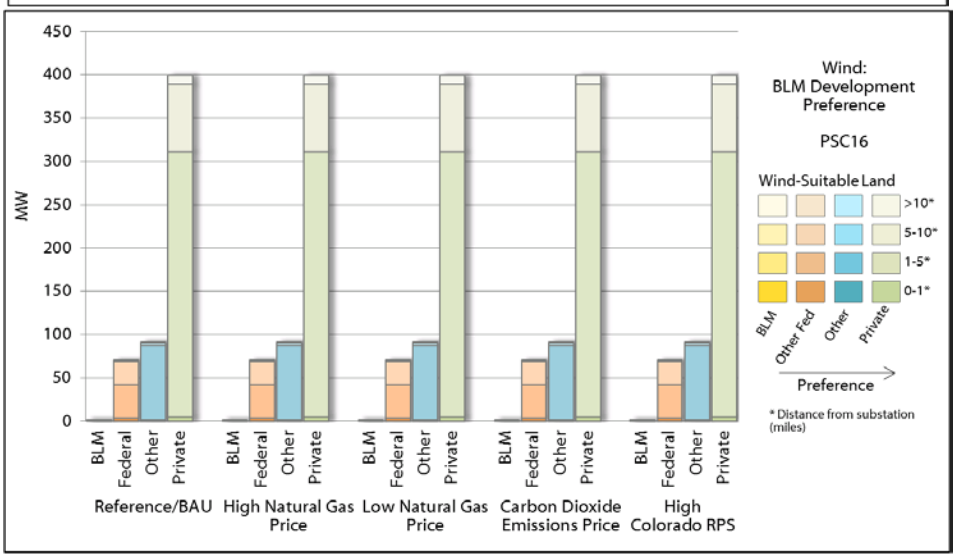


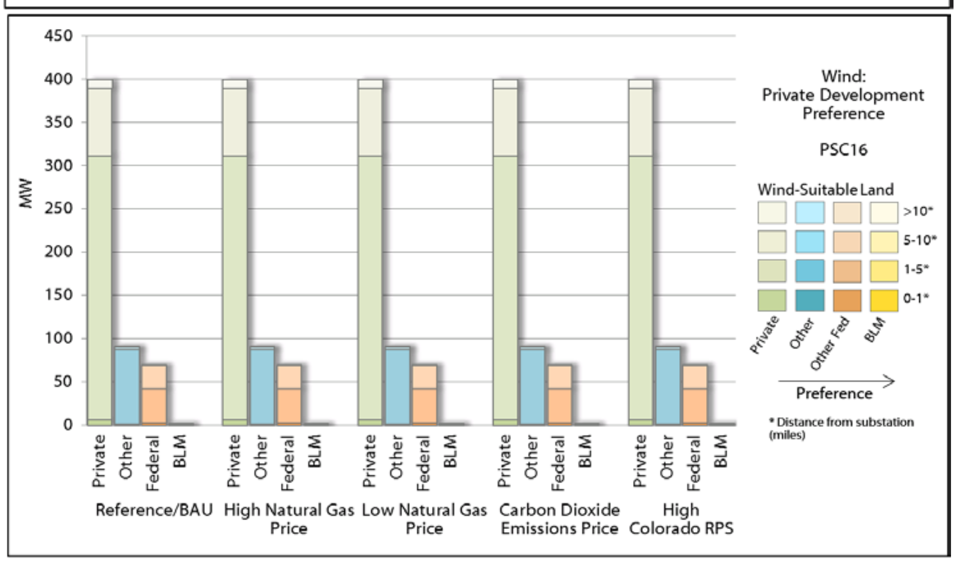
PSC16—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	80	0	72	0	0	0
Federal	274	3	3,220	39	2,199	26	128	1
Other	135	1	7,082	86	264	3	66	0
Private	464	5	25,160	305	6,473	78	862	10

PSC16—Modeled Wind Capacity[33]				
Ref	HI-NG	LO-NG	C02	HI-RPS
1,368	1,459	1,297	1,498	1,450

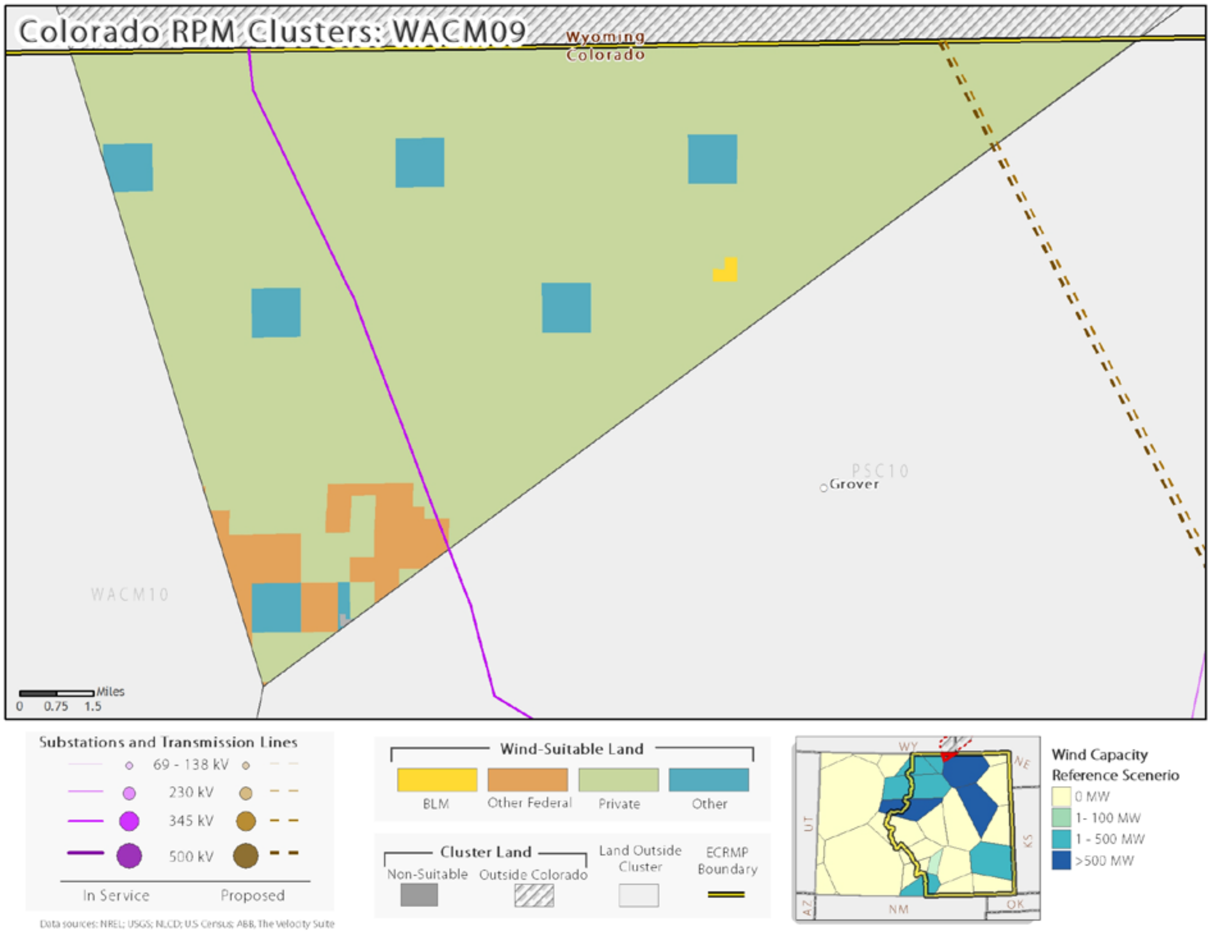
[33] The total MW potential for wind-suitable lands in PSC16 is 557 MW. RPM capacity expansion consistently exceeds this number. Excess capacity expansion results in certain regions are due to non-coterminous resource availability and prescribed capacity expansion data sets.


Wind:
Proportional+
Development
Preference
PSC16
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
0
50
100
150
200
250
300
350
400
450
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Wind:
BLM Development
Preference
PSC16
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
0
50
100
150
200
250
300
350
400
450
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

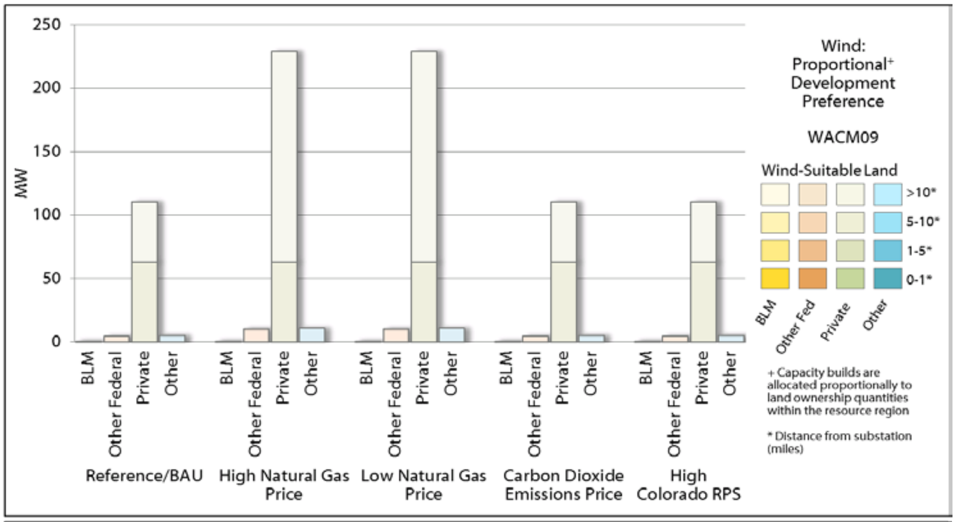

Wind:
Private Development
Preference
PSC16
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
0
50
100
150
200
250
300
350
400
450
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

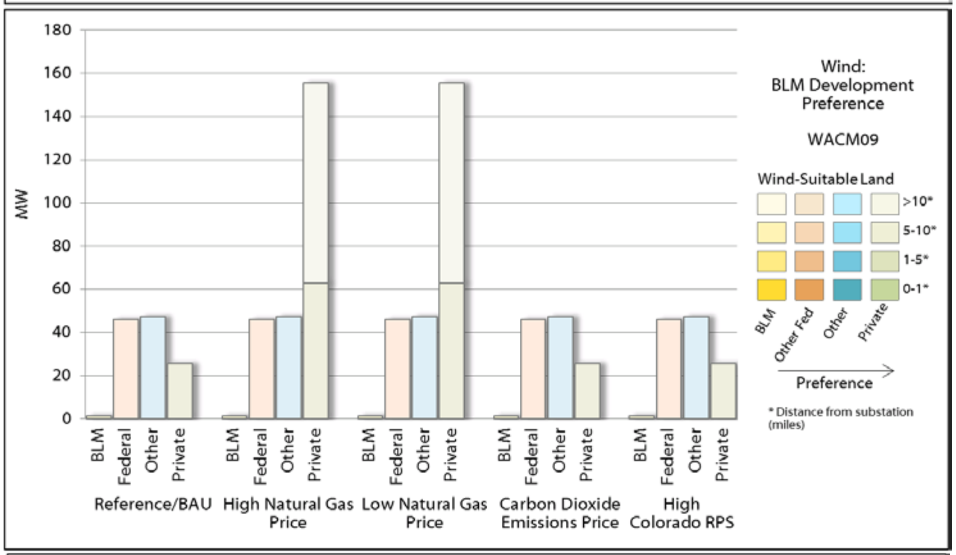
WACM09 Wind Resource Region

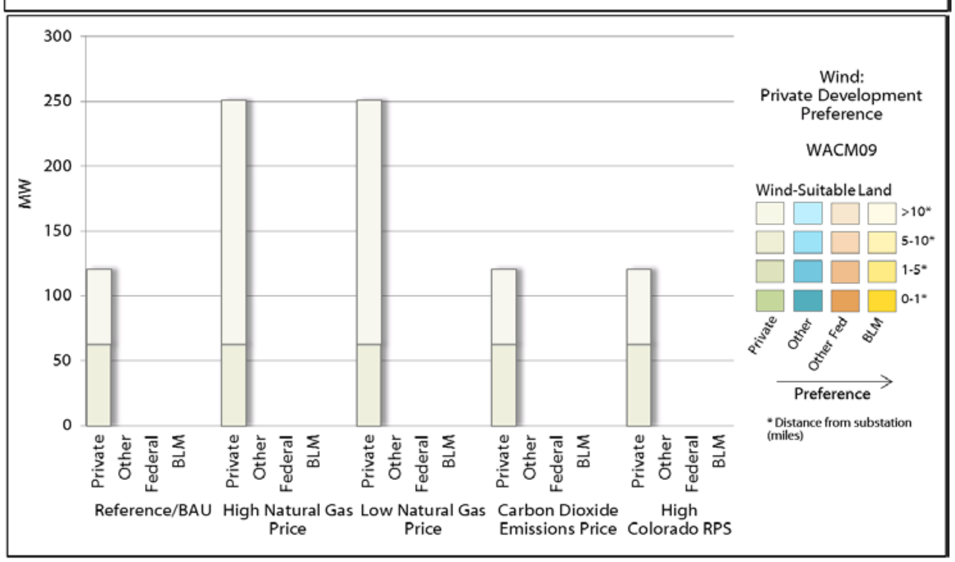


WACM09—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	0	0	0	0	122	1
Federal	0	0	0	0	0	0	3,806	46
Other	0	0	0	0	0	0	3,909	47
Private	0	0	0	0	5,180	62	77,048	936

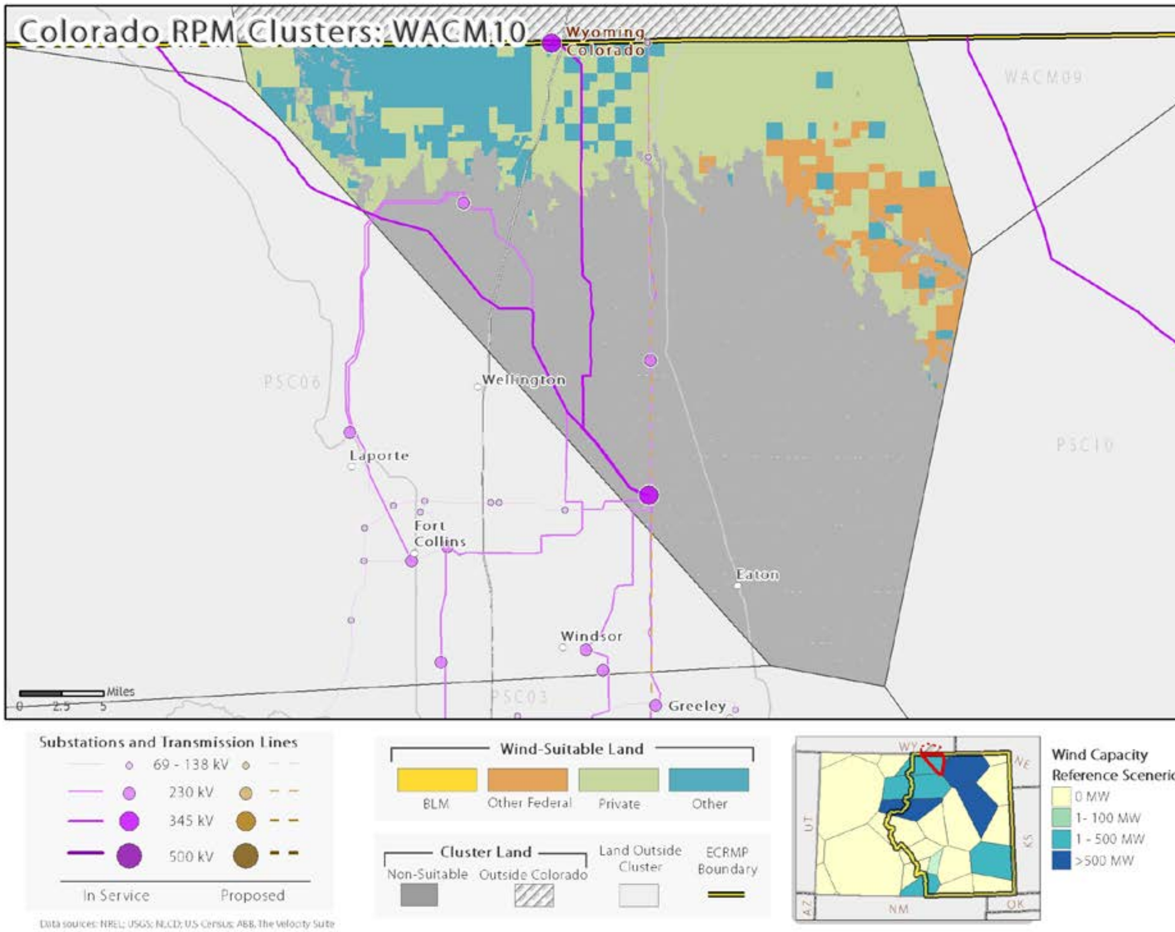
WACM09—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
121	251	251	121	121


Wind:
Proportional+ Development Preference
WACM09
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
250
200
150
100
50
0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Wind:
BLM Development Preference
WACM09
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
180
160
140
120
100
80
60
40
20
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

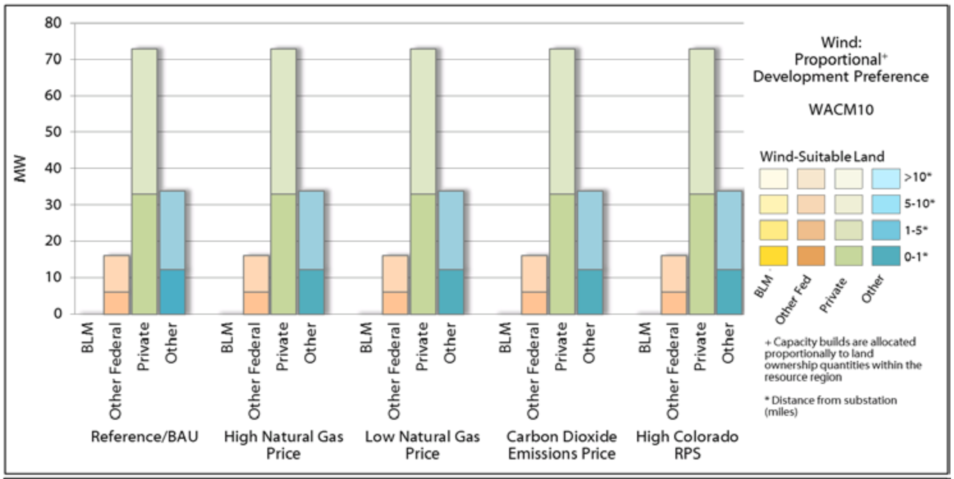

Wind:
Private Development Preference
WACM09
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
300
250
200
150
100
50
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

WACM10 Wind Resource Region

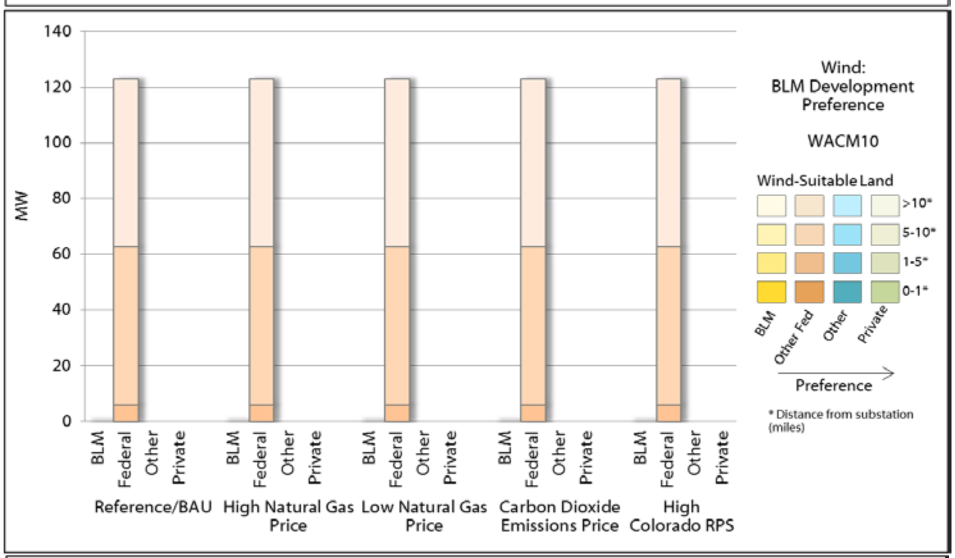


WACM10—Wind-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	0	0	0	0	0	0
Federal	0	0	503	6	4,675	56	25,570	310
Other	1,022	12	23,833	289	26,700	324	13,622	165
Private	2,718	33	51,209	622	35,043	425	51,276	623

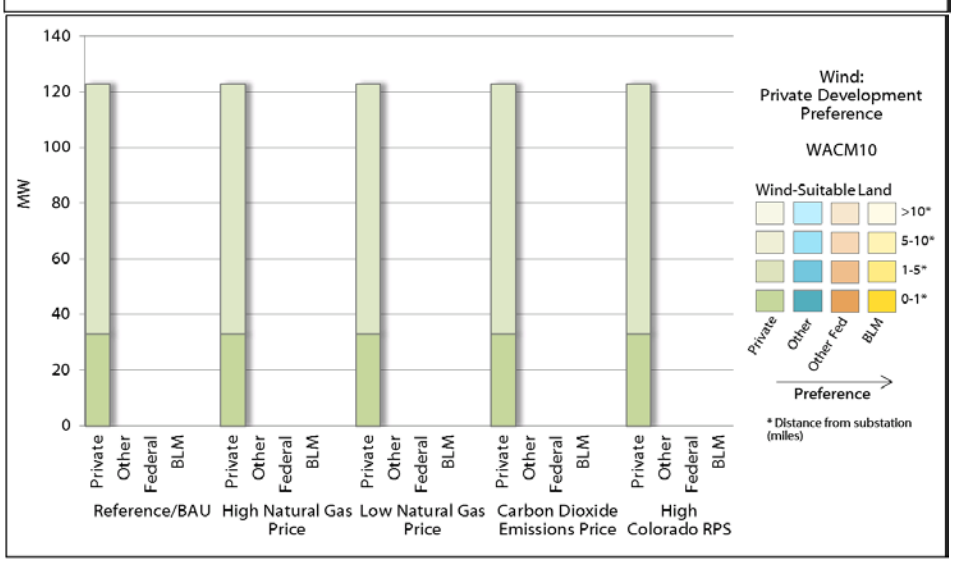
WACM10—Modeled Wind Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
123	123	123	123	123



Wind:
Proportional+
Development Preference
WACM10
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
0
10
20
30
40
50
60
70
80
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS



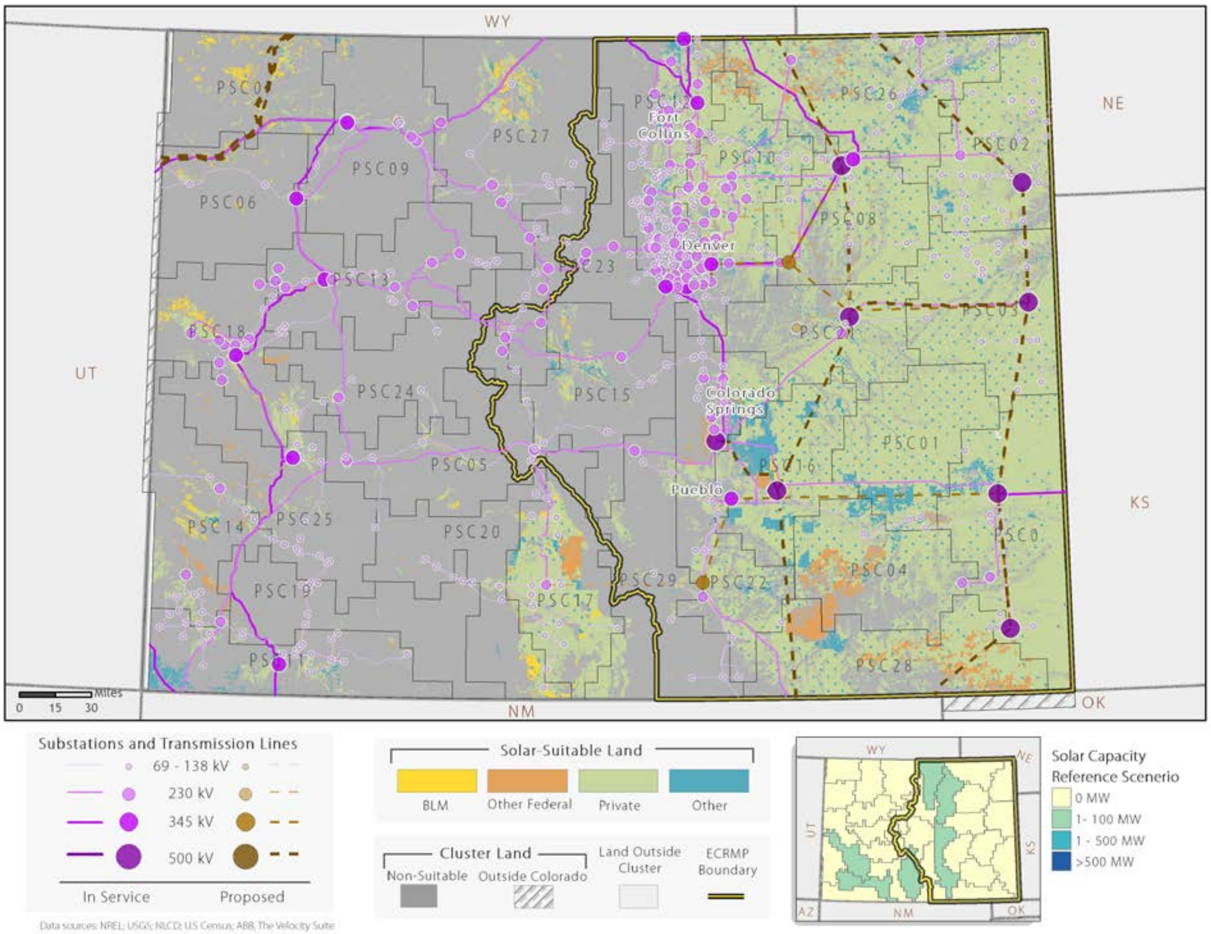
Wind:
BLM Development
Preference
WACM10
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
0
20
40
60
80
100
120
140
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS



Wind:
Private Development
Preference
WACM10
Wind-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
0
20
40
60
80
100
120
140
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

Solar Resource Regions

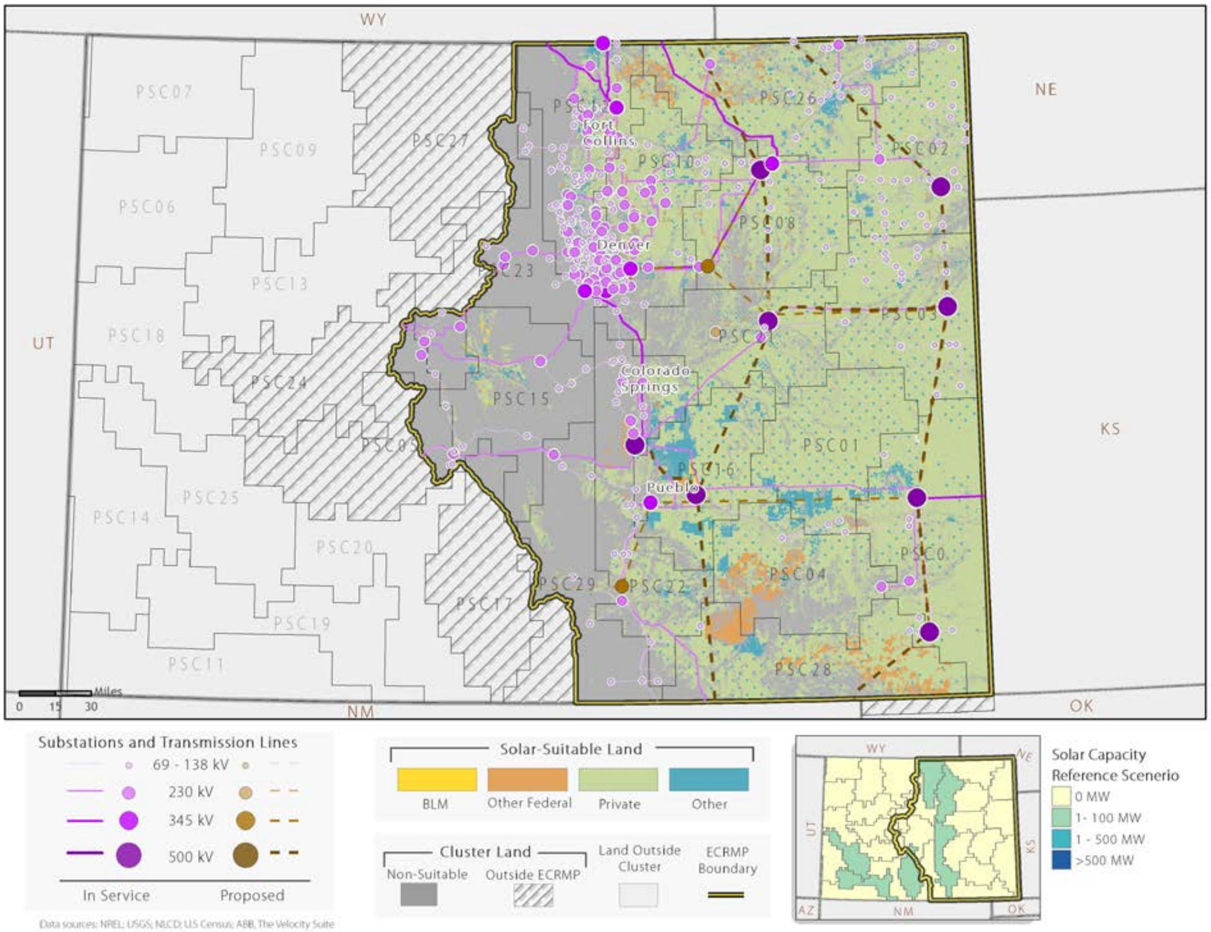
Colorado Solar Resource Regions



Colorado—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	542	155	53,225	15,251	111,854	32,050	259,125	74,248
Federal	936	268	65,781	18,848	212,993	61,030	605,166	173,400
Other	18,784	5,382	321,219	92,040	489,051	140,129	1,050,674	301,053
Private	311,631	89,293	5,025,581	1,439,995	5,892,545	1,688,408	9,035,090	2,588,851

Colorado—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
118	1,198	112	195	132

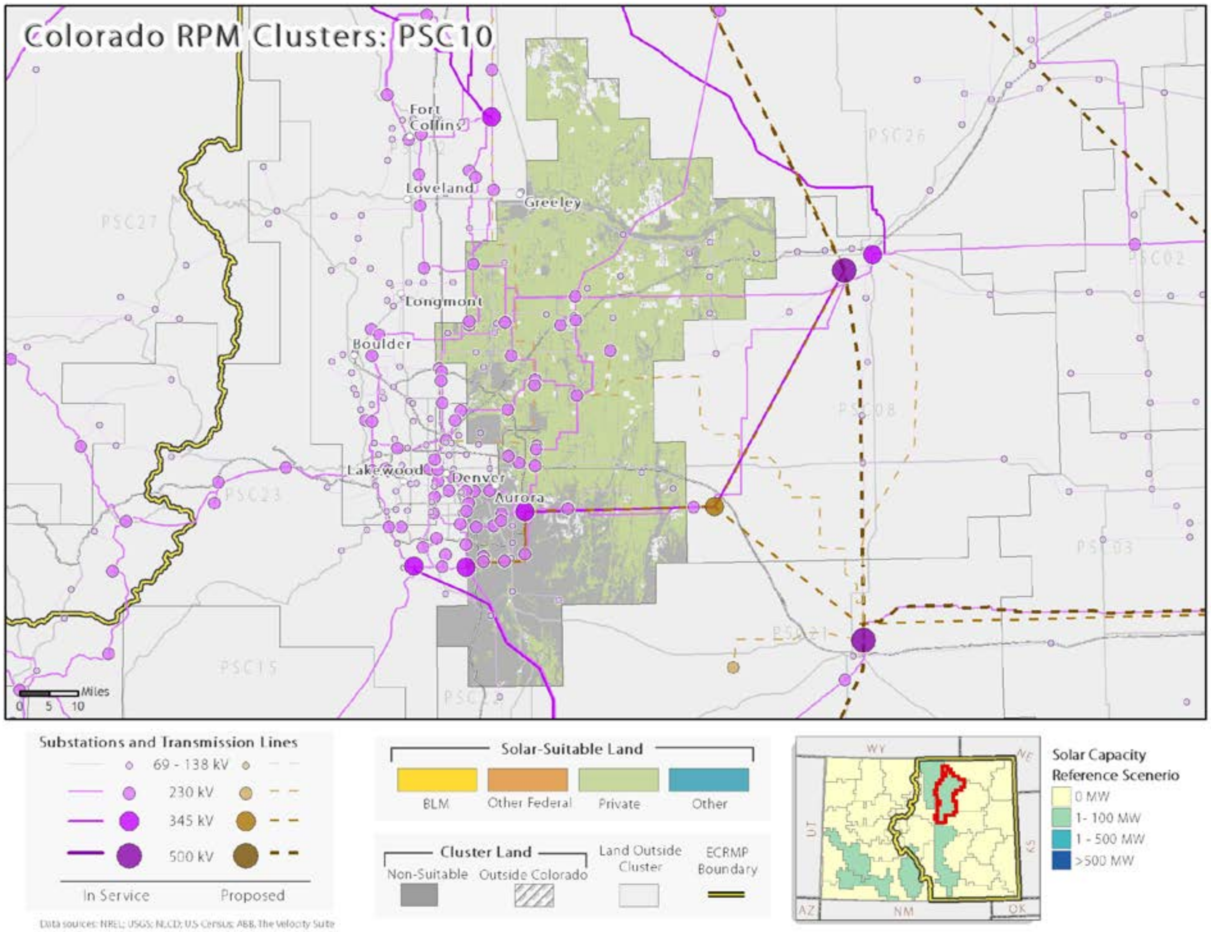
ECRMP Solar Resource Regions



ECRMP—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	43	12	3,296	945	12,376	3,546	24,173	6,926
Federal	731	209	47,607	13,641	117,043	33,537	549,218	157,369
Other	17,180	4,923	289,844	83,050	425,478	121,914	877,034	251,299
Private	264,183	75,697	4,292,574	1,229,964	5,237,288	1,500,655	8,428,131	2,414,937

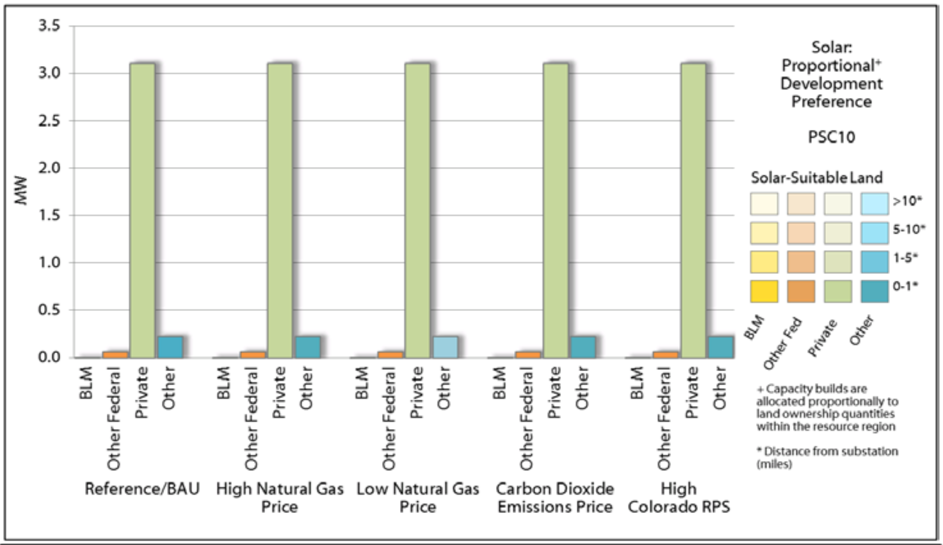
ECRMP—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
17	107	17	29	28

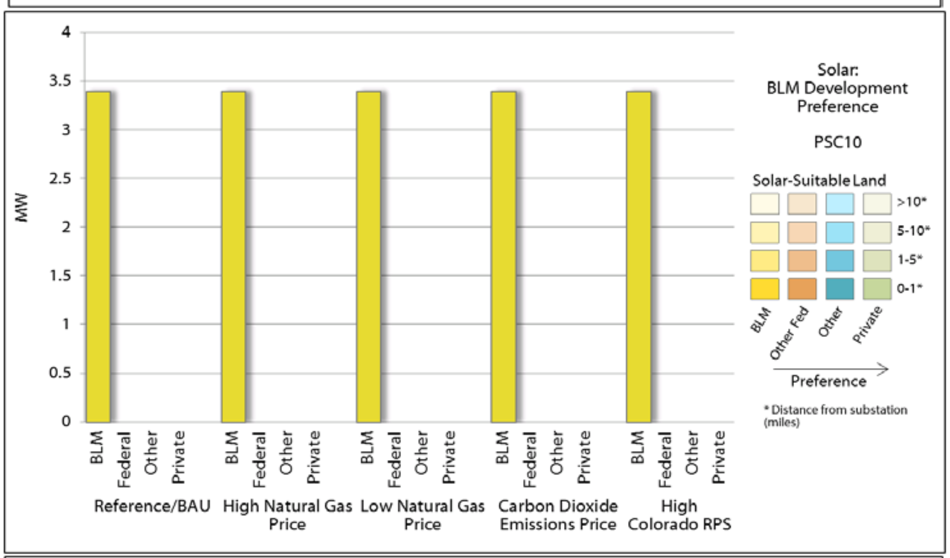
PSC10 Solar Resource Region

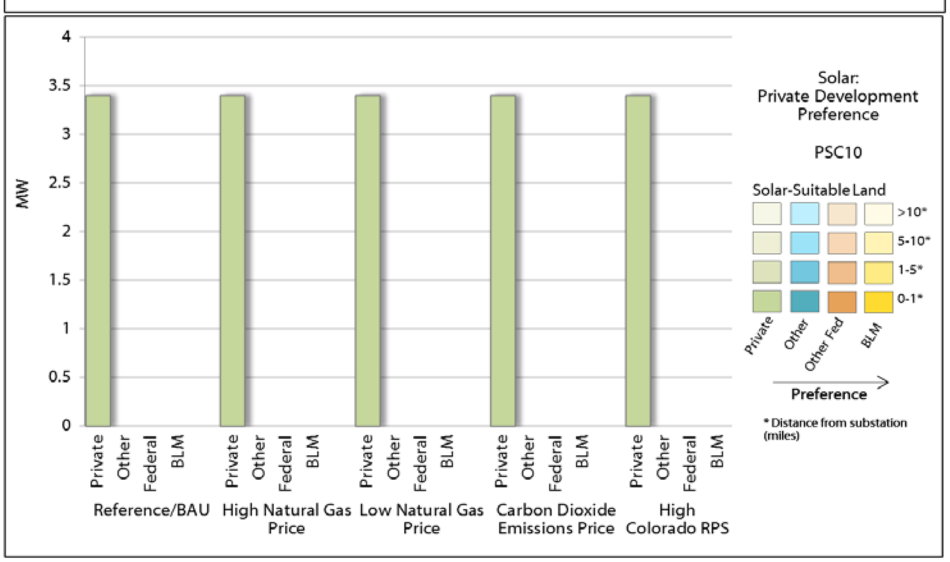


PSC10—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	13	4	80	23	226	65	0	0
Federal	84	24	2,264	649	5,716	1,638	18,386	5,268
Other	2,021	579	41,812	11,981	41,398	11,862	10,240	2,934
Private	57,509	16,478	701,083	200,883	397,722	113,960	172,623	49,462

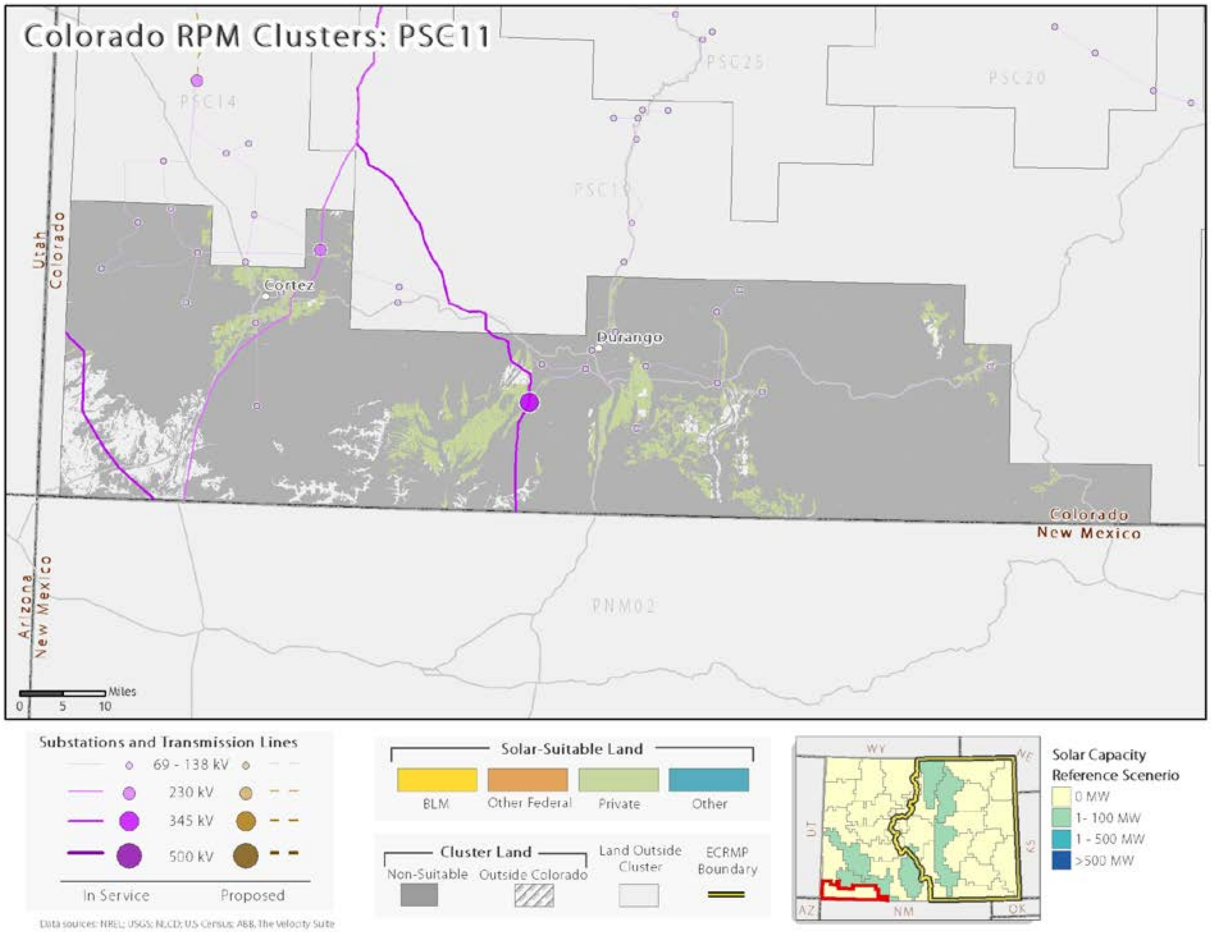
PSC10—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
3	3	3	3	3


Solar: Proportional+ Development Preference
PSC10
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Solar: BLM Development Preference
PSC10
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
4
3.5
3
2.5
2
1.5
1
0.5
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

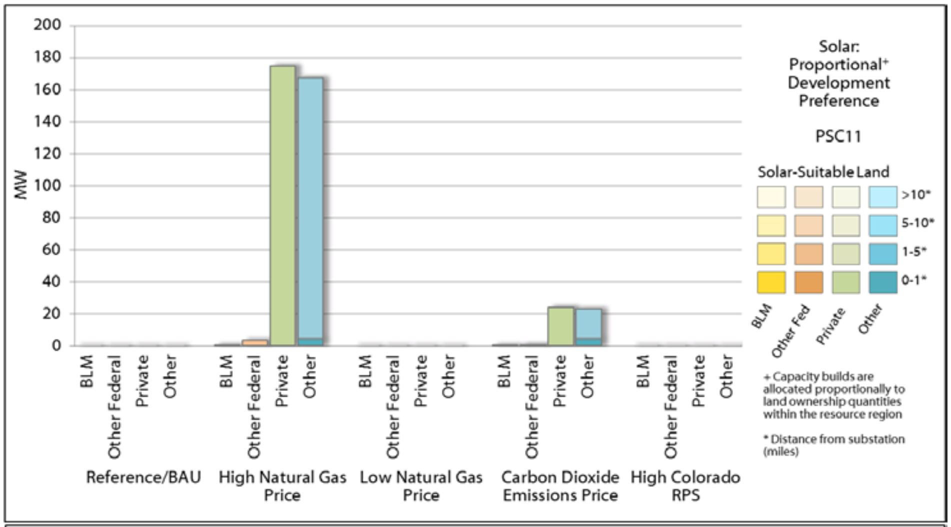

Solar: Private Development Preference
PSC10
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
4
3.5
3
2.5
2
1.5
1
0.5
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

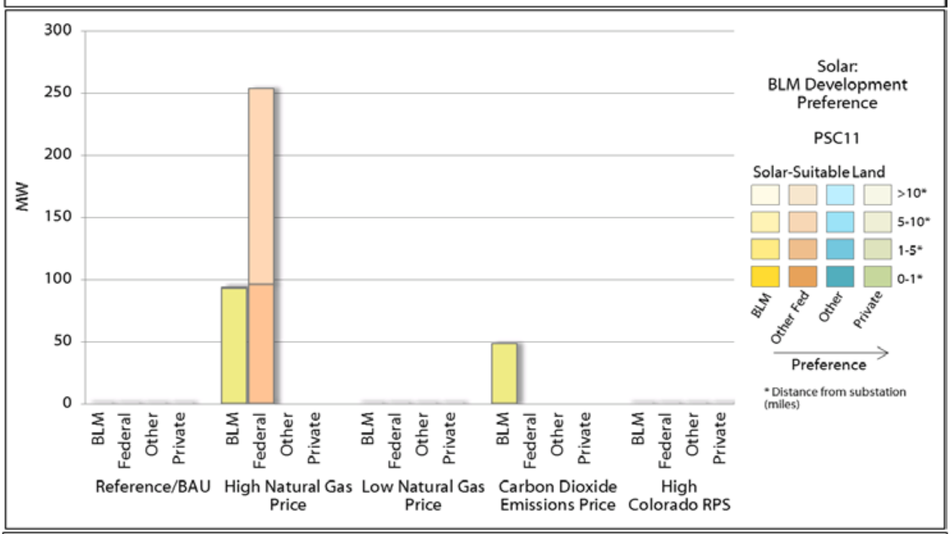
PSC11 Solar Resource Region

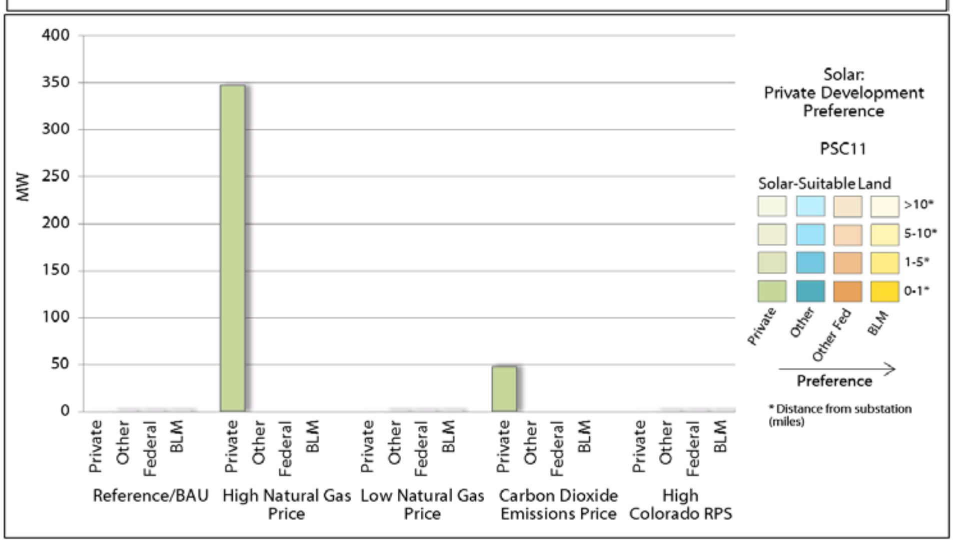


PSC11—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	323	93	3	1	0	0
Federal	0	0	335	96	1,788	512	424	121
Other	16	5	8,020	2,298	14,720	4,218	88,186	25,268
Private	3,783	1,084	60,999	17,478	26,232	7,516	24,787	7,102

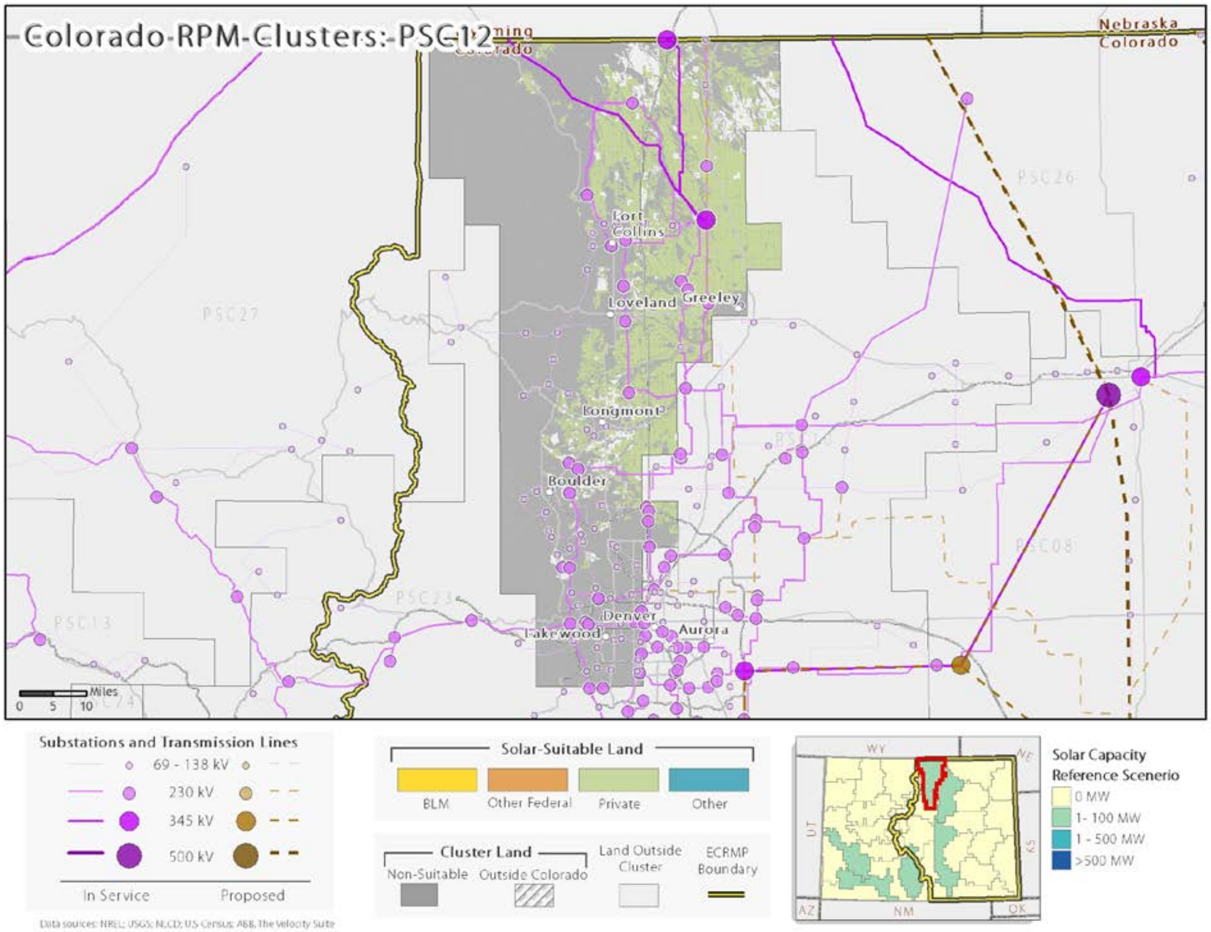
PSC11—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
0	347	0	48	0


Solar: Proportional+ Development Preference
PSC11
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Solar: BLM Development Preference
PSC11
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

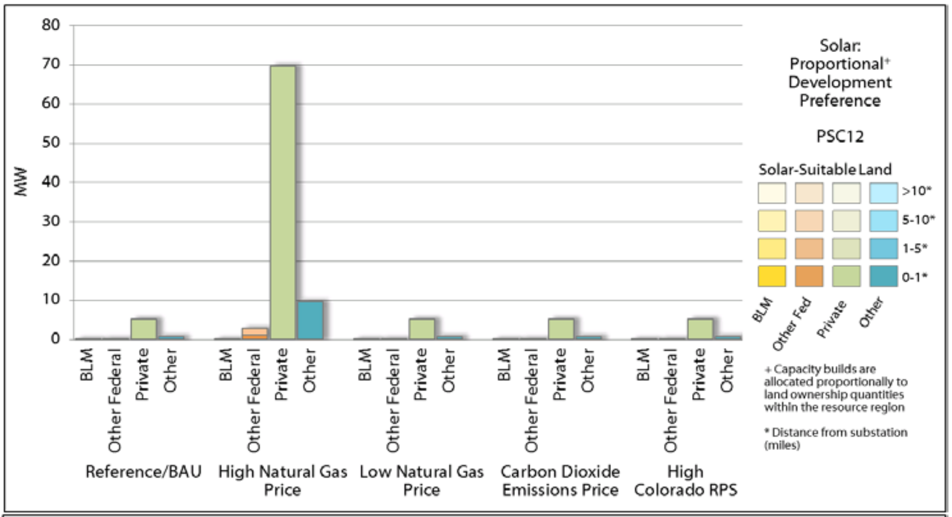

Solar: Private Development Preference
PSC11
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

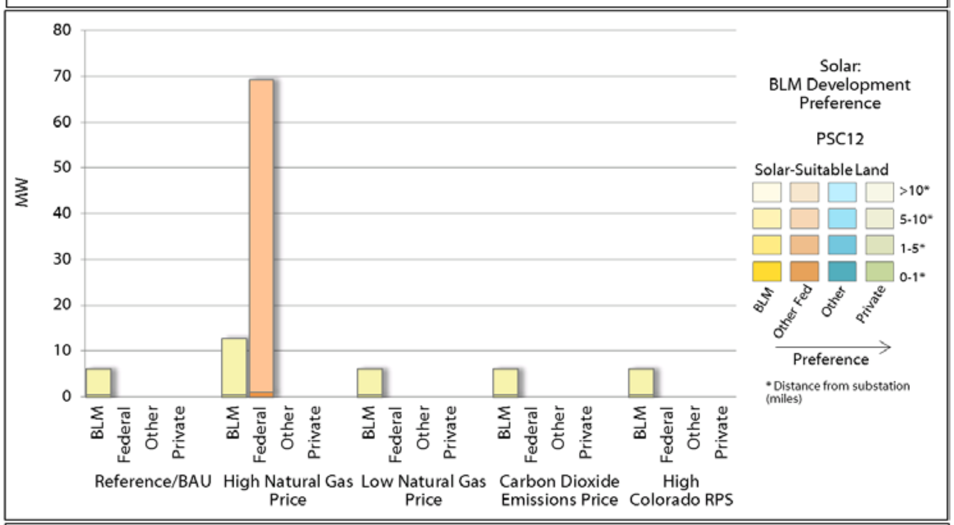
PSC12 Solar Resource Region

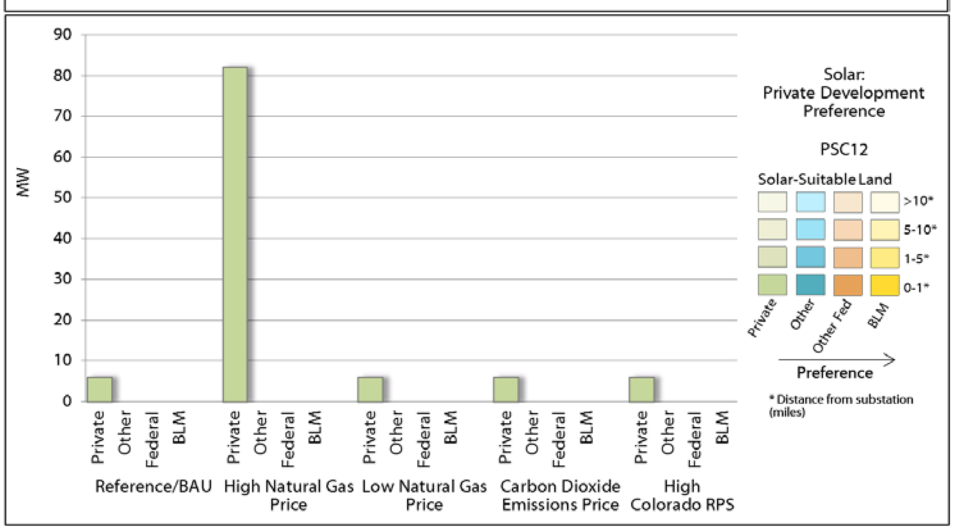


PSC12—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	1	0	43	12	0	0
Federal	4	1	2,313	663	15,170	4,347	3,212	920
Other	3,128	896	53,761	15,404	12,438	3,564	1,782	511
Private	28,706	8,225	346,056	99,156	124,534	35,683	13,002	3,725

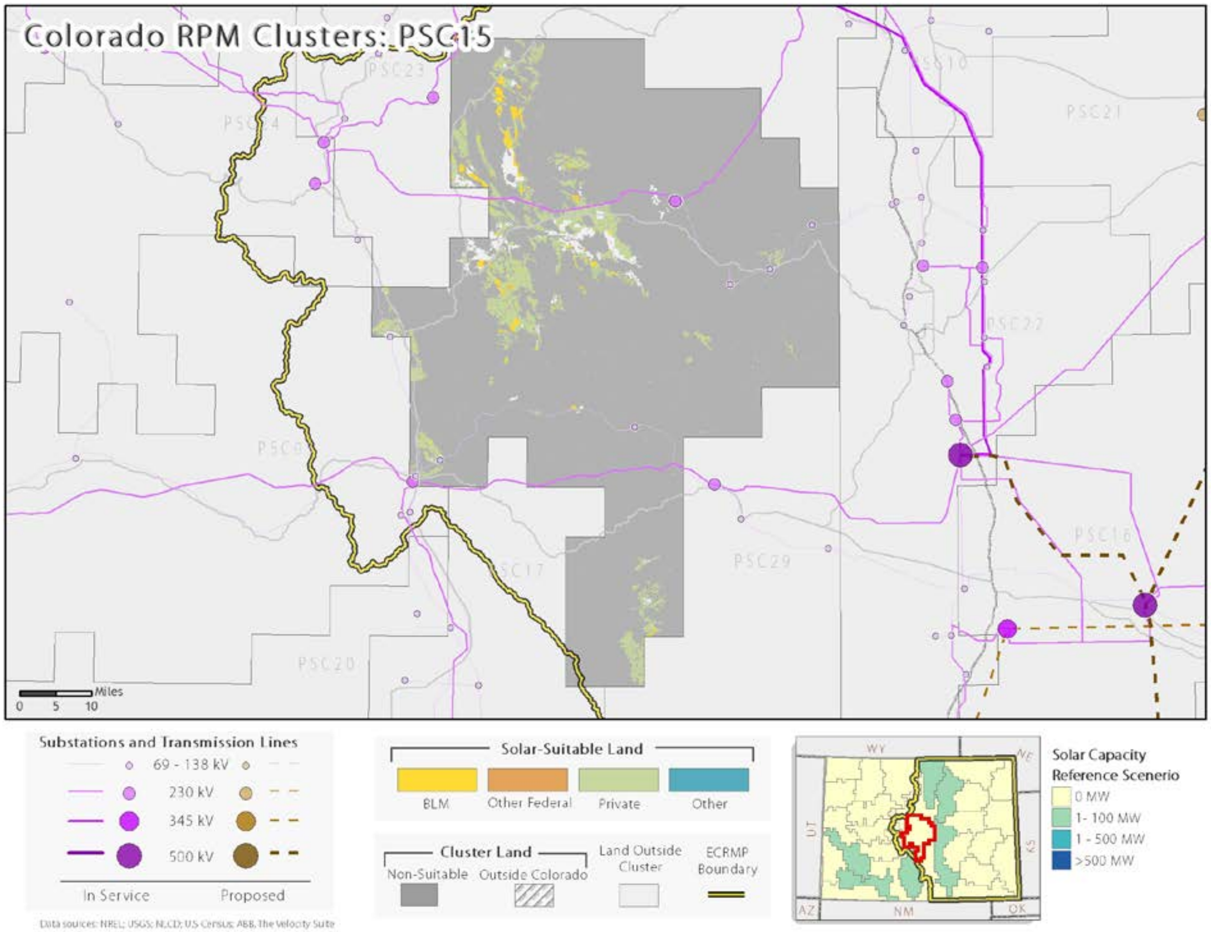
PSC12—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
6	82	6	6	6


Solar: Proportional+ Development Preference
PSC12
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
0
10
20
30
40
50
60
70
80
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Solar: BLM Development Preference
PSC12
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
0
10
20
30
40
50
60
70
80
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

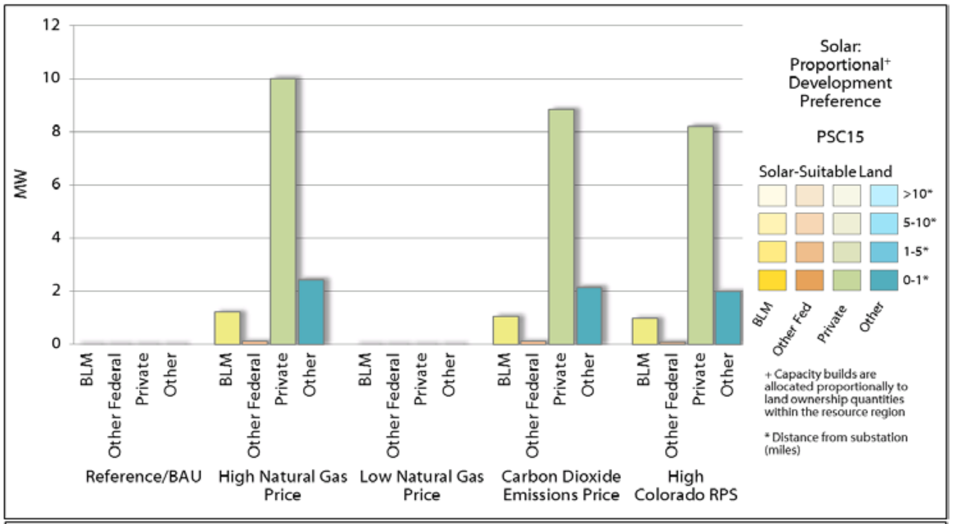

Solar: Private Development Preference
PSC12
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
0
10
20
30
40
50
60
70
80
90
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

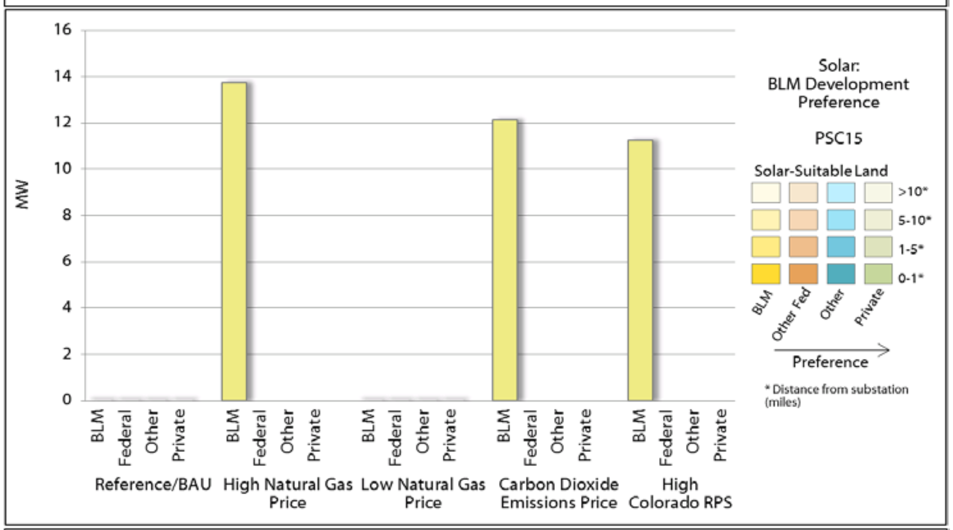
PSC15 Solar Resource Region

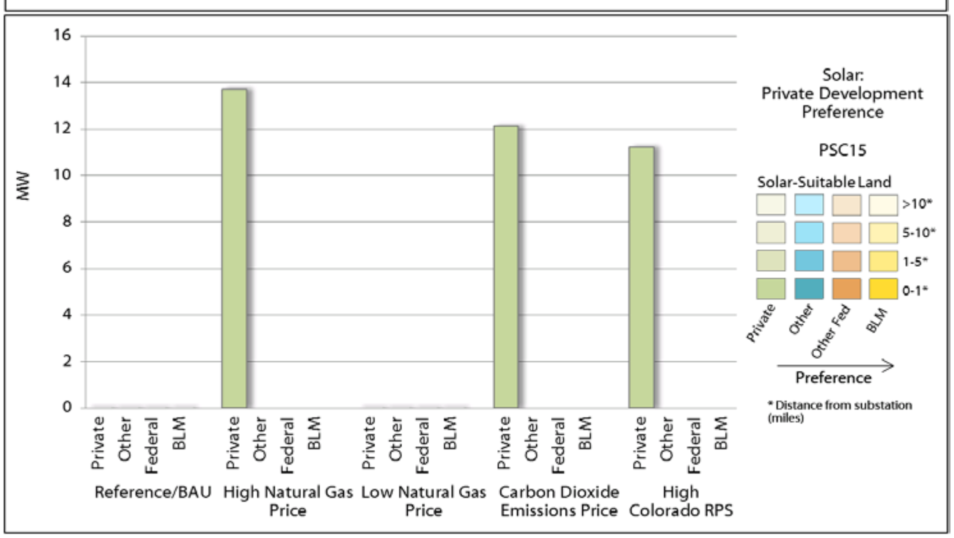


PSC15—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	242	69	2,971	851	11,350	3,252
Federal	0	0	1,100	315	2	1	24	7
Other	673	193	298	85	515	148	28,035	8,033
Private	1,309	375	10,887	3,119	16,523	4,735	93,418	26,767

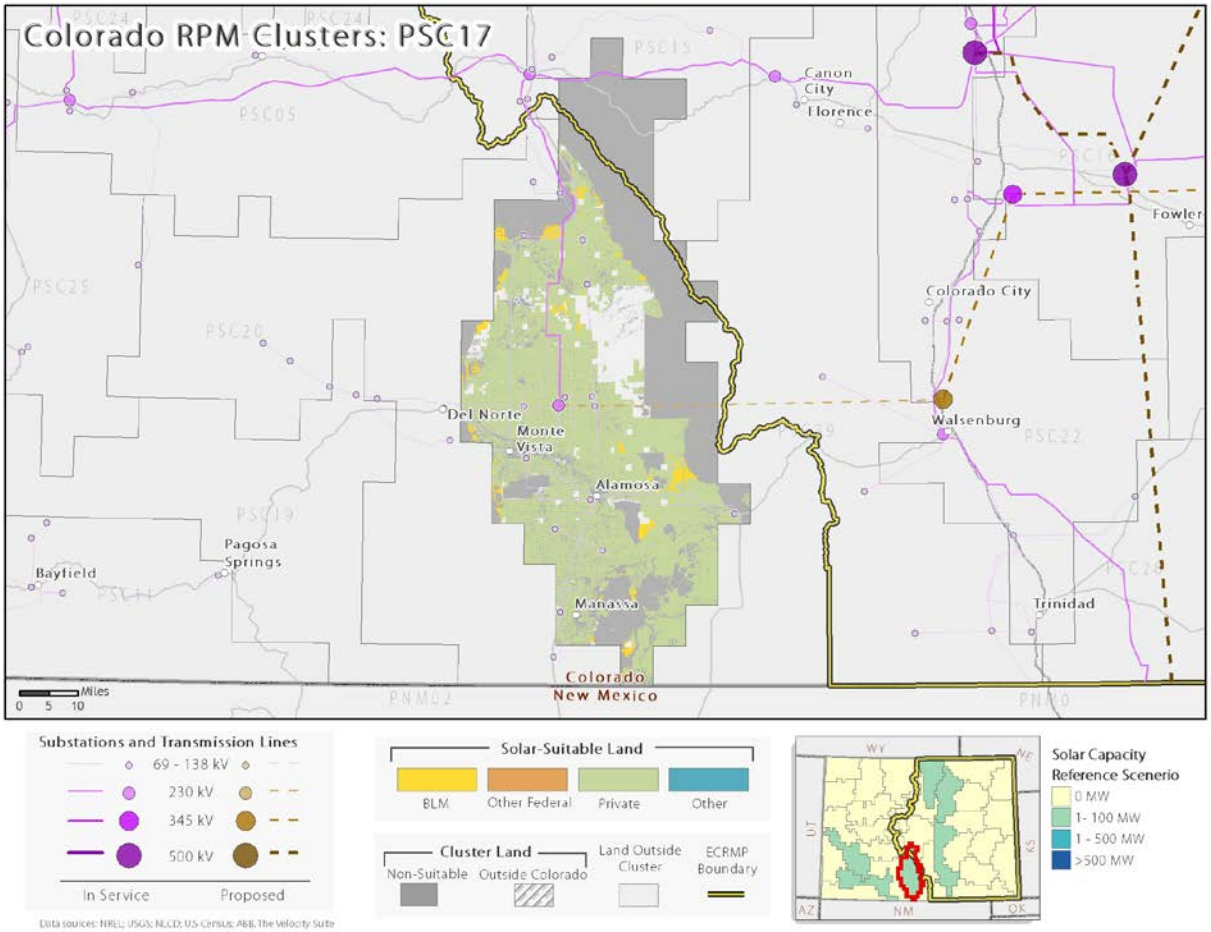
PSC15—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
0	14	0	12	11


Solar: Proportional+ Development Preference
PSC15
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Solar: BLM Development Preference
PSC15
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

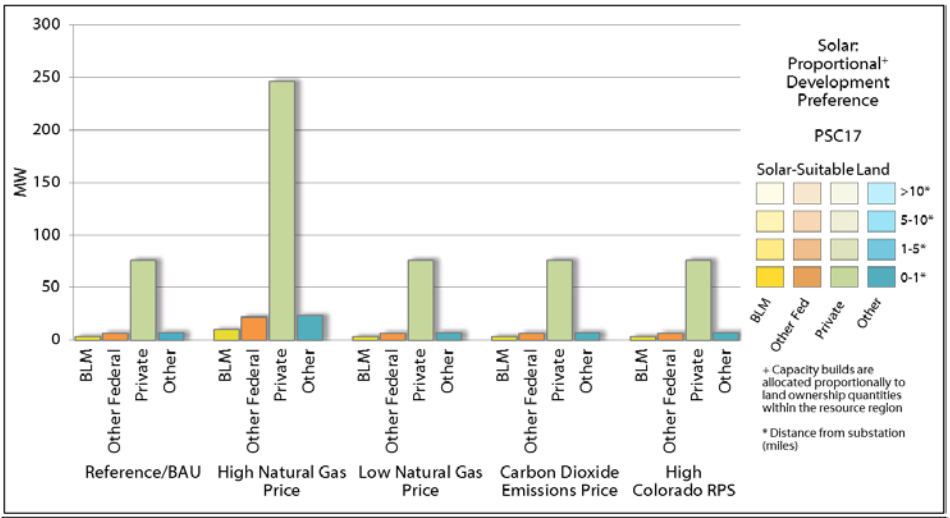

Solar: Private Development Preference
PSC15
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

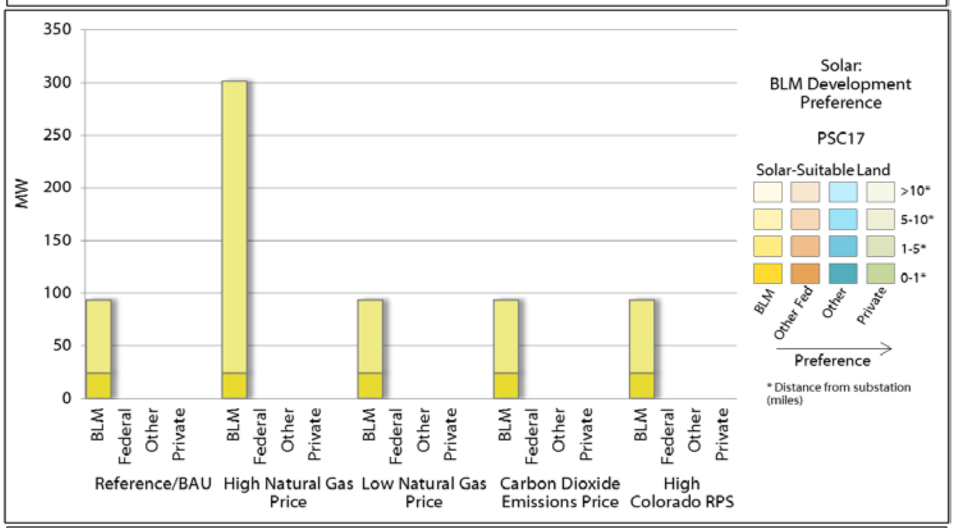
PSC17 Solar Resource Region

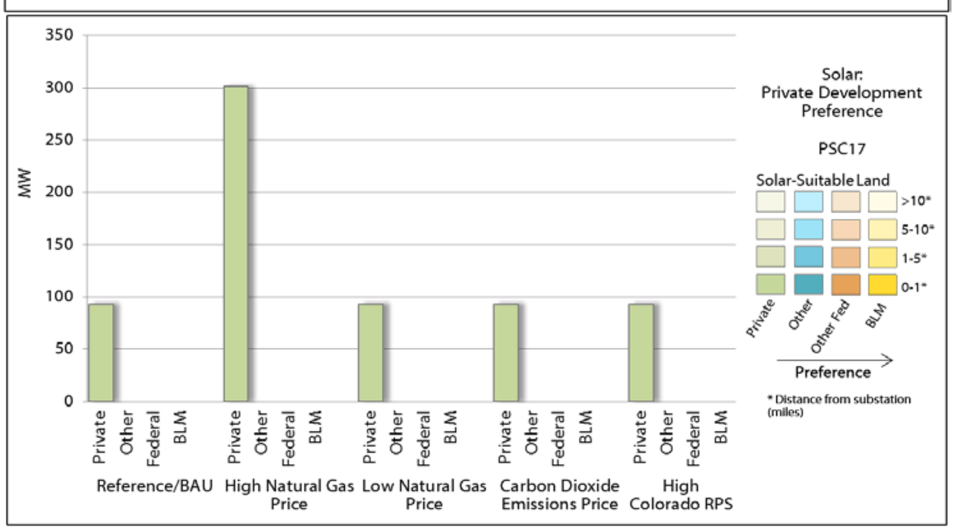


PSC17—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	86	25	9,934	2,846	16,833	4,823	10,998	3,151
Federal	151	43	9,417	2,698	56,086	16,070	19,218	5,507
Other	684	196	16,657	4,773	36,869	10,564	37,076	10,623
Private	23,994	6,875	376,762	107,955	370,048	106,031	185,197	53,065

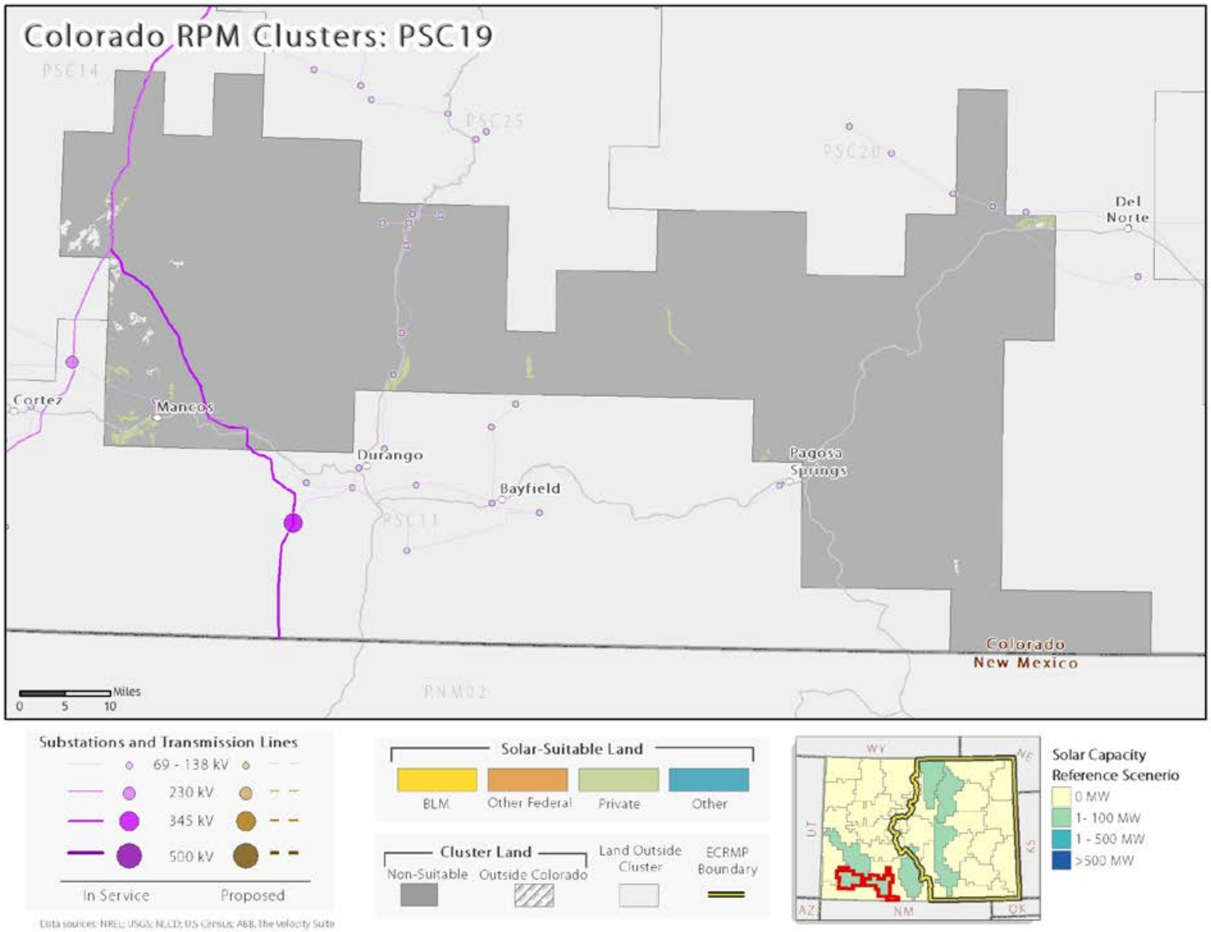
PSC17—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
93	301	93	93	93


Solar: Proportional+ Development Preference
PSC17
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
300
250
200
150
100
50
0
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Solar: BLM Development Preference
PSC17
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
350
300
250
200
150
100
50
0
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

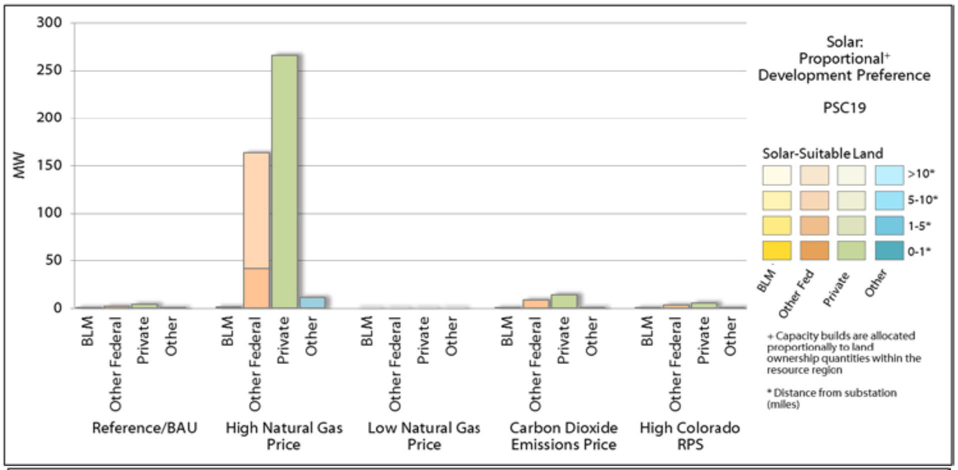

Solar: Private Development Preference
PSC17
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
350
300
250
200
150
100
50
0
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

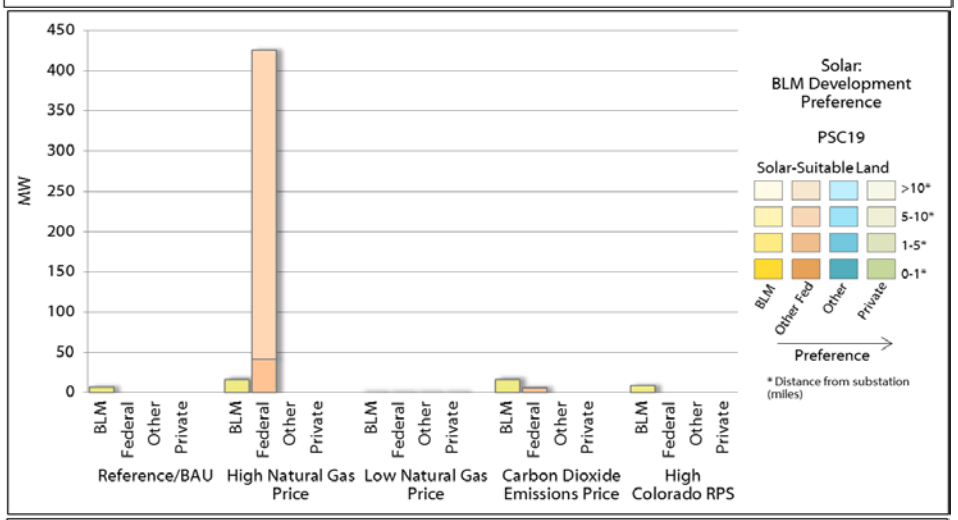
PSC19 Solar Resource Region

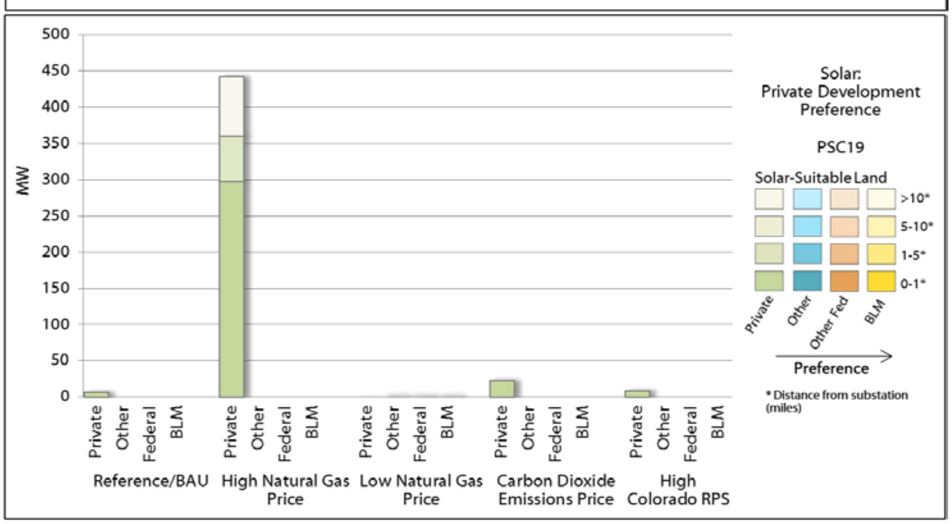


PSC19—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	58	17	0	0	0	0
Federal	0	0	145	42	3,679	1,054	3,308	948
Other	0	0	221	63	0	0	289	83
Private	1,038	297	8,229	2,358	737	211	1,618	464

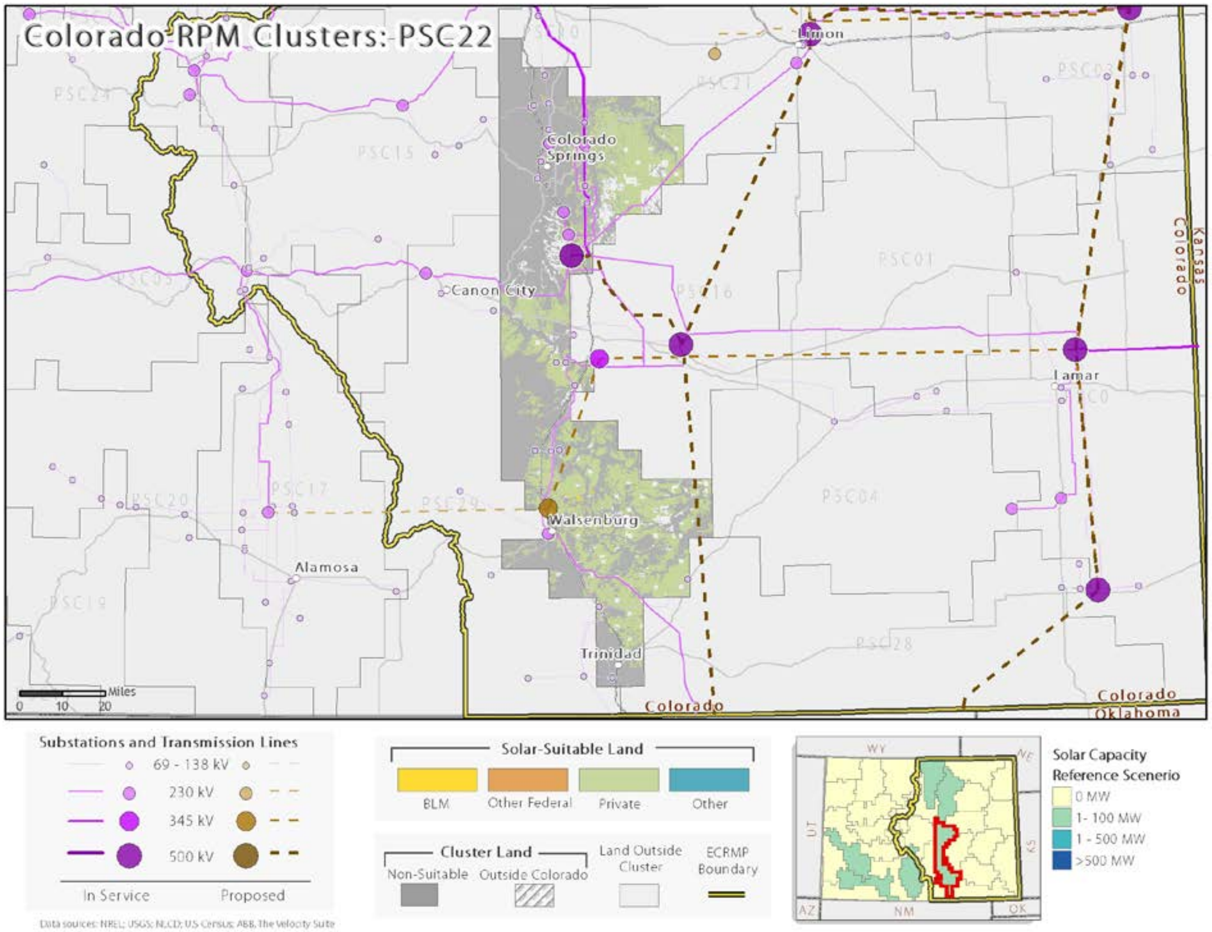
PSC19—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
7	442	0	23	9


Solar:
Proportional+
Development Preference
PSC19
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Solar:
BLM Development
Preference
PSC19
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

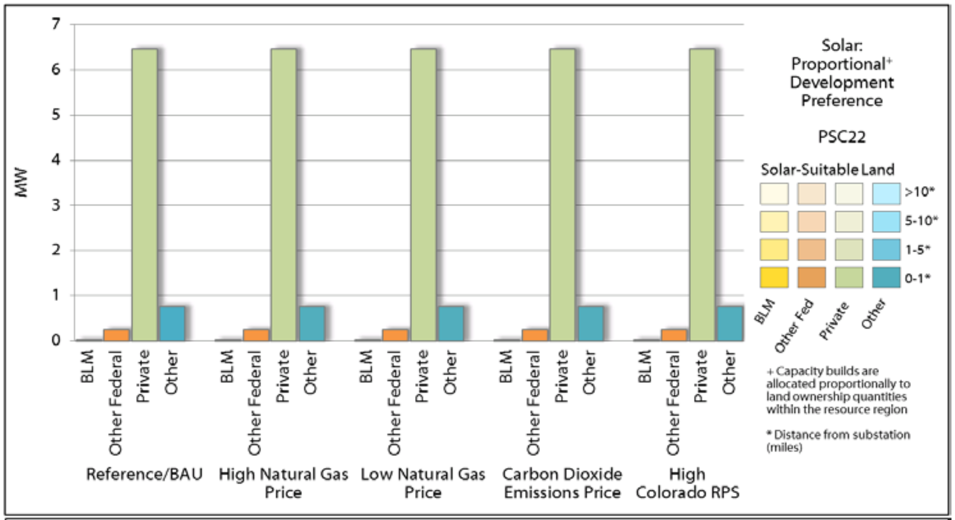

Solar:
Private Development
Preference
PSC19
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

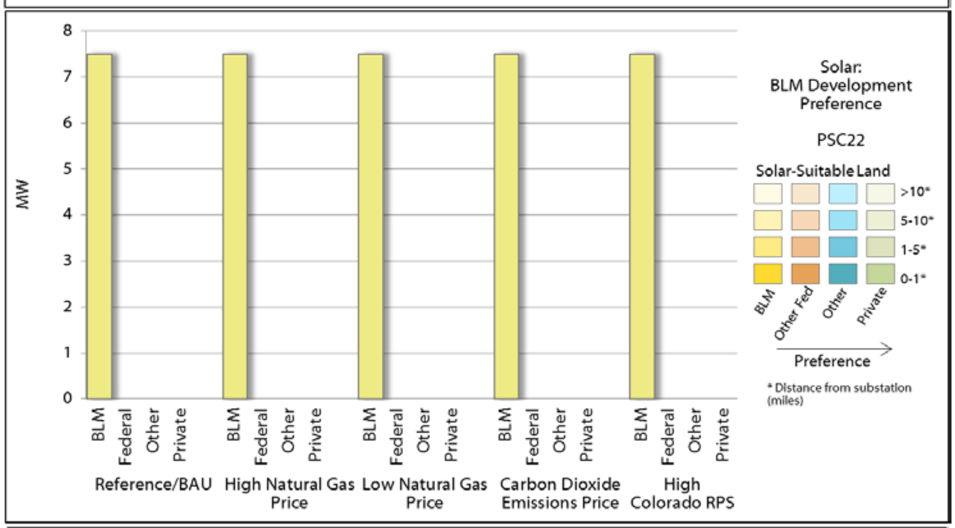
PSC22 Solar Resource Region

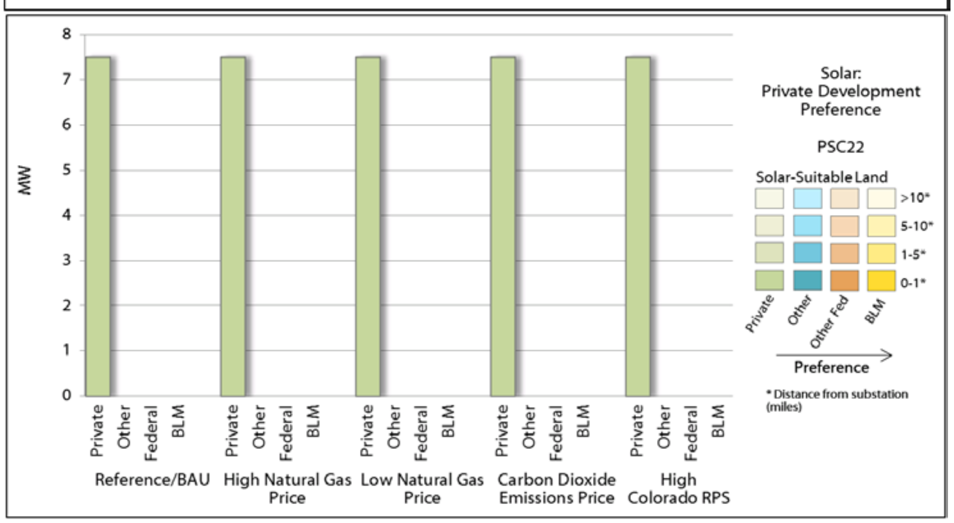


PSC22—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	**0-1 Miles**		**1-5 Miles**		**5-10 Miles**		**>10 Miles**	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	0	0	506	145	1,651	473	718	206
Federal	14	4	17,372	4,978	12,380	3,547	2,879	825
Other	613	176	17,010	4,874	26,880	7,702	55,287	15,842
Private	15,939	4,567	209,334	59,981	301,807	86,478	311,033	89,121

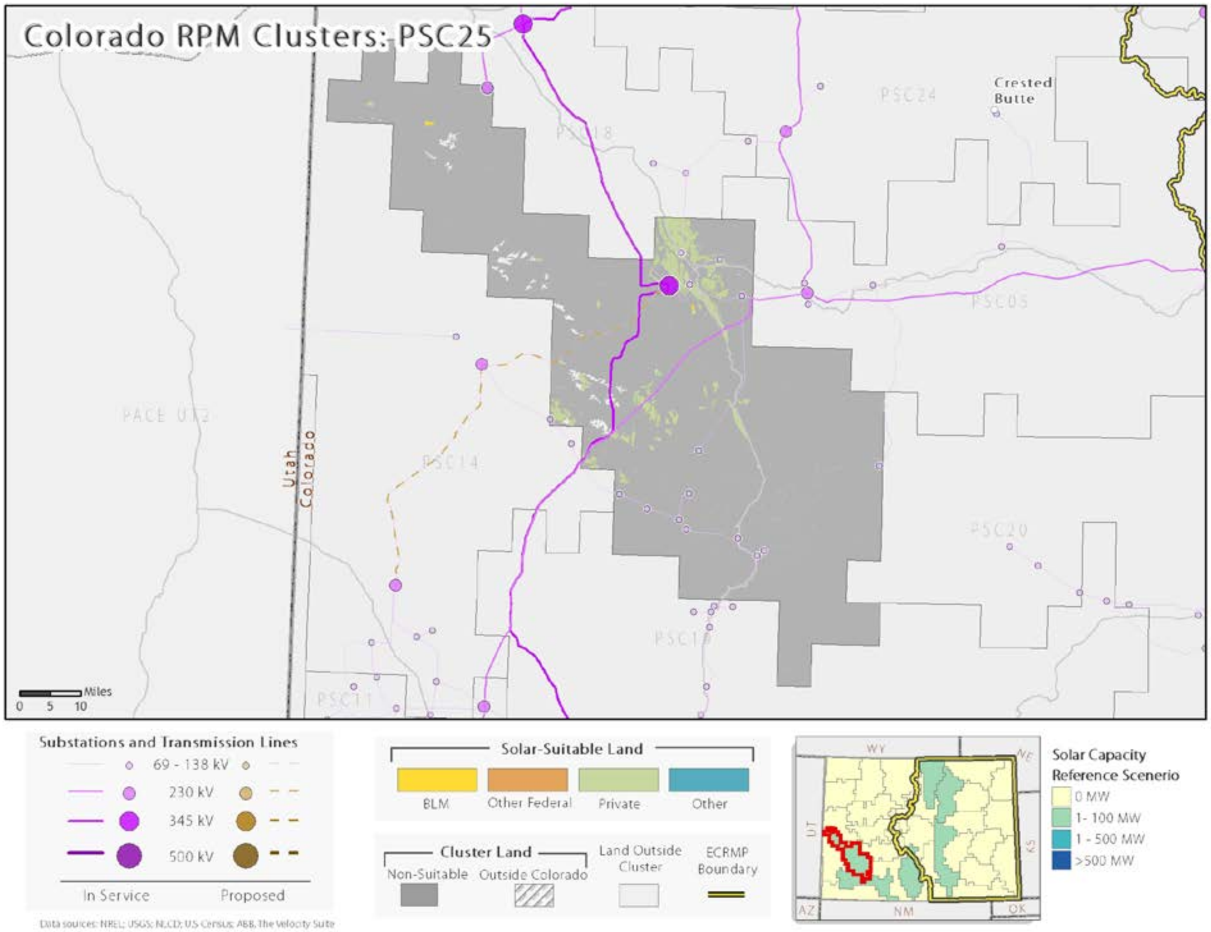
PSC22—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
8	8	8	8	8


Solar: Proportional+ Development Preference
PSC22
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+ Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
BLM
Other Federal
Private
Other
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS


Solar: BLM Development Preference
PSC22
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
BLM
Federal
Other
Private
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

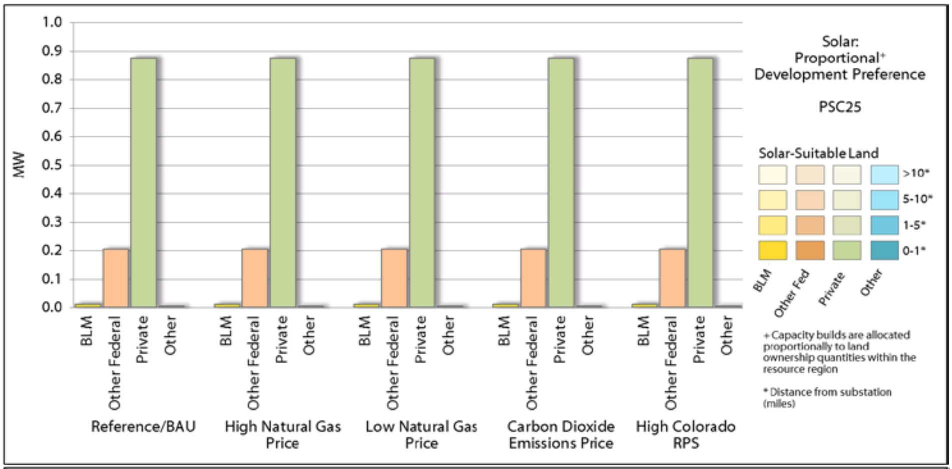

Solar: Private Development Preference
PSC22
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
Private
Other
Federal
BLM
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS

PSC25 Solar Resource Region

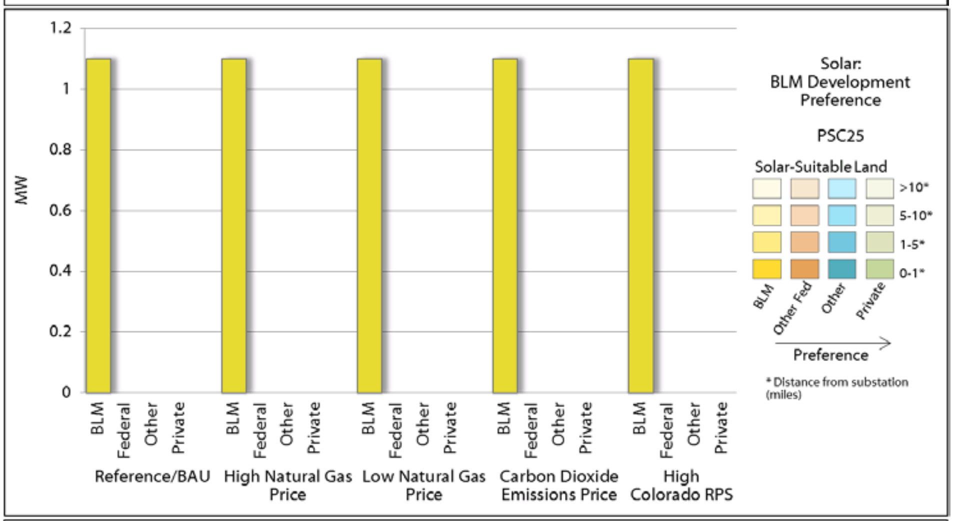


PSC25—Solar-Suitable Land: Area and MW Potential								
Distance to Transmission	0-1 Miles		1-5 Miles		5-10 Miles		>10 Miles	
	Acres	MW	Acres	MW	Acres	MW	Acres	MW
BLM	25	7	433	124	57	16	443	127
Federal	0	0	241	69	5,756	1,649	9,800	2,808
Other	0	0	338	97	75	21	0	0
Private	3,447	988	39,198	11,231	16,890	4,840	7,986	2,288

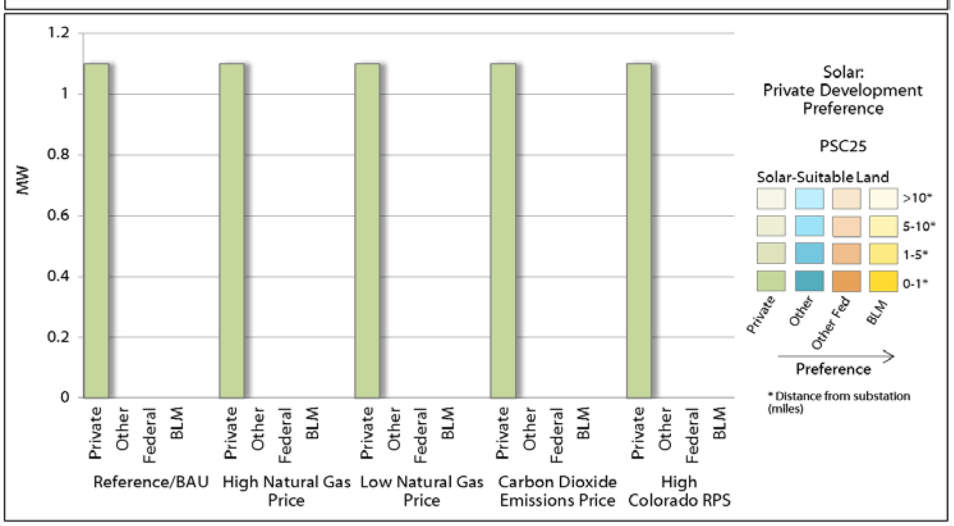
PSC25—Modeled Solar Capacity				
Ref	HI-NG	LO-NG	C02	HI-RPS
1	1	1	1	1



Solar:
Proportional+
Development Preference
PSC25
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Private
Other
+Capacity builds are allocated proportionally to land ownership quantities within the resource region
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
BLM
Other Federal
Private
Other



Solar:
BLM Development Preference
PSC25
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
BLM
Other Fed
Other
Private
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
BLM
Federal
Other
Private



Solar:
Private Development Preference
PSC25
Solar-Suitable Land
>10*
5-10*
1-5*
0-1*
Private
Other
Other Fed
BLM
Preference
* Distance from substation (miles)
MW
Reference/BAU
High Natural Gas Price
Low Natural Gas Price
Carbon Dioxide Emissions Price
High Colorado RPS
Private
Other
Federal
BLM