connecting colorado's renewable resources to the markets

Report of the

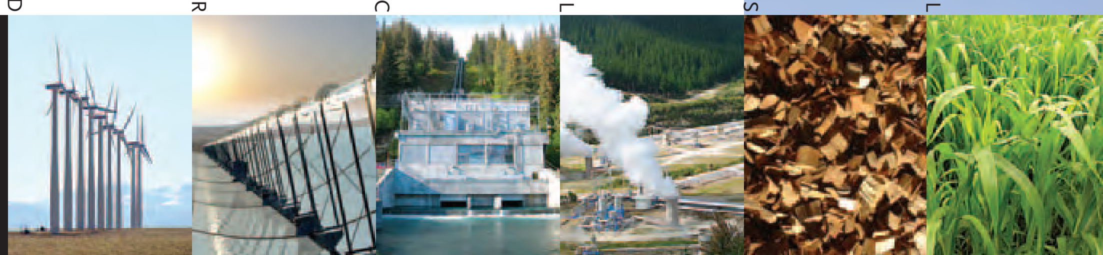
Colorado Senate Bill 07-091

Renewable Resource Generation

Development Areas

Task Force

WIND SOLAR HYDROELECTRIC GEOTHERMAL BIOMASS ETHANOL



Report of the Task Force on Renewable Resource Generation Development Areas

Pursuant to Colorado Senate Bill 07-091

To the Governor, the Legislature, and the Citizens of Colorado:

The Task Force on Renewable Resource Generation Development Areas, created by SB07-091, has produced and approved this report. The Task Force was given the charge to map the renewable resources throughout the State of Colorado. This report contains maps of these resources and identifies "Generation Development Areas" where the resource can be developed with competition among developers for utility-scale wind and solar projects. The report also identifies local development opportunities for geothermal, hydroelectric power, biomass, and ethanol. The maps identify existing generation and where high voltage transmission is needed to bring renewable resources to the markets.

The report is part of the work of Governor Ritter's "New Energy Economy" to develop these areas to derive a variety of benefits, including new jobs, economic development, energy security, and environmental improvements.

Colorado has renewable resources in such abundance that we can meet the current minimum utility renewable energy standard of 20% for investor owned utilities by 2020 and 10% for rural electric cooperatives and municipal utilities by 2020 by tapping a small portion of our total renewable resources. Even after we meet a growing portion of our electric power needs with Colorado's renewable resources, the state has abundant renewable resources for export to other electricity markets. An additional benefit of fully developing Colorado's renewable resources is that in doing so, we can help implement the goals contained in Governor Ritter's Climate Action Plan.

The local development opportunities identified consist of a broad diversity of smaller electric power generation projects that can be developed. Colorado's distributed solar, hydroelectric, biomass, and geothermal resources will play an increasingly vital role once developed to their potential. By so doing, Colorado citizens will benefit from local ownership, diversity, and energy security. On-site and local projects are needed to complement our utility-scale resources. A wide variety of stakeholders are working diligently to see that these smaller projects come to fruition.

This report is part of an ongoing process of furthering progress to achieve the goals of the New Energy Economy. The report is posted on the Governor's Energy Office website at www.colorado.gov/energy

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Executive Summary

Colorado has tremendous renewable resource potential. The state is number eleven in the nation for wind potential. The state ranks fourth in the nation for solar potential. According to one report, Colorado is fourth among Western states for geothermal development site potential. We have sizeable relatively untapped hydroelectric, geothermal, and biomass resources. In addition to extensive renewable resources, Colorado is also blessed with great intellectual and institutional resources. Of note, under the auspices of the Colorado General Assembly, Colorado's Research Collaboratory has partnered with National Renewable Energy Laboratory, the University of Colorado, Colorado State University, and the Colorado School of Mines. In addition, the state is fortunate to enjoy a vibrant and growing New Energy Economy of entrepreneurs and businesses.

Although bringing these abundant and clean energy resources to the markets, and continuing to grow the institutions and businesses to support the markets is challenging, Colorado is well situated to respond. Integrating larger amounts of renewable resources into our electric grid will take the talent, creativity, skill, and coordination of many partners, including project developers, electric utilities, regulators, federal, state and local agencies, and many other stakeholders. We are encouraged by the focus of the Western Governors' Association's on these topics, and the General Assembly's creation of the Clean Energy Development Authority to pursue these challenges.

Renewable Energy Attributes and Challenges

Renewable resources have well-known attributes, including, but not limited to:

- lower comparative environmental impacts
- continuous fuel supplies at dependable prices
- decreasing costs for central solar power
- economic development opportunities for businesses and landowners increased energy assurance
- a hedge to ensure a degree of protection from higher conventional fuel and environmental costs

However there are significant challenges to address, including, but not limited to:

- variable energy production driven by diurnal solar cycles and weather
- costs, which are typically up front capital, rather than long term fuel
- lack of quantification of the qualitative benefits that offset quantifiable costs
- disparate regulatory treatment
- land use disputes
- environmental siting issues
- transmission constraints
- financing issues, and
- timing

Renewable energy represents a large opportunity, both at the utility- and community-scales. However, there are great challenges to connect Colorado's renewable resources to the markets. Several issues have historically hindered large-scale development of Colorado renewable energy resources. These include, but are not limited to:

- understanding cost differentials between traditional resources and renewable energy
- appreciating the difficulty of projecting fuel costs over decades into the future
- correlating transmission congestion and development timelines so transmission is ready when projects are being developed
- finding least cost methods to integrate operational characteristics of some renewables
- electric control area differences and impacts
- utility incentives regarding the utilities' "make versus buy" decision, and
- the timelines associated with purchase power contracts

Over the past few years several policies and incentives aimed at achieving favorable economic and environmental benefits have been created to remove or reduce these obstacles to renewable development for large scale projects. This report is part of the process of finding solutions to first serve the needs of Colorado and to strengthen our role in the regional electricity market.

Transmission Constraints

Perhaps foremost among the challenges are the unique transmission capacity constraints that exist in Colorado. These constraints have already prevented cost effective Colorado wind projects from being built and from delivering their full value of benefits to Colorado electric customers. Transmission investment lags both wind project development time frames and consumers' requirements for wind projects to offset high, and unexpectedly variable, natural gas priced for electric generation. Due to the interconnected nature of the electric grid, Colorado and neighboring states are working cooperatively to craft solutions. The Task Force appreciates the electric utilities, regulators, legislators, the Clean Energy Development Authority, and others who are working together to arrive at a variety of approaches to address these issues.

Renewable Resource Generation Development Areas

The Task Force was charged to identify Renewable Resource Generation Development Areas (GDAs) within Colorado that have the potential to support renewable energy development. The Task Force defined a GDA as a concentration of renewable resources within a specific geographic region that provides a minimum of 1000 megawatts (MW) of developable electric generating capacity that could connect to an existing or new high voltage transmission line. 1000 MW is equivalent to 1 gigawatt (GW). A GDA does not encompass disparate or diffuse points where the developable electric generating capacity does not reach 1 GW.

The Task Force identified eight GDAs for wind, and two GDAs for central solar power. The eight wind GDAs are located on the Front Range and Eastern Plains, and the two solar GDAs are located in the San Luis Valley and south and southeast of Pueblo. Because no hydroelectric power, geothermal, biomass, biofuel, or ethanol resources specific to a geographic sub-region in Colorado met the 1 GW capacity threshold at which the Task Force thought robust competition among developers would ensue, GDAs were not identified for those resources. However, the Task Force did map these local resources and makes recommendations for their development along with those made for the solar and wind GDAs. The non-GDA areas have been denominated as local development opportunities.

Wind Resources

Colorado's statewide summer electric generation peak is approximately 11 GW. The eight wind GDAs have the potential for development of over 96 GW of capacity— over eight times Colorado's current peak electricity use. Having this extent of resources does not impose a logical limit on the amount of wind that Colorado can develop for its own use. In fact, there is growing interest in developing more wind than Colorado can use for export to markets in the Southwestern states of Arizona, Nevada, and Southern California. These states experience high levels of reliance on natural gas generation, and have initiated new goals to limit carbon dioxide emissions. The combination of these, and other factors, provide a strong market for wind from Colorado and adjacent electrically interconnected wind rich states such as Wyoming and New Mexico.

Solar Resources

Without screening for the highest direct normal irradiance and without screening for terrain slope, the two solar GDAs represent a hypothetical of producing 1300 GW if the entire GDAs were covered with equipment. Obviously, only a small fraction of the land area would ever be contemplated for central solar power (CSP) farms. For illustrative purposes, if only 2% of the land area in the CSP GDAs was used, 26 GW of solar capacity could be developed. The National Renewable Energy Laboratory (NREL) conducted an analysis of the two CSP GDAs. NREL's analysis screened out the slightly lower direct normal insolation in these two GDAs. NREL's analysis also screened out the land area in the GDAs that has a terrain slope of more than 1%. This was an arbitrary screening done for analytical purposes and should not be construed to be an upper limit constraint on CSP development. NREL's analysis resulted in an estimated 275 GW of capacity in the two CSP GDAs. If just 2% of the NREL-screened GDAs were developed, 5.5 GW of CSP generating capacity is available.

Local Development Opportunities

Renewable energy represents opportunities for projects that can serve at the individual and community levels. Throughout the state there is a wide expressed interest in energy security, economic development, and commercial profit opportunities that locally developed and owned projects can offer. Distributed generation, both grid interconnected and customer-generated, is becoming more economical. These improving economics will further encourage local distributed generation development.

The time to produce the Task Force report was limited to just a few months, and more analysis will be forthcoming. Task Force members view this report as a means to encourage further dialogue among all interested stakeholders, and are pleased to submit this report to continue discussion on these important topics.

Connecting Colorado's Renewable Resources to the Markets

Introduction and Background on SB07-091

Legislative Sponsors

SB07-091 was sponsored by Senators Schwartz, Boyd, Fitz-Gerald, Gordon, Groff, Isgar, Romer, Sandoval, Shaffer, Tapia, Tochtrop, Tupa, Veiga, Williams, and Windels; and Representatives Massey, Carroll M., Frangas, Gibbs, Green, Hodge, Jahn, Kerr A., Kerr J., Labuda, McFadyen, Merrifield, Romanoff, Solano, Stafford, Stephens, Summers, and Todd. The bill was enacted into law on May 29, 2007. The Task Force acknowledges the legislative endeavors of the SB07-091 sponsors. Their leadership on renewable energy made the Task Force and this report possible.

Appointment of the Task Force

The legislation established a sixteen member SB07-091 Renewable Resource Generation Development Areas Task Force appointed by the Governor, the President of the Senate, the Speaker of the House, the Senate Minority Leader, and the House Minority Leader. The following individuals were appointed to be Members of the SB07-091 Renewable Resource Generation Development Areas Task Force:

Chair:

Dan McClendon, Delta-Montrose Electric Association. Representing cooperative electric associations. Appointed by the Governor.

Vice-Chair:

Barbara Walker, Independent Bankers of Colorado. Appointed by the Senate President.

John Bleem, Platte River Power Authority. Representing municipal utilities. Appointed by the Governor.

Craig Cox, Interwest Energy Alliance. Appointed by the Governor, the President of the Senate, and the Speaker of the House.

Tony Frank, Rocky Mountain Farmers Union. Representing agricultural interests. Appointed by the Governor.

Glenn Gibson, Larimer County Commissioner. Designated by Colorado Counties Incorporated. Appointed by the Minority Leader of the Senate.

Rick Gilliam, SunEdison. Representing solar generation interests. Appointed by the Governor.

David Hurlbut, National Renewable Energy Laboratory. Designated by the Director of the National Renewable Energy Laboratory.

Ron Larson, Colorado Renewable Energy Society. Appointed by the President of the Senate.

Ron Lehr, American Wind Energy Association. Representing wind interests. Appointed by the Governor.

Sam Mamet, Colorado Municipal League.

Mac McLennan, Tri-State Generation and Transmission Association. Appointed by the Speaker of the House.

John Nielsen, Western Resource Advocates. Appointed by the Speaker of the House.

Frank Prager, Xcel Energy. Representing Investor-Owned Electric Utilities. Appointed by the Governor.

Richard Smart, Community Hydropower Consulting. Representing renewable energy (other than wind and solar). Appointed by the Governor.

Morey Wolfson, Governor's Energy Office. Designated by the Director of the Governor's Energy Office.

A Generation Development Area (GDA) is a concentration of renewable resources within a specific geographic sub-region in Colorado that provides a minimum of one gigawatt of developable electric generating capacity that could connect to an existing or new high-voltage transmission line.

The Charge to the Task Force

The Task Force was charged to "develop a map of existing generation and transmission lines and potential renewable resource generation development areas within Colorado that have potential to support competition among renewable energy developers for development of renewable resource generation projects." The report was required to be submitted to the General Assembly and the Governor before December 31, 2007.

The SB07-91 Budget

While the legislation did not provide funding for the work, the legislature authorized the Governor's Energy Office (GEO) to raise funds to provide support for staffing the effort, and other expenses. Thirteen corporations and associations provided $43,000 in funding to move the process forward. The contributors include: Aquila Colorado, Colorado Association of Municipal Utilities, Duke Energy Generation Services, FPL Energy, H2PRO LLC, Iberdrola, Interwest Energy Alliance, Midwest Research Institute, PPM Energy, Trans-Elect LLC, Tri-State Generation and Transmission Association, VestasWind, and Xcel Energy. The support paid for the retention of contractors to assist GEO staff with geographic information system mapping support, design services, printing, and supplies. In addition to a direct contribution to the Task Force, Midwest Research Institute provided funding that allowed NREL to provide significant technical assistance to the effort.

Task Force Meetings

The first Task Force meeting was held on August 6, 2007. As required by the statute, a Chair (Dan McClendon, Delta-Montrose Electric Association) and a Vice-Chair (Barbara Walker, Independent Bankers of Colorado) were elected. The Task Force approved a work plan, a budget, a time line, a schedule of meetings, a procedure for receiving public comment, guidelines for posting minutes and presentations, and public notices of the meetings. Full Task Force meetings were then held on September 10, October 15 and November 19, 2007. Task Force Work Group meetings were held on August 15, September 18, October 1, and November 5, 2007.

Definition of Generation Development Areas

The Task Force defined a Renewable Resource Generation Development Area (GDA) as a concentration of renewable resources within a specific geographic sub-region in Colorado that provides a minimum of 1000 megawatts (MW) of developable electric generating capacity that could connect to an existing or new high-voltage transmission line. 1000 MW is equal to 1 gigawatt (GW). The Task Force determined that a GDA does not encompass disparate or diffuse points where the developable electric generating capacity does not reach 1 GW. For comparison, Colorado's statewide summer electric demand peaks at approximately 11 GW. Because no single hydroelectric, geothermal, biomass, biofuel, or ethanol resource specific to a geographic sub-region in Colorado meets the 1 GW capacity threshold, GDAs could not be identified for those resources.

Eight Wind GDAs, and Two Solar GDAs Designated

The Task Force identified eight GDAs for wind, and two GDAs for central solar power (CSP). The eight wind GDAs are located on the Front Range and Eastern Plains, and the two CSP GDAs are located in the San Luis Valley and south and southeast of Pueblo. Maps of the GDAs are located further on in the report.

In total, the eight wind GDAs have 96 GW of capacity. NREL conducted a detailed analysis of the wind GDAs, located in the appendix of this report.

In total, the two CSP GDAs represent a hypothetical of producing 1300 GW if the entire area was covered with equipment, without screening for the highest direct normal insolation or terrain slope. Only a small fraction of the GDA's land area would realistically be contemplated for solar farms. However, for example, if only 2% of the land area in the solar GDAs was used, 26 GW of CSP capacity could be produced.

NREL conducted an analysis of the two CSP GDAs. That analysis screened out areas of slightly lower direct normal insolation and screened out land area that has a terrain slope of more than 1%. This resulted in an estimated 275 GW of capacity. If just 2% of this screened area was used for CSP farms, 5.5 GW of CSP generating capacity is available. The appendix contains NREL's analysis for supporting documentation.

The Process for Renewable Energy Projects to Enter the Electric Power Markets

Colorado is rich in renewable energy resources. However, by themselves, wind, solar, hydroelectric, geothermal, and biomass resources do not add value. Renewable resources require development projects that install technology to produce electricity, and deliver the power to markets. For developments to materialize on a utility level, a focus should be on determining and streamlining the pathway to obtain a power purchase agreement from the sole buyers in the electricity marketplace- electric utilities.

Lessons learned from the first decade of renewable energy development in Colorado suggest that success requires that several key issues be addressed. A project due diligence checklist could be of assistance to developers. Several elements would be included, such as addressing legal considerations, developing an organizational and financial structure, accessing resources and markets, obtaining interconnection agreements, conducting transmission studies and agreements, developing sound project economics, determining the consumer benefit, securing project finance, gaining access to supplier markets, and obtaining broad public policy support.

Local Development Opportunities

In addition to wind and solar resources, opportunities for diverse local development benefits are available from hydropower, geothermal, biomass, and biofuel resources. The General Assembly and the Public Utilities Commission (PUC) endorse diversity policies.[ii] Energy from local development opportunities provides security benefits that larger systems, particularly those involving fuel supplies and prices that can vary substantially over time, are not always able to provide. As Colorado has seen in the past several years, rural economic development benefits result from renewable energy projects. Local owners can find commercial returns on investment in smaller projects, if policy and financial support is available. Another benefit of local development opportunities is that smaller projects do not necessarily involve the long lead time or large scale transmission investments that may accompany the utility-scale projects. Diverse projects can spread benefits among many parties, can include more projects, and can encompass more areas across the state.

"Development," as used in the SB07-091 statute, is not limited to large projects. While the Task Force did not provide GDAs for smaller resources given the Task Force definition of GDAs, all of Colorado's renewable resources, small and large, provide opportunities for development assessment. In this regard, the PUC is expected to issue its "Distributed Generation Incentives for Colorado Consumers" Staff Report by the end of 2007. The report is expected to recommend policies to extend statewide net metering and other incentives to foster distributed generation. As a complement to the PUC Staff report, the hydroelectric, geothermal, and biomass maps in this report should help further inform business and policy considerations so smaller projects can be more fully developed to meet the state's energy diversity goals.

Mapping of Colorado's Renewable Resources

The Task Force reviewed a variety of information resources concerning Colorado's renewable resources. NREL has developed very detailed wind and solar maps.[iii] These were used as base maps for the Task Force. A variety of maps and data sources were used for the hydroelectric, geothermal, biomass, and ethanol maps. The sources used to create the maps are referenced in the narrative that follows the maps. GEO contracted with David Skiles to produce maps and other deliverables, and John Boak, who created graphic design for the maps and other design work for the report.

A complete record of the SB07-91 Task Force is available on the Governor's Energy Office website.[i]

Wind Power Generation Development Areas

The Task Force found that 96 GW of wind generation can be developed in 8 GDAs.

A GDA is a concentration of renewable resources within a specific geographic sub-region in Colorado that provides a minimum of 1 GW of developable electric generating capacity that could connect to an existing or new high voltage transmission line. For purposes of identifying a wind GDA, the Task Force selected areas that were within a Wind Power Class (WPC) 4 area or better. The reference to "50" in the legend represents wind speeds (watts/square meter) measured at a height of 50 meters.The green lines represent high voltage lines. The thicknesses of the lines represent their capacity to carry power. Note the lack of thick (higher voltage lines) that intersect with the wind GDAs. Colorado's Eastern Plains offer immense opportunities for utility scale electric generation from wind after the wind turbines are connected to much larger high voltage transmission lines. The Task Force found that 96 GW of wind generation can be developed in 8 GDAs.

Wind Power Class	*Wind Speed*
WPC 2	between 13-15 mph
WPC 3	between 15-17 mph
WPC 4	between 17-18 mph
WPC 5	between 18-19 mph
WPC 6	between 19-21 mph
WPC 7	greater than 21 mph

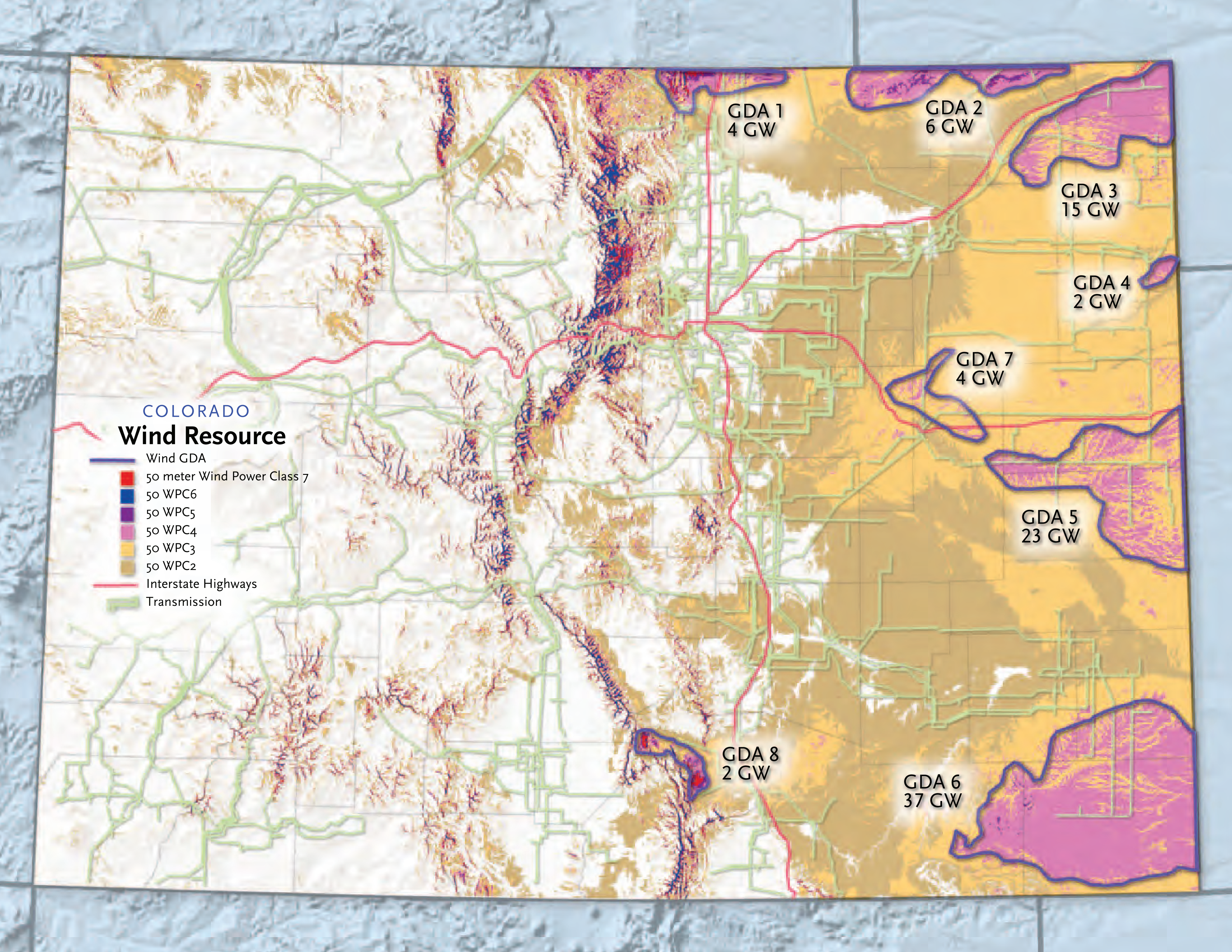
With NREL's technical assistance, the Task Force identified utility-scale wind power opportunities concentrated in eight GDAs with the following capacity potentials:

Colorado Wind GDAs	*GW of capacity in WPC 4 areas or better*
1 – North-central	4
2 – North-east	6
3 – North-east	15
4 – East-central	2
5 – East-central	23
6 – South-east	37
7 – Front Range-east	4
8 – Walsenburg area	2
Total	96

A significant amount of wind power potential exists in Colorado's WPC2 and WPC3 areas, though the Task Force did not create GDAs in these areas (as they would have covered too much land area.) Note that there are many instances where WPC4 exists in pockets outside of the GDAs, and therefore have development potential, especially if they are in close proximity to a transmission line with available capacity. Since WPC2 and WPC3 areas reside outside the eight denominated GDAs, these lower wind power class areas were not measured as part of the Task Force exercise. While Colorado's Eastern Plains has the greatest potential in terms of total GW of wind capacity, Colorado's most productive and least costly wind power is located along the Wyoming border. A detailed discussion of the economic potential within each of the eight wind GDAs was produced by NREL's David Hurlbut and Donna Heimiller, located in the Appendix of this report.

An excellent wind resource map for Colorado is published in a report by the Department of Energy's (DOE) Wind Program and NREL.[iv] That report states:

"Colorado has wind resources consistent with utility-scale production. Significant contiguous areas of good resource with embedded regions of excellent resource are found in the eastern quarter of the state. The excellent resource areas within the eastern quarter of Colorado are concentrated near the New Mexico and Nebraska borders. An area of excellent-to-outstanding resource is located along the Wyoming border north of Fort Collins. The exposed ridge crests of the Front Range, the Continental Divide, and in western Colorado also have good-to-outstanding wind resource." Local wind development opportunities, where a broad diversity of smaller projects may be targeted, can be identified using the NREL map.


COLORADO
Wind Resource
Wind GDA
50 meter Wind Power Class 7
50 WPC6
50 WPC5
50 WPC4
50 WPC3
50 WPC2
Interstate Highways
Transmission
GDA 1
4 GW
GDA 2
6 GW
GDA 3
15 GW
GDA 4
2 GW
GDA 7
4 GW
GDA 5
23 GW
GDA 8
2 GW
GDA 6
37 GW

Wind Energy Overview

The DOE's website on wind energy[v] states: "Wind energy is the fastest growing type of energy generation in the United States and around the world. This growth can be attributed to a greatly reduced cost of production (from 80 cents [current dollars] per kilowatt-hour [kWh] in 1980 to 4 cents per kWh in 2002). Customer demand for clean, diverse sources of electricity, and state and federal incentives to stimulate the markets also contributed to wind energy's growth. As a renewable domestic resource, wind energy is poised to become our least expensive form of bulk electricity generation."

Wind and solar energy consistently lead national opinion polls in terms of consumer preference. In Colorado, the popularity of wind energy is reflected by the success of Windsource®, Xcel Energy's voluntary green-pricing program, which has one of the highest participation levels of any such utility program in the nation and is currently experiencing another period in which consumers are on waiting lists.

Wind and solar energy enjoy strong popular support for various reasons, including environmental benefits and rural economic development opportunities. Consumers of wind energy are now benefiting from its long-term cost stability. As a greater percentage of a utility's portfolio consists of wind, this provides a hedge against the increasing volatility of fossil fuel prices.

Wind Energy in Colorado

According to Interwest Energy Alliance,[vi] with 1,067 MW of installed wind capacity at the end of 2007, Colorado has vaulted into sixth place nationally in wind capacity, trailing only Texas, California, Iowa, Washington and Minnesota. Colorado's strong showing was made possible by the installation in 2007 of 775 MW of new wind capacity (400 MW at Peetz Table in Logan County, 300 MW at Cedar Creek in Weld County, and 75 MW at Twin Buttes in Bent County).

Wind energy project construction employed over 600 people in Colorado in 2007. As the new Vestas wind blade manufacturing plant is completed in Windsor in early 2008, well over 700 people will be directly employed in Colorado by the wind industry alone. This level of activity does not count the many indirect jobs that this burgeoning industry is creating.

Community and Small-Scale Wind

Colorado abounds in opportunities for community-based wind power. Unlike utility-scale wind power, these opportunities tend not to be concentrated geographically in any one area of the state. Both the wind potential and the technical challenges can vary significantly between neighboring land owners, particularly in the mountainous terrain of western Colorado. It is difficult, therefore, to geographically describe the potential for small-scale wind power the same way as for utility-scale wind. Detailed information about wind data at a number of Colorado sites is available at the Plains Organization for Wind Energy Resource.[vii]

A successful model for community wind exists in Minnesota where 300 MW is slated to be developed through "community-based energy development" (C-BED).[viii] There is a growing interest in community wind in our state. Colorado Harvesting Energy Network brings together agricultural, environmental and rural interests to pursue a common vision for energy production from farms and ranches and the strategies to bring the vision to life. Two leading agriculture organizations – the Colorado Farm Bureau and the Rocky Mountain Farmers Union have joined with Environment Colorado in the coalition coordinated by the nonprofit Colorado Working Landscapes. The coalition continues to evolve as an affiliate of the national 25 x '25 movement by actively organizing strategic partnerships and seeking to support grass-roots efforts with public policy initiatives and technical support.

DOE's Wind Powering America program has published a guide for Colorado homeowners, ranchers, farmers, community planners and others who are looking into the potential benefits of a small wind system.[ix] Detailed studies have been conducted to determine the extent to which community wind projects can be connected to the grid.

Wind Energy and the Western Governors' Association

At the regional level the Western Governors' Association (WGA) has taken an active role in addressing the pressing lack of transmission capacity. From 2004-6, WGA's multi-stakeholder Clean and Diversified Energy Advisory Committee (CDEAC) prepared a series of recommendations on how the region could achieve 30,000 MW of clean energy by 2020, along with an energy efficiency improvement of 20% by 2020.[x] The WGA has

With 1,067 MW of installed wind capacity at the end of 2007, Colorado has vaulted into sixth place nationally, trailing only Texas, California, Iowa, Washington and Minnesota in wind capacity.

continued to aggressively pursue west-wide transmission expansion, together with many stakeholder parties, including utilities, the energy industry, conservation groups and many others. This has led to several new WGA initiatives, including creation of a new Energy Working Group that will make recommendations related to wildlife corridors and crucial habitat overlapping with energy development, as well as consideration of a process to identify "Renewable Energy Zones" throughout the West.

Wind Integration

The Independent System Organization and Regional Transmission Organization Council reported in December 2007 that almost half of proposed generation in the United States is from renewable energy.[xi] The Council reports that nearly half (44%) of the 300,000 MW of proposed new generation in the nation's 10 independent system operator (ISO) and regional transmission organization (RTO) regions are renewable energy projects, with wind being the largest single energy source in interconnection queues, according to a set of three reports. The reports highlight the value ISOs and RTOs bring to electricity markets. Much of that value has to do with fostering the development of renewable energy sources. The wholesale electricity markets "play an especially critical role in developing renewable resources," the report stated. Large, organized markets in ISO and RTO regions are open to all those interested in investing and building new power plants, the report noted, opening up such markets to wind and other renewables developers. In addition, price transparency within the markets lets developers know the value of their power, helping them to make investment decisions. "Third, the five- to fifteen-minute dispatch of these large markets and the large size of these markets reduce the cost of integrating wind into the power system by taking advantage of wind diversity and the ramping capability of conventional generators," the report observed. And finally, the report noted that the coordination of regional transmission planning makes it possible to build the transmission needed to bring renewable energy to the markets.

The Utility Wind Integration Group (UWIG) was established in 1989 to provide a forum for the critical analysis of wind technology for utility applications and to serve as a source of credible information on the status of wind technology and deployment. The group's mission is to accelerate appropriate integration of wind power for utility applications through the coordinated efforts and actions of its members and in collaboration with the DOE, NREL, and utility research organizations. UWIG currently has over 100 members spanning the United States, Canada, and Europe, including IOU, public power, and rural electric cooperative utilities; transmission system operators; and associate member corporate, government, and academic organizations. Various reports are available that characterize the impacts of wind on power system operations and integration and costs to integrate various levels of wind generation.[xii]

Solar Power Generation Development Areas

Two percent of the land area in the two Central Solar Power GDAs would accomodate 26 gigawatts of capacity.

A GDA is a concentration of renewable resources within a specific geographic sub-region in Colorado that provides a minimum of 1 GW of developable electric generating capacity that could connect to a new or existing high voltage transmission line. There are two large sections in southern Colorado capable of producing large blocks of power deploying utility-scale central solar power (CSP) technologies. These areas are identified as CSP GDAs. They include the San Luis Valley and hundreds of square miles south and east of Pueblo.

Without screening for the highest direct normal insolation and terrain slope, these two CSP GDAs represent a theoretical solar energy potential of some 1300 GW. Clearly, this would be impractical as (1) all the land area would have to be covered with solar generation equipment (assuming current technology efficiency levels) and (2) the capacity potential is over 100 times the current peak demand for the state.

Realistically, only a small portion of the GDAs would be developed. Nevertheless, just 2% of the two CSP GDAs would accommodate 26 GW of capacity. In addition, NREL further screened the two GDAs for terrain slopes less than 1%. (It is noted that the 1% screen is arbitrary- it should not be concluded that CSP cannot be developed on land with a slope greater than 1%.) Both of these arbitrary screens serve as rough proxies for all the factors other than direct normal insolation that might make a site difficult to develop. These factors include existing agriculture, sensitive habitat, distance from existing transmission, and high land cost. After applying these two thumbnail screens, approximately 5.5 GW of capacity could be developed, equivalent to about half of the peak demand for power in the state. A detailed discussion of the economic potential within the two CSP GDAs has been produced by NREL's David Hurlbut and Donna Heimiller, located in the appendix of this report.

Colorado has abundant solar energy, enjoying 300 sunny days a year. This is more annual sunshine than San Diego or Miami Beach. Some solar technologies convert energy from the sun into heat, light, and hot water such as passive solar heating, daylighting, solar hot water, and solar process heat and space heating and cooling. In addition, electrical energy can be generated directly from solar energy through semi-conducting photovoltaic materials. Electrical energy can also be generated indirectly through heat capture and transfer, ultimately spinning an electric turbine generator. Each of these two broad categories contains a number of technology types and can be used to generate electricity at utility scale.

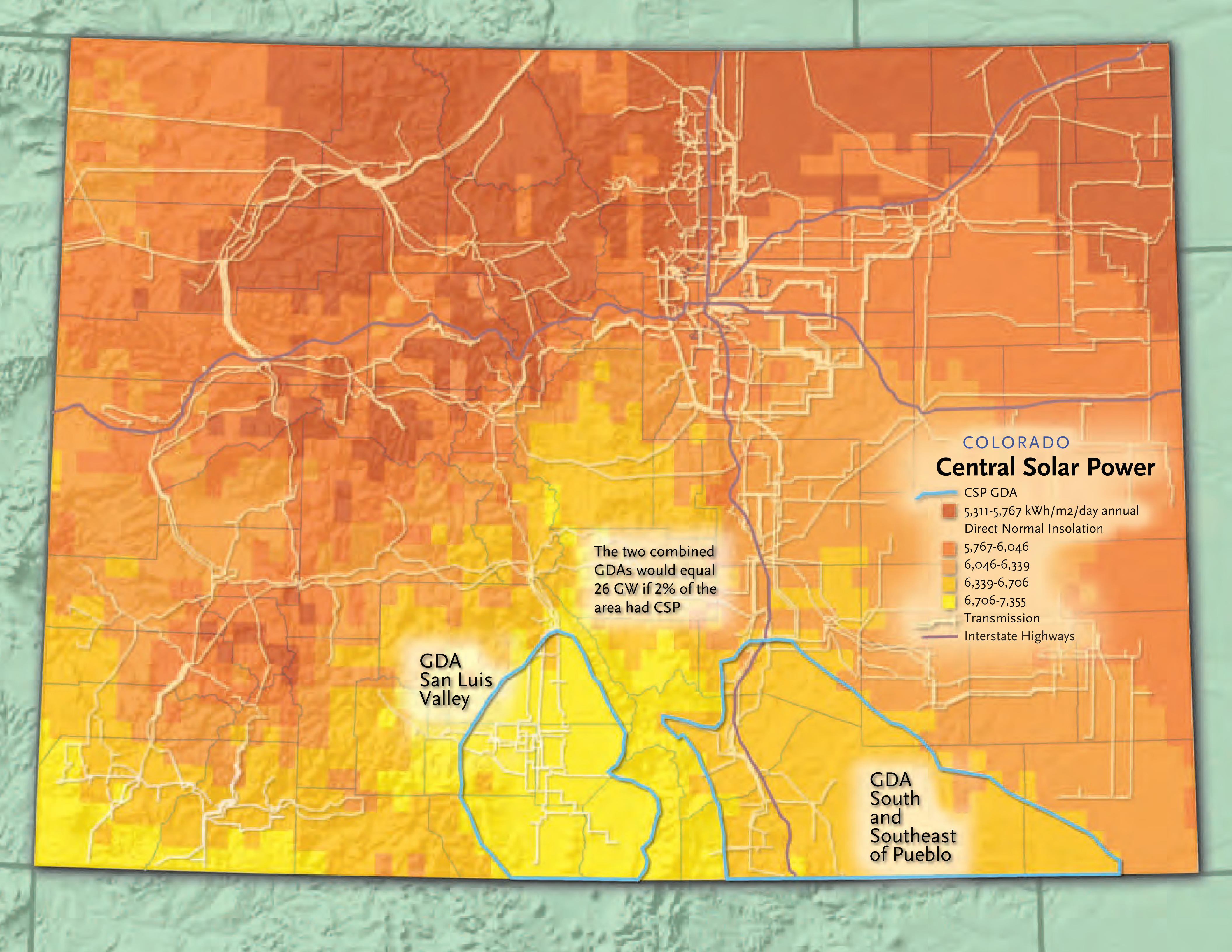
Utility-Scale Solar Technologies

Concentrating Solar Thermal Power (CSTP)

These technologies are primarily used in large-scale applications. As a result, it allows utilities to reap the benefits of solar power without having to depend on investment by individual consumers in the marketplace. Within the U.S., over 350 MW of CSTP capacity exists and these plants have been operating reliably for more than 15 years. Many more CSTP plants are scheduled for development in California and southwest. There are three main types of CSTP systems: parabolic-trough, dish/engine, and power tower.

Parabolic-trough systems use long rectangular, curved mirrors to concentrate energy from the sun. These mirrors focus the sun's energy on a pipe which contains oil. Once the oil is heated, it can be used to boil water. This boiling water can then be used to produce electricity in a conventional steam generator.

A ***dish/engine system*** uses a curved, mirrored dish to collect and concentrate


COLORADO
Central Solar Power
CSP GDA
5,311-5,767 kWh/m2/day annual Direct Normal Insolation
5,767-6,046
6,046-6,339
6,339-6,706
6,706-7,355
Transmission
Interstate Highways
The two combined GDAs would equal 26 GW if 2% of the area had CSP
GDA San Luis Valley
GDA South and Southeast of Pueblo

heat onto a receiver. This receiver absorbs and transfers the heat to a fluid located in an engine. As the temperature of the fluid increases, it expands and creates pressure. This pressure is used to drive a piston or turbine which can power an electric generator.

A ***power tower system*** uses several large mirrors to concentrate solar energy onto a receiver located on a central tower. The receiver contains molten salt which is heated and used in a conventional steam generator to create electricity. Molten salt can be stored without losing much heat. As a result, these systems can generate electricity on cloudy days, or several hours after sunset.

Xcel Energy and five other Western utilities are seeking proposals to build a CSTP rated at 250 MW. The plant, to be located in either Arizona or Nevada, would be the second-largest solar power plant of its kind in the nation. At present, approximately 2,500 MW of CSTP are under contract for future development, primarily in California.

On November 29, 2007, the DOE announced a new solar energy initiative that provides up to $5.2 million in funding to twelve projects to be implemented with nine U.S. companies. The projects selected for awards are expected to reduce today's 12–14 cents/kWh cost of power to 7–10 cents/kWh by 2015 and reduce the cost to under 7 cents/kWh with 12–17 hours of storage by 2020. One of the grants was awarded Solucar, with its headquarters in Lakewood.

On December 4, the DOE announced that it is awarding SkyFuel, Inc. a $435,000 grant to develop its advanced CSP system known as the Linear Power Tower (LPT) for utility-scale solar thermal power plants. SkyFuels has its research and development office in Arvada.

Photovoltaic Systems

These technologies are modular by design and can be scaled over a very wide size range for large-scale utility applications. PV continues to generate electricity on cloudy days, albeit at lower levels. The basic PV technology has been around for over fifty years, and the first PV cells are still generating electricity today. In addition, PV generation has no moving parts, which allows for better projections of future maintenance. There are many variations of PV technology including crystalline silicon, amorphous silicon, thin film, triple junction PV, concentrating PV and non-silicon based technology. Space availability and economics become the driving factors for selecting the appropriate PV technology for a given application. Colorado is home to one of the largest central PV projects in North America, located near Alamosa. Following its eight month construction, it will produce over 8 MW using both conventional and concentrating PV.

Storage of Solar Energy

Each of these utility scale solar technologies is dependent on the availability of the sun for production of electricity in varying degrees. The generation curve for these technologies typically peaks in the middle of the day, while utility load patterns often peak later in the day. By adding energy storage to these technologies, their ability to be utilized by the utility to meet demand at peak times is greatly increased. Storage technologies include heat storage, many types of batteries, flywheels, pumped storage, compressed air, and super-capacitors. Recognizing the opportunities ahead, considerable public and private research and development is occurring in this field worldwide. Xcel Energy, for example, is testing battery technology, hydrogen storage, and plug-in hybrid electric vehicles.

Distributed Photovoltaics [xiii]

While utility-scale solar generation, including PV, can help capture economies of scale, distributing solar generating equipment around the utility grid can provide other benefits, such as reduced transmission and distribution investment. There are several means of distributing solar generation around a utility grid. Locating solar generation in excess of the 1 MW range at utility substations can eliminate the cost of transmission needed to bring the generation to the markets and the energy lost through its transmission, while still capturing most of the scale economies.

In addition, solar generation located at the point of delivery, i.e. on the electric consumer's premises, can reduce the cost of transmission and distribution needed to bring the generation to the markets and the energy lost through its delivery. While installation costs are generally somewhat higher, land is not needed for the solar equipment as it will typically be located on the roof. Moreover, new thin film technology has made it possible to create solar cells that mimic standard building materials such as rooftop shingles, roof tiles, building facades, or the glazing for skylights or

■ *While some parts of Colorado have a slightly better solar resource for photovoltaics, the benefits of that better solar resource are far outweighted by the presence of effective utility-sponsored solar incentives.*

atria. Utilizing PV for customer-sited generation is limited by economic trade-offs, solar access and policy treatment by the local utility. While some parts of Colorado have a better solar resource, the benefits of the increased resource are far outweighed by effective policy mechanisms.

Central Solar Power Policy

Solar energy is virtually limitless, non-polluting, quiet, has no security implications, generates skilled jobs and does not exacerbate greenhouse gases. These benefits have resulted in polling data that repeatedly demonstrates that the public overwhelming favors solar over other energy options. Electric utility regulation, however, has traditionally evaluated electric supply options on a pure economic cost basis from a centralized utility supply perspective. The current higher initial cost of solar energy electric generating technology results in very low penetration levels under traditional processes. To overcome this barrier, development of solar energy currently requires effective policies that take into account solar's long-term benefits. For example, new regulatory practices could recognize that utility scale solar energy with storage can become a baseload resource with no risk of future fuel price increases. The cost of its fuel will be the same in 30 years as it is now – zero. This hedge value is important to businesses, in particular, who try to project their own future costs, revenue and income. Therefore, carefully siting the solar generation is important in terms of maximizing the efficiency of the solar technology in use. However, effective policy is crucial to the development of solar generation in the near term.

Effective Solar Policy

Effective policy is critical as well for distributed solar applications. Solar energy is ubiquitous throughout Colorado, allowing the use of distributed solar energy across the state. Effective policies for the deployment of customer-sited solar generation will go a long distance to make this a reality. The Solar Alliance suggests the following policy drivers to assist customer-sited solar: [xiv]

Utility Rates and Revenue Policies. The electric bill is where clean energy turns into dollars and cents. Smart rates can drive clean and efficient use of energy while making sure utilities are paid in full, while poor ones can encourage sub-optimal use of energy.

Interconnection Policies. A solar electric system cannot be installed unless the rules for grid connection are fair and streamlined. Many states have recently adopted best practice interconnection standards, including the Colorado PUC.

Net Metering Policies. Net metering governs the economic transaction between customer-generator and utility. The benefits of distributed solar generation typically far exceed the direct fuel cost savings by the utility. Best practice net metering policy, such as that adopted by the Colorado PUC, recognizes these benefits.

Standards and Incentive Policies. All forms of energy have incentives. Good incentive design can provide sustained orderly development of the customer-sited solar market while maintaining economic controls as technologies improve and costs decline.

Colorado's IOUs currently have effective policies in these areas. The policies of many municipal and rural electric cooperative utilities are in a state of development.

Detailed information about how Xcel Energy is progressing with rebates to customers in its service territory is available in an article in the appendix, and at Xcel Energy.[xv] Xcel Energy filed its proposed Colorado Resource Plan with the PUC on November 15, 2007. In that application, Xcel proposes to add a 25 MW CSP plant in 2011, and a 200 MW CSP plant to their portfolio in 2016.[xvi]

Colorado Statutory Policies Related to Solar Power

There are a variety of new solar policies in Colorado that are moving the state forward, including, but not limited, to:

HB07-1281 increased the RES to 20% by 2020, of which 4% must be derived from solar electric resources. A minimum of fifty percent of the 4% set-aside must be customer-sited, as distinct from utility-scale. The solar set-aside requirement only applies to IOUs. The IOUs have implemented financial incentives for the promotion of customer-sited solar generation. A detailed description of this legislation is located further on in the report.

HB07-1228 requires the PUC to develop a policy to establish incentives for customer generated heat or electricity through the use of renewable resources, without restriction to its jurisdictional utilities. The Commission's findings are expected to address net metering, rate structures, and financial incentives.

HB07-1169 requires rural electric cooperatives to use the same interconnection standards for distributed resources under 10 MW that are required for IOUs, as adopted by the PUC.

Hydroelectric Power

Hydroelectric power is well characterized in Colorado. Because there are no single hydroelectric sites in Colorado that are 1 GW or larger, GDAs for hydroelectric were not identified. Indicated on the map are local development opportunities, where a broad diversity of smaller projects may be targeted. Sources used to create the map are listed in the endnotes.[xvii]

Colorado's rivers and streams provide hydroelectric power as water falls from a higher to lower elevation through a turbine. These plants, operated by federal, state, utility, and local entities, provide hydropower generation at locations throughout the state. An estimated 100 additional locations for hydropower have been identified at existing impoundments and water diversions.

Existing Hydropower Facilities in Colorado

There are sixty-two operating hydropower facilities in Colorado, based on a 2005 inventory developed by NREL. These sites have a combined installed capacity of approximately 1162 MW and produce about 1036 GWh of electric energy annually.[xviii]

These plants range in size from 5 kW to 300 MW and include three pumped storage facilities. Some of the plants are relatively new, while others were built during the late 1800s and early 1900s.[xix] Older plants may offer several opportunities for improvements in efficiency and plant production. These include installing more efficient turbines, upgrading generator windings and replacing mechanical controls with solid state equipment. These improvements can range from 1-2% to as high as 25-30% and thus offer the potential of significant additional generation with little or no negative environmental impacts.

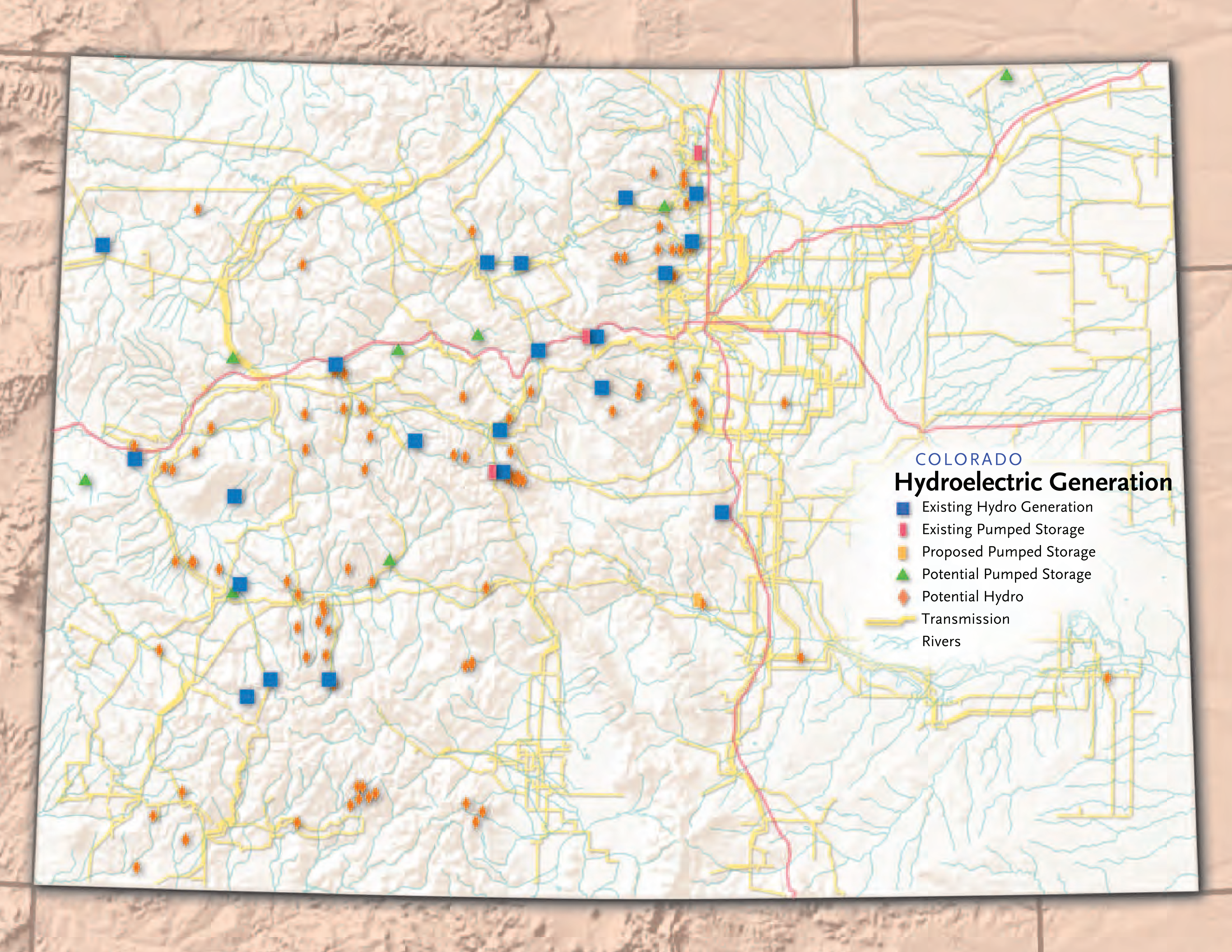
Most municipal water systems have numerous pressure reducing valves which can be replaced with small turbines to generate power. Although several such systems are currently in place, a statewide inventory of potential sites has not been developed. An initial review suggests several MW of power may be available at existing infrastructures for this resource.

Pumped Storage Hydroelectric Plants are facilities with both an upper and lower reservoir for water storage. They operate by releasing water for generation from the upper reservoir to the lower reservoir during periods of high demand and then pumping the water back into the upper reservoir during the evening or other periods of low demand. Pumped storage plants allow existing off-peak generation to be shifted to peak periods and thus reduce the need for new generating plants. Adding pumped storage hydro facilities in electric systems that have increasing amounts of variable generation resources, like wind or solar, can be very beneficial. Currently there are three pumped storage plants in Colorado:

Mount Elbert – a 200 MW facility, near Leadville.

Cabin Creek – a 300 MW facility, near Georgetown.

Flatiron/Carter Lake – an 8 MW facility, near Loveland.


COLORADO
Hydroelectric Generation
Existing Hydro Generation
Existing Pumped Storage
Proposed Pumped Storage
Potential Pumped Storage
Potential Hydro
Transmission
Rivers

Existing impoundments and other water diversion features without turbines represent opportunities for new hydropower development. Colorado has 91 such sites.

Opportunities for New Hydropower Development in Colorado

Existing impoundments and other water diversion features without turbines represent opportunities for new hydropower development. As part of a larger assessment of water energy resources, the DOE's Idaho National Engineering and Environmental Laboratory (INL) identified 91 such sites in Colorado. These sites, with an estimated capacity of about 782 MW, are located on the resource assessment map. Many of these sites can be developed with minimal environmental impact and any development should ensure that steps are taken to avoid or minimize environmental impacts and not preclude dam re-operation that would benefit stream ecology. They are often located close to electrical loads which would reduce transmission losses. With the recent acceptance of wind energy programs, small hydroelectric projects, based on local resources, might also be favorably included in renewable energy programs.

An energy storage research program at the University of Colorado at Boulder has evaluated the use of existing pumped storage hydro facilities and has also identified several opportunities for new projects. An economic model (calculator) was developed to assist in the evaluation of these sites (pumped hydro research papers).[xx] Seven potential sites were evaluated with a total estimated capacity of about 2,562 MW. Several attributes of each site, in addition to the economic analysis, were identified including: infrastructure in place, adjacent to load centers, adjacent to large generation, and natural resource availability. As Colorado moves to increase its wind and solar resources, hydroelectric pumped storage may be an important element in the state's electric supply system. More information on energy storage is available at the University of Colorado.[xxi]

Summary of Colorado Hydropower Resources

There appear to be several hundred MW of undeveloped hydropower available at existing impoundments and diversions. Several MW of undeveloped hydropower may also be available in existing municipal water systems. Development of these resources would capture a significant amount of energy that is otherwise lost. There are also potential opportunities for improvement in efficiency and production at existing hydropower facilities. These improvements can range from 1-2% to as much as 25-30% of the installed capacity.

Several opportunities for additional pumped hydro projects were also identified. These include sites with existing infrastructure as well as undeveloped sites with favorable preliminary attributes. A re-evaluation of the operating plans for the existing pumped hydro facilities may result in a more efficient use of the plants for integrating renewable energy into the grid and seize opportunities to improve stream flows and remedy existing impacts. Development of these hydropower resources would be a significant addition to the generation profile for Colorado.

The Task Force identified the following hydroelectric topics for further study:

- Provide a more detailed assessment of potential sites (especially those with high head) in Colorado for use with renewable energy integration.
- Re-evaluate the operating plans for existing pumped storage facilities to see if greater value could be provided by also using these plants for wind integration.
- Continue to evaluate opportunities for additional pumped hydroelectric storage in Colorado [xxii]
- Re-evaluate the operating plans for existing pumped storage facilities to see if greater value could be provided by also using these plants for regulation service rather than as base load plants.
- Evaluate the advantages of having FERC oversight delegated to a Colorado state agency to facilitate the development of small hydropower facilities.
- A re-evaluation of the operating plans for the existing pumped hydro facilities, particularly the Mt. Elbert facility, may result in a more efficient use of the plants for integrating renewable energy into the grid.

The Task Force identified the following hydroelectric additional references:

- USDOE Feasibility Assessment of the Water Energy Resources of the United States for New Low Power and Small Hydro Classes of Hydroelectric Plants, DOE-ID-11263, January, 2006.
- Idaho National Engineering and Environmental Laboratory, Estimation of Economic Parameters of U.S. Hydropower, INEEL/EXT-03-00662, June 2003.
- Hydropower Prospector [xxiii]
- James Francfort, U.S. Hydropower Resource Assessment for Colorado, DOE/ID-10430, May 1994.

Geothermal

Geothermal power is a potentially vast resource, but the geothermal development potential in Colorado remains largely unknown. Because there are no single geothermal sites in Colorado that are 1 GW or larger, GDAs for geothermal were not identified. Indicated on the map are geothermal local development opportunities, where a broad diversity of smaller projects may be targeted.

There is significant movement of heat from the Earth's interior to its surface in Colorado, and this heat is a potential source of renewable energy. Areas of high heat flow indicate geographic areas that are conducive to finding geothermal resources at depth. Much of Colorado has higher heat flow than the world continental average of about 65 milliwatts/square meter (mW/m2). Areas with relatively high heat flow include regions around Buena Vista, Ouray, Pagosa Springs, Trinidad, Canon City, Leadville, Georgetown and west of Rocky Mountain National Park. Other areas of the state may have high heat flow, but a lack of heat flow data limits their identification.

Geothermal describes technology that uses heat from the earth to generate heat or electricity.[xxiv] Sources of geothermal heat include hot water and steam at depth and the constant temperatures in the earth in the shallow subsurface. Several technologies exist to convert this energy into a source of heat or electricity for buildings. The Western States, Hawaii, and Alaska have the most potential for utility-scale geothermal.

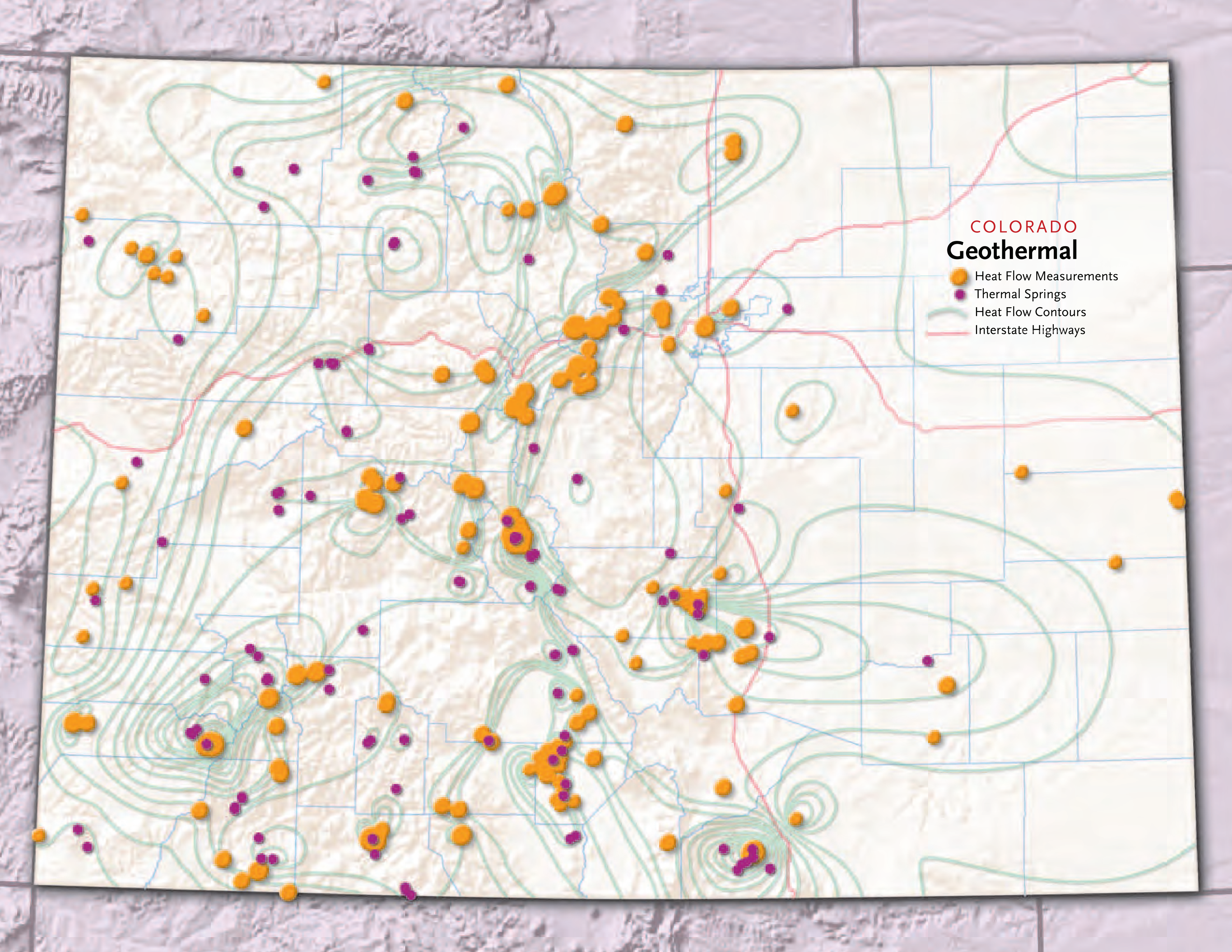
Geothermal Electricity

There are three different methods to convert geothermal heat into energy: dry steam systems, flash steam, and binary cycle.

Dry steam systems pump steam directly from underground sources to a power generation unit. Because there are only two known major U.S. sources of underground steam (Yellowstone National Park in Wyoming and the Geysers in Northern California) this method of electricity production is fairly uncommon. Currently there is only one dry steam plant, located at the Geysers in Northern California.

Flash steam power plants use reservoirs of hot water (>360°F) located beneath the earth's surface. Wells are drilled to bring the hot water to the earth's surface. The water is brought to the surface under pressure to keep it in liquid form. As the superheated water is released into the turbine area, it "flashes" to steam and expands, driving the turbine to generate power. Excess water is pumped back into the reservoir. This is the most popular method of geothermal power generation.

Binary Cycle power plants use two independent cycles or loops. One loop contains thermal water from a geothermal well. The other contains a working fluid


COLORADO
Geothermal
Heat Flow Measurements
Thermal Springs
Heat Flow Contours
Interstate Highways

with a lower boiling point than water. The thermal water heats the working fluid through a heat exchanger, causing it to convert to a vapor and driving the turbine. These plants can utilize thermal water in the 200-360°F range. Some applications have been successful with temperatures as low as 165°F.

Geothermal Direct Use

Naturally occurring sources of hot water (100-360°F) can be used directly for many applications including heating buildings (either individually or whole towns), raising plants in greenhouses, drying crops, heating water at fish farms, and several industrial processes, such as pasteurizing milk. Many locales in Colorado currently use thermal water directly from natural hot springs for recreational opportunities.

Geothermal Heat Pumps or Geoexchange

These technologies use the relatively constant temperature of the shallow subsurface of the earth (50-60°F) through the seasons. During the winter, heat is drawn from the subsurface into a working fluid in vertical or horizontal shallow ground loop piping. The fluid then transfers its heat to a home heating system. In the summer, the process is reversed, providing cool air for the home. An investigation is under way at the Governor's mansion to determine the geoexchange opportunities at that location.

Colorado Geothermal Development Strategic Plan

In August 2007 a "Colorado Geothermal Development Strategic Plan" was produced by the GeoPowering the West Colorado State Working Group.[xxv]

The report states:

"The Colorado Geothermal Development Strategic Plan is an action-oriented document prepared by the GeoPowering the West Colorado State Working Group. The DOE's GeoPowering the West initiative is designed to increase the use of geothermal energy by linking the power industry, geothermal users, and governments with technical and institutional support, educational outreach, and limited cost-shared funding.

Geothermal resources are most easily defined as useable manifestations of the Earth's heat energy and may represent the largest useable energy resource base available to man. Geothermal power production offers several advantages over other renewable energy production sources. Modern closed loop binary systems have virtually no emissions, a small plant footprint, low noise emissions, high reliability, and can produce high capacity factors with energy production available in most hours of the year.

Colorado ranks fourth among western states in the number of potential sites for geothermal power generation, according to a 2006 Western Governors' Association report. While Colorado has numerous geothermal direct use and aquaculture projects, the state currently has no geothermal electrical generation projects."

Key recommendations include:

- New state loan guarantees on financing are needed for geothermal energy projects.
- Creation of a state drilling incentive to encourage geothermal exploration.
- Creation of a state production tax credit for geothermal energy production.
- Recognizing ground source heat pumps as a renewable energy source.
- Encouraging electric utilities to pursue ground source heat pumps as part of their demand side management programs under HB-1037.

The GeoPowering the West report also covers the barriers and opportunities faced by the direct use and geothermal heat pump industries, as well as suggested action items. It also notes that industry effort is needed to outreach to key stakeholders to educate them about the important role geothermal energy plays in our energy future. By developing Colorado's abundant geothermal resources, the state can continue on its path of creating a widespread renewable energy economy, while helping to limit carbon emissions, ensuring Colorado's splendor remains for future generations to enjoy. The geothermal resources within the state can also play a critical role in bolstering rural economies through creation of new jobs in power generation, agriculture, aquaculture, and construction."

Colorado ranks fourth among western states in the number of potential sites for geothermal power generation.

PUC Investigation of Geothermal

On October 10, 2007, the Staff of the PUC hosted a Commissioners' Information Meeting to brief the Commissioners on the status of, and prospects for, geothermal energy development in Colorado. Experts from the Staff, Colorado Geological Survey, DOE, utilities, and developers made presentations to educate the Commissioners, and address Commissioners' questions, concerning the nature and extent of Colorado's geothermal resources, geothermal electricity generation, direct use of geothermal resources, prospective applications using geothermal resources, and the statutory and regulatory landscape. A record of that meeting is located in the endnote. [xxvi]

Additional information on geothermal resources and uses in Colorado are available at the GEO's website and the Colorado Geological Survey website.[xxvii]

Biomass

Biomass is available in very different volumes throughout the state. Because there are no single biomass sites in Colorado that are 1 GW or larger, GDAs for biomass were not identified. Indicated on the map are local biomass development opportunities, where a broad diversity of smaller projects may be targeted.

Biomass and Biofuel Defined

Biomass is plant matter such as trees, grasses, agricultural crops or other biological material. Several technologies exist to convert these materials into useful sources of energy such as solid fuel, liquid or gas. These fuels can then be used for production of electric power, heat, chemicals, or fuels. A recent summary of biomass for heat applications in Colorado has been produced.[xxviii]

Biofuel is broadly defined as solid, liquid, or gas fuel consisting of or derived from biomass. Biodiesel and ethanol are the two most popular types of biofuel.

Anaerobic Digestion

Anaerobic digestion (AD) is the naturally occurring breakdown of organic materials (such as animal waste, food waste and municipal solid waste) by microorganisms when oxygen is not present, creating methane gas that is captured. This gas can be utilized to create heat and power. The net economics of applying large AD projects varies dramatically based on geography, electrical rates and usage, facility size, and utility cooperation with buy-back programs.

Colorado's Biomass

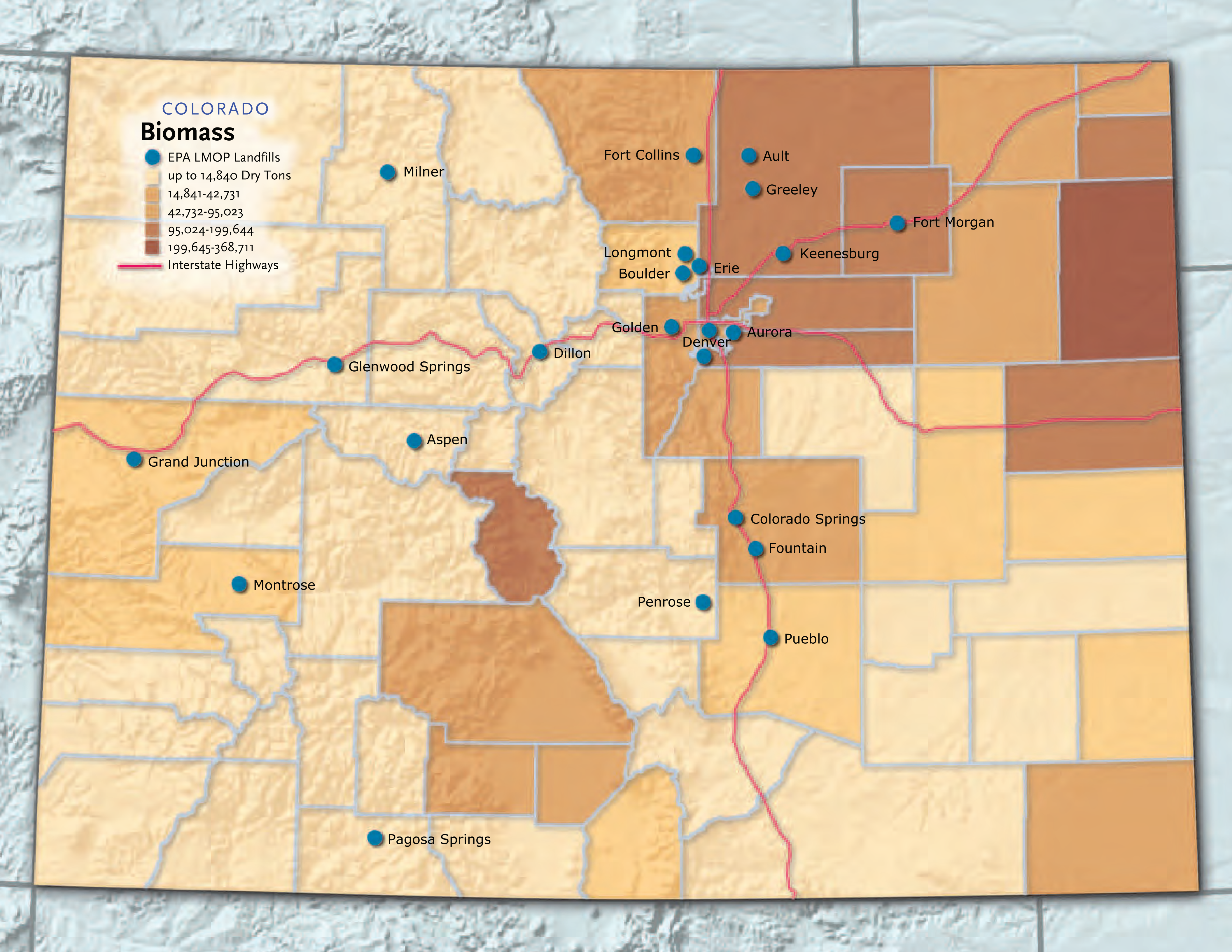
Colorado's biomass includes forest resources, agricultural residues and products, and resources from municipal waste streams including solid wastes, bio-solids, sewage, and waste buried in landfills. The map references EPA Landfill Methane Outreach Program (LMOP) areas. The total estimated resource in Colorado is 2.6 million dry tons per year. A 50 MW power plant uses 50 dry tons per hour of operation and most biomass electric generation plant capacities will be in the range of 15-30 MW. NREL has produced a chart that lists currently operating wastewater or landfill gas biomass power plants in Colorado. The chart shows that there is about 6 MW of capacity from wastewater plants, and about 14 MW from landfill gas.[xxix] The WGA estimates biomass electric generation costs are approximately 8 cents per kilowatt hour.

Examples of biomass projects and biomass ideas in Colorado include, but are not limited to:

- A small amount of co-firing of wood with coal takes place at Aquila's Clark plant in Canon City. No other large electric generating station in Colorado is currently co-firing with bioenergy. The Nucla Station (fluidized bed) plant in Western Colorado could be a candidate for utilizing biofuel.
- Opportunities may exist with respect to Colorado's forest annual thinnings and wastes, resulting from the devastation caused by the beetle kill epidemic. However, there are many logistical, financial, and other barriers that must be overcome.
- A new 21,700 square foot Road and Bridge building in Gilpin County is heated by woody biomass.
- A second county-owned biomass heated facility is located in Boulder County.
- NREL is installing a biomass (wood) district heating system on the permanent site.
- There are two pellet mills planned for Grand County.
- Colorado Springs Utilities tested co-fired wood and biomass for approximately six months.
- An anaerobic digester/generator is located in Lamar.
- The installation of a biomass gasification system is designed to convert the Denver Zoo's solid waste materials into on-site energy generation and distribution. It works by generating fuel to serve a combustion engine generator that creates electrical energy.

Today's biomass power plants typically have electrical generation efficiencies in the range of 15-25%. Gasification and advanced technologies indicate power generation efficiencies in the range of 35-40% are possible. Combined Heat and Power modes could increase the overall plant efficiencies up into the 70-80% range.

Pyrolysis, a high value gas (and/or in some approaches a liquid) can be created from almost every form of biomass through low temperature heating in the absence of oxygen. This gas can be used directly in power plants. A potentially even higher-valued charcoal residue is a co-product of pyrolysis, containing up to 50% of the original carbon content. If the charcoal is placed in soil, two benefits and profit streams result: sequestration of atmospheric CO_2 and soil productivity improvement. This charcoal-use technology, alternatively going by the names "biochar" and "terra preta," is at an early stage of development. There is ongoing biochar research under way at the four Colorado Collaboratory institutions.


COLORADO
Biomass
EPA LMOP Landfills
up to 14,840 Dry Tons
14,841-42,731
42,732-95,023
95,024-199,644
199,645-368,711
Interstate Highways
Milner
Fort Collins
Ault
Greeley
Fort Morgan
Longmont
Boulder
Erie
Keenesburg
Golden
Denver
Aurora
Dillon
Glenwood Springs
Aspen
Grand Junction
Colorado Springs
Fountain
Montrose
Penrose
Pueblo
Pagosa Springs

Ethanol and Biodiesel

Colorado's ethanol fuel facilities produce an estimated 350 million gallons per year (MMgy) at seven locations on the Front Range. At the time of this report there are 20 biodiesel fueling locations and more than 30 E-85 fueling locations across the state. Ethanol and biodiesel are used in the transportation sector, not for electric power generation. The SB07-091 Task Force was charged to assess electric power generation. Accordingly, ethanol and biodiesel GDAs were not considered.

Ethanol Defined[xxx]

Ethanol is an alcohol-based fuel produced by fermenting and distilling starchy crops that have been converted into simple sugars. Feedstocks for ethanol include corn, sugar beets, sugar cane, sorghum, barley, and wheat. Ethanol can also be made from fast growing trees and grasses with high cellulose content. While ethanol works well in combustion engines, it contains 33% less energy by volume than standard fuel. Ethanol is most commonly used in the form of E85 as an alternative to gasoline in vehicles. E85 is a blend of 85% ethanol and 15% gasoline. Ethanol is a cleaner-burning fuel that emits fewer pollutants than regular petroleum and has a greenhouse gas reduction of 10%- 35% for corn and up to 80% for cellulosic feedstocks. Corn is the dominant feedstock for ethanol at present. A relatively small amount of corn ethanol is produced in Colorado. Most of the state's supply of ethanol is imported from Midwestern states.

It is anticipated that cellulosic material may produce commercially viable ethanol volumes in the future. Colorado has a growing cellulosic ethanol presence. NREL is a national center for bioenergy research and development. Cellulosic biomass includes agricultural residues like corn stover and wheat straw and woody biomass. Once fractionated into separate streams, each component becomes an intermediate feedstock for producing many products including liquid transportation fuels (including ethanol and butanol), bioplastics, pulps and many key industrial chemicals. PureVision Technology, Inc., based in Fort Lupton, has developed, and is scaling up, a biorefining process that fractionates or separates the three primary constituents of cellulosic biomass (hemicellulose, lignin and cellulose) into fermentation sugars, fiber and lignin, which are renewable raw materials for producing many bio-products. Range Fuels Inc., based in Broomfield, develops cellulosic ethanol. The firm has announced the construction of the nation's first commercial cellulosic ethanol plant near Soperton, Georgia.

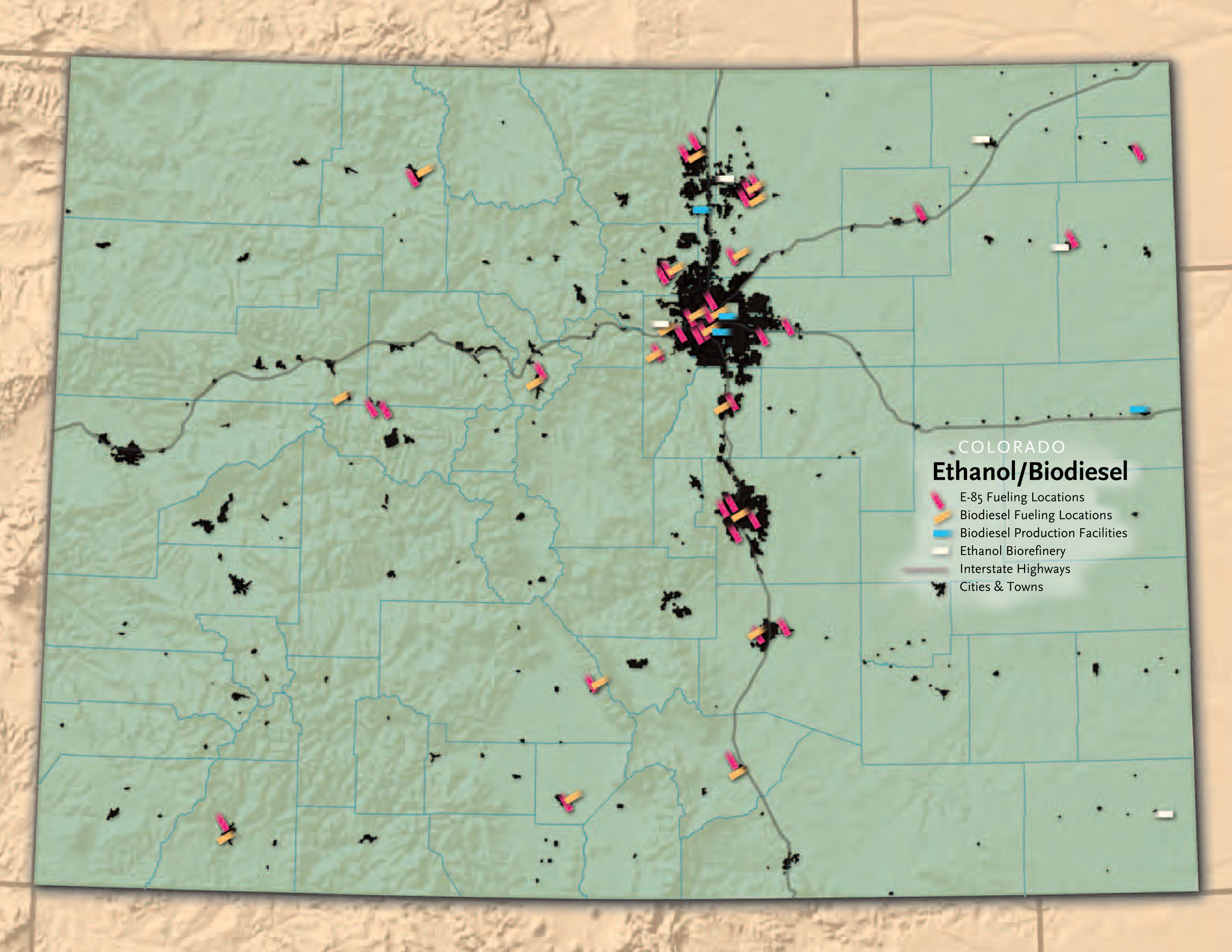
Biodiesel Defined [xxxi]

Biodiesel is a fuel that can be manufactured from vegetable oils, animal fats, or recycled restaurant greases. Biodiesel can be used to power any standard diesel engine with little or no modification. Biodiesel is available in several different blends including B20 and B100, where the numbers correspond to the percentage of biodiesel used in the blend. Biodiesel is cleaner-burning compared to diesel, with less greenhouse gas, criteria, and hazardous pollutants. Advanced biodiesel fuels include algae and other energy crops. Several companies are conducting algae research and development in Colorado.

In October, 2004, Chevron Corporation and NREL announced that they had entered into a collaborative research and development agreement to produce biofuels from algae. Under the agreement, Chevron and NREL scientists will collaborate to identify and develop algae strains that can be economically harvested and processed into transportation fuels such as jet fuel.

Colorado Center for Biorefining and Biofuels

Colorado is pursuing bioenergy through the Colorado Center for Biorefining and Biofuels (C2B2). The organization is a cooperative research and educational center devoted to the conversion of biomass to fuels and other products, supported by state, institutional, and industry funds. They provide private industry with one-stop access to researchers, laboratories, students, and educators from four innovative institutions, each having unique strengths in biofuel and biorefining application areas. Partners include the University of Colorado at Boulder, Colorado State University, Colorado School of Mines, and NREL.


COLORADO
Ethanol/Biodiesel
E-85 Fueling Locations
Biodiesel Fueling Locations
Biodiesel Production Facilities
Ethanol Biorefinery
Interstate Highways
Cities & Towns

Developing Renewable Resources within Colorado's Electricity Environment

Colorado Public Policy

Colorado has a long history in support of renewable energy starting back with irrigators and ranchers utilizing wind energy to support their operations to the state's embracing of solar energy during the energy crises in the 1970s. In addition, cooperatives and municipal utilities have long had a portion of their requirements met by hydroelectric preference power allocations from federal dams marketed by the Western Area Power Administration.

In 2004 Western Resource Advocates (WRA) produced an in-depth study on how the Interior West can address energy and environmental challenges. In addition they produced a report on the tie between energy resources and water. WRA also produced a Renewable Energy Atlas, with valuable information to complement this report. See the endnote for the reference to the WRA reports.[xxxii]

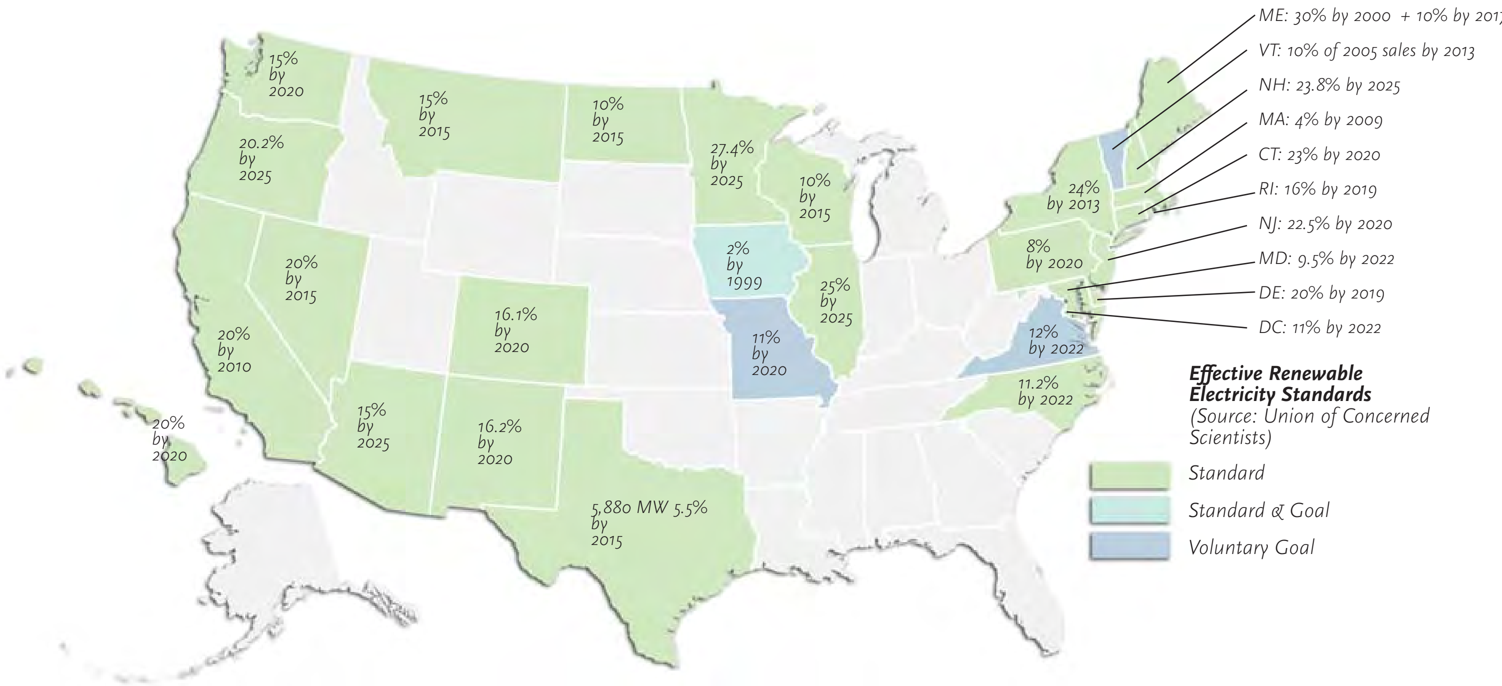
Interest in developing renewable resources in Colorado has been growing steadily over the past several years. Beginning in 2001, bills were introduced to craft a Colorado Renewable Energy Standard (RES) that would create an orderly development path to harness the state's renewable resources for electric power generation. RES requires that a certain minimum percentage of a utility's overall or new generating capacity or energy sales must be derived from renewable resources, i.e., a minimum of x% of electric sales must be from renewable energy in the year 20yy. RES most commonly refer to electric sales measured in megawatt-hours, as opposed to electric capacity measured in megawatts. The term "set asides" is frequently used to refer to programs where a utility is required to include a certain amount of renewables capacity in new installations.

After a petition campaign collected 115,000 signatures, a statewide citizen-initiated referendum item was placed on the November, 2004 state-wide ballot. The initiative was denominated as Amendment 37 by the Secretary of State's office. The statutory measure proposed to create a 10 percent RES by 2015 for IOUs, and for those municipal utilities and rural electric cooperatives in the state with 40,000 or more meters. The measure included a specific solar requirement for the state's two IOUs and an opt-out provision for RECs and municipal utilities. For IOUs, four percent of the standard was required to be obtained from solar electric resources, with at least half of that from customer-owned solar electric technologies. The initiative passed by a 54-46% margin. At that time, Colorado became the 18th state to enact a RES.

In 2005, the Colorado General Assembly made minor modifications to the statute. Despite skeptic's claims during the election that the RES would be too aggressive and cost consumers billions of extra dollars, Xcel Energy committed to sufficient cost-effective wind plants and announced that it would meet the 2015 10 percent goal by the end of 2007—eight years early.

During the 2006 gubernatorial race, then-candidate Bill Ritter campaigned on a platform entitled the "Colorado Promise." In that platform, he emphasized the need to complement Colorado's existing energy economy with renewable energy and energy efficiency as key components of what he denominated as the "New Energy Economy." During the 2007 legislative session, the General Assembly and the Governor met the New Energy Economy commitment by increasing the Amendment 37 RES by passing HB07-1281.

Governor Bill Ritter signing HB07-1281 and SB07-100 into law at the National Wind Technology Center, March 27, 2007. Behind Ritter are (left to right) Senate President Joan Fitz-Gerald (D-Golden, Senate sponsor of SB07-100), Rep. Liane "Buffie" McFadyen (D-Pueblo, House sponsor of SB07-100), Rep. Rob Witwer (R-Genesee, House sponsor of HB07-1281), Sen. Gail Schwartz (D-Snowmass, Senate sponsor of HB07-1281) and Rep. Jack Pommer (D-Boulder, House sponsor of HB07-1281).



House Bill 07-1281 — Colorado's Renewable Energy Standard

HB07-1281 increased the RES to 20 percent by 2020 for IOUs, eliminated the "opt-out" provision for RECs and established a 10 percent RES for all RECs in the state, regardless of size. Specifically, HB 07-1281 expands the definitions of a "qualifying retail utility" to include all utilities, except municipally owned utilities serving less than 40,000 customers, and "eligible energy sources" to include recycled energy. The bill raises the minimum standard for electricity generation from eligible energy sources for IOUs from:

- 3 to 5 percent for 2008 through 2010
- 6 to 10 percent for 2011 through 2014
- 10 to 15 percent for 2015 though 2019
- 10 to 20 percent for 2020 and after.

The bill also establishes a new minimum standard for electricity generation from eligible energy sources for RECs, and municipal utilities serving over 40,000 customers at:

- 1 percent for 2008 through 2010
- 3 percent for 2011 through 2014
- 6 percent for 2015 through 2019
- 10 percent for 2020 and after.

With regard to standard compliance, the bill establishes bonuses for certain types of generation facilities. For all qualifying utilities, each kilowatt-hour of eligible electricity generated from a community-based project as defined in the bill will count as 1.5 kilowatt-hours. For RECs and municipal owned utilities, each kilowatt-hour generated from solar generation technologies that produce electricity before FY 2015-16 will count as 3 kilowatt-hours. However, utilities may take advantage of only one bonus for each kilowatt-hour of generated electricity.

For IOUs, the maximum allowable retail rate impact from meeting the standard is raised from Amendment 37's 1 percent to 2 percent of the total electric bill annually for each customer. The opt-out provision available in Amendment 37 for RECs was eliminated, and RECs are required to submit an annual report to the PUC on or before June 1 of each year. However, reports submitted by RECs are not subject to the same compliance report review process as those submitted by IOUs.

Finally, the bill allows utilities to develop and own as utility rate-based property up to 25 percent of total new eligible energy resources if these resources can be constructed at reasonable cost compared to the cost of similar eligible energy resources available on the market. If the utility shows that its proposal provides significant economic development, employment or energy security benefits, the utility is allowed to own between 25 and 50 percent of total new eligible energy resources.

The bill was co-sponsored by fifty Members of the House, ten Members of the Senate, and was supported by electric utilities across the state. It may be that Colorado's existing RES will be reviewed in the future to determine whether the standard could be increased over time. A review of the current standard could be driven by potential cost escalation of conventional fuel sources, increased resolve to address environmental constraints, transmission expansion, and other factors.

■ *"We will continue to expand the New Energy Economy, show leadership as a state, increase our energy security, and call on the federal government to take strong action."*

— Governor Bill Ritter

Colorado Clean Energy Development Authority [xxxiii]

The legislature also passed HB07-1150, which created the Colorado Clean Energy Development Authority (CEDA). CEDA is a quasi-governmental entity created to facilitate production and consumption of clean energy. Its purpose includes the objectives of increasing transmission and the use of clean energy by financing and refinancing projects located within or outside the state for production, transportation, transmission and storage of clean energy, including pipelines and related supporting infrastructure.

CEDA was created to establish partnerships with utilities, the financial community, Colorado communities, and other key stakeholders to assist with transmission financing, and other clean energy infrastructure development. Members of the CEDA are:

Joel Bladow, appointed by the Senate Minority Leader.

Don Elliman, Director of Economic Development.

Cary Kennedy, State Treasurer.

Jeff Nathanson, appointed by the Speaker of the House.

Tom Plant, Director, Governor's Energy Office.

Lola Spradley, appointed by the House Minority Leader.

John Stulp, Commissioner of Agriculture.

Sam Weaver, appointed by the President of the Senate.

Lee White, appointed by the Governor.

In addition, the legislature passed a variety of other renewable energy and energy efficiency bills. See the endnote for a comprehensive listing of 2007 Colorado Renewable Energy and Energy Efficiency Legislation.[xxxiv]

Federal Support

New federal energy legislation is pending in Congress. It includes a national RES, long term Production Tax Credit extension, and renewable energy funding. Passage depends on reconciliation of different versions in the House and Senate. The Senate Agriculture Committee has written a new Senate-passed Farm Bill that, if also passed by the House and signed by the President, would provide additional funding and support for expanding renewable energy production in the agricultural sector. One example of an existing program that would be expanded is Agriculture Department grants for farmers (Sec. 9006). These competitive grants have funded a variety of renewable energy projects.

Clean Renewable Energy Bonds (CREBs) are a new renewable energy incentive for RECs and municipal utilities created in the Energy Policy Act of 2005. As not-for-profit entities, both RECs and municipal utilities are unable to utilize production tax credits as an incentive for renewable energy development, since these organizations are not taxable, do not report income for tax, and hence have no tax liability to offset with a production tax credit. Congress created CREBs at the request of RECs as a "comparable" incentive for renewable energy generation for not-for-profit utilities. Although the production tax credit has unlimited accessibility, CREBs have limited bond authority and are geared towards smaller renewable projects. CREBs have been a success story, oversubscribed in its first year and expanded by Congress to support rural economic development, business investment, and agriculture sector production diversity interests.

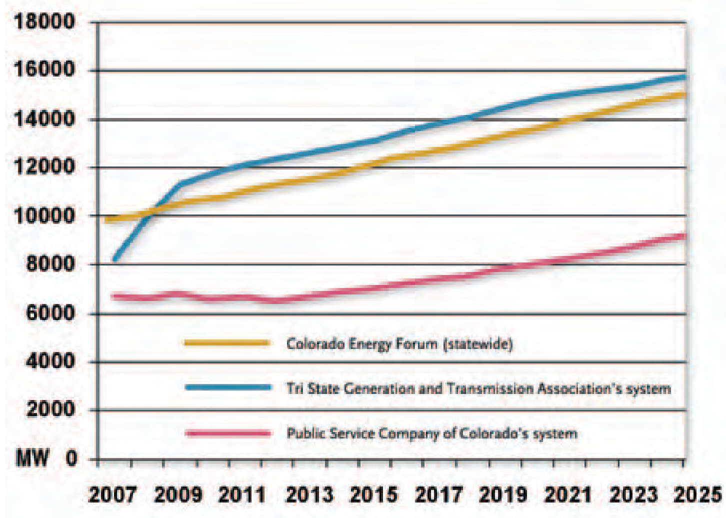
Renewable Energy and Economic Development

A major impetus for renewable energy development is the economic development activity that follows. Over the past year a number of positive results have stemmed from Colorado's encouraging renewable energy.

These include, but are not limited to:

- The world's largest wind equipment manufacturer, Vestas Wind, is building a wind blade factory in Windsor, bringing hundreds of jobs to Northern Colorado.
- One of the nation's leading solar installers, SunEdison, is in the final stages of building an 8 MW central PV power station in Alamosa, one of the largest central PV stations in North America.
- Colorado has attracted business offices of several wind plant and solar developers.
- Recent announcements concerning financing and development have been in the news, including several Colorado-based photovoltaics companies (AVA, PrimeStar, and Ascent).

The GEO and the Office of Economic Development and International Trade (OEDIT) work together to attract renew-



Colorado Electric Demand Forecasts

Summary of demand projections supplied by the Colorado Energy Forum, Public Service Company of Colorado, and Tri-State Generation and Transmission Association

able energy enterprises to the state. OEDIT promotes the creation of high quality jobs through business growth, retention and expansion programs. OEDIT Business Development services help companies relocate, expand or remain in Colorado, provide training for a company's existing and new workforce, and assists Colorado with international and domestic business development.

Renewable Energy and Colorado's Climate Action Plan [xxxv]

On November 5, 2007 Governor Ritter issued Colorado's first Climate Action Plan, which in part, calls for strengthening Colorado's dependence on renewable energy. The Governor issued an ambitious call to action that establishes firm goals and clear strategies to reduce harmful greenhouse gas emissions.

The Governor said, "I strongly believe we can make a difference. In setting and achieving the goals in this Colorado Climate Action Plan, we will continue to expand the New Energy Economy, show leadership as a state, increase our energy security, and call on the federal government to take strong action. The success of this very balanced plan depends on everyone doing their part and taking personal responsibility for our future." Specific strategies contained in the Climate Action Plan, related to this report's topic, include:

- Work collaboratively to reduce emissions from IOUs by 20% by 2020 and create reasonable goals for other utilities.
- Adopt energy-efficiency programs to reduce the demand for electrical energy.
- Expand renewable energy opportunities.
- By the end of this year, issue a climate change executive order that establishes a 20 percent greenhouse-gas emissions-reduction goal by 2020, and directs all state agencies to join a statewide effort to achieve this goal.
- Direct the Governor's Energy Office to provide bi-annual reports on the status of renewable energy development across Colorado, and suggest measures to accelerate development.
- Request the Colorado Public Utilities Commission to seek from each utility within its jurisdiction an Electric Resource Plan that will include an analysis of how the utility will reduce emissions. The order will also instruct appropriate state agencies to remove barriers and help utilities achieve these goals.

Electric Demand Forecasts

The Task Force has received demand forecasts from four different sources, and presents them for comparative purposes. The forecasts include Platte River Power Authority, the Colorado Energy Forum, Public Service Company of Colorado, and Tri-State Generation and Transmission Association. The Task Force did not specifically endorse any of these demand forecasts.

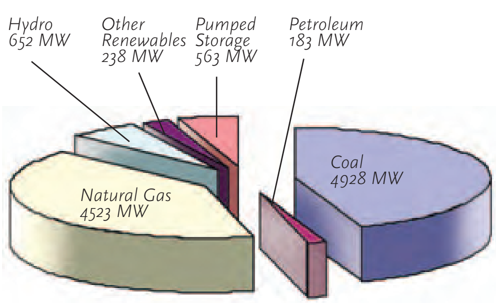
Platte River Power Authority serves Fort Collins, Longmont, Loveland and Estes Park. The predicted summer peak load growth for these cities is estimated at approximately 2.7% (about 19 MW per year) for the 2007 to 2016 period. Peak demand is estimated to grow from 636 MW to about 800 MW during this period. Winter season peak demand is estimated to grow at a rate of 2.3% annually, and annual energy consumption is expected to grow at 2.2% annually for the 2007 to 2016 period.

The Colorado Energy Forum (CEF) produced a report entitled "Colorado's Electricity Future," which includes a 36 page chapter entitled "Colorado Power Market Study" prepared by R.W. Beck Consulting. "Colorado's Electricity Future" is the most comprehensive recent compilation of information on Colorado's electricity industry and includes projections of Colorado's future electricity needs.

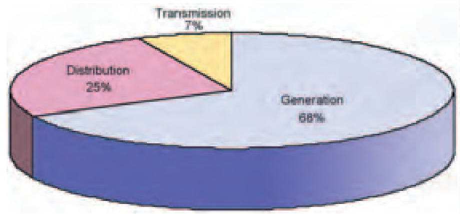
Colorado's Electricity Generation

Location and Fuel Mix of Colorado's Electric Generation Stations 3 MW and Above

Due to its size, a complete listing of power plants in Colorado has been placed in the Appendix. The source of the information is eGRID, a database developed by the Environmental Protection Agency, characterizing U.S. electric power generation.[xxxvi] All Colorado electric generating stations are listed in a chart that shows plant name, company ownership, MW size, status of operation, year placed in service, and fuel type. Additional information regarding Colorado generation is available at the PUC.[xxxvii]



Colorado Generation Resource Mix
(Source: DOE 2006)

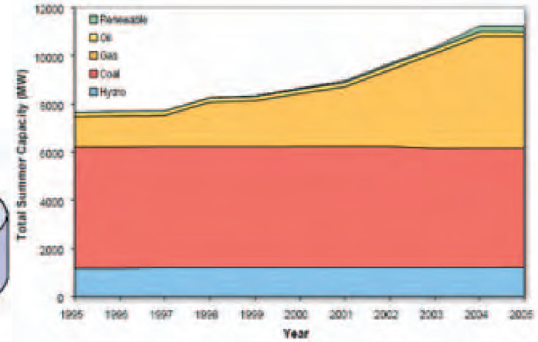


National Average Cost of Electricity Breakdown
(Source: EIA Annual Energy Outlook 2007)

Electric Generation Costs

Generation costs vary among different generating resources, locations, and stage of technology development. In the case of fossil fueled generation, costs are largely influenced by the price for fuel used to generate electricity. Such costs are also influenced by installed costs of generation facilities, as well as efficiency and utilization of those facilities. Recent Western U.S. public stakeholder venues have developed consensus projections of levelized all-in costs for different electricity generation technologies. There is an expectation that renewable energy technology will improve and that costs will decline over the next decade for different renewable generation technologies, particularly for central solar power. See the Appendix for details on this topic.

The key point of this cost breakdown is that the cost of transmission is less than ten percent of the total cost of the delivered cost of electricity.



Colorado Electric Fuel Mix Forecast
(Source: Colorado Energy Forum)

Results from the Colorado Energy Forum

The Colorado Energy Forum (CEF) has recently produced Colorado-specific source material. The CEF, a non-profit organization funded by utilities, recently commissioned and published four reports that provide an overview of the history, current status, and future of Colorado's electricity industry.[xxxviii] These reports, listed below, coupled with data compiled by the Energy Information Administration at the DOE, comprise current sources of information regarding the Colorado electricity industry:

- The Basics of Electricity in Colorado.
- Colorado's Electricity Future.
- More Transmission Needed.
- Colorado's Renewable Energy Standard.

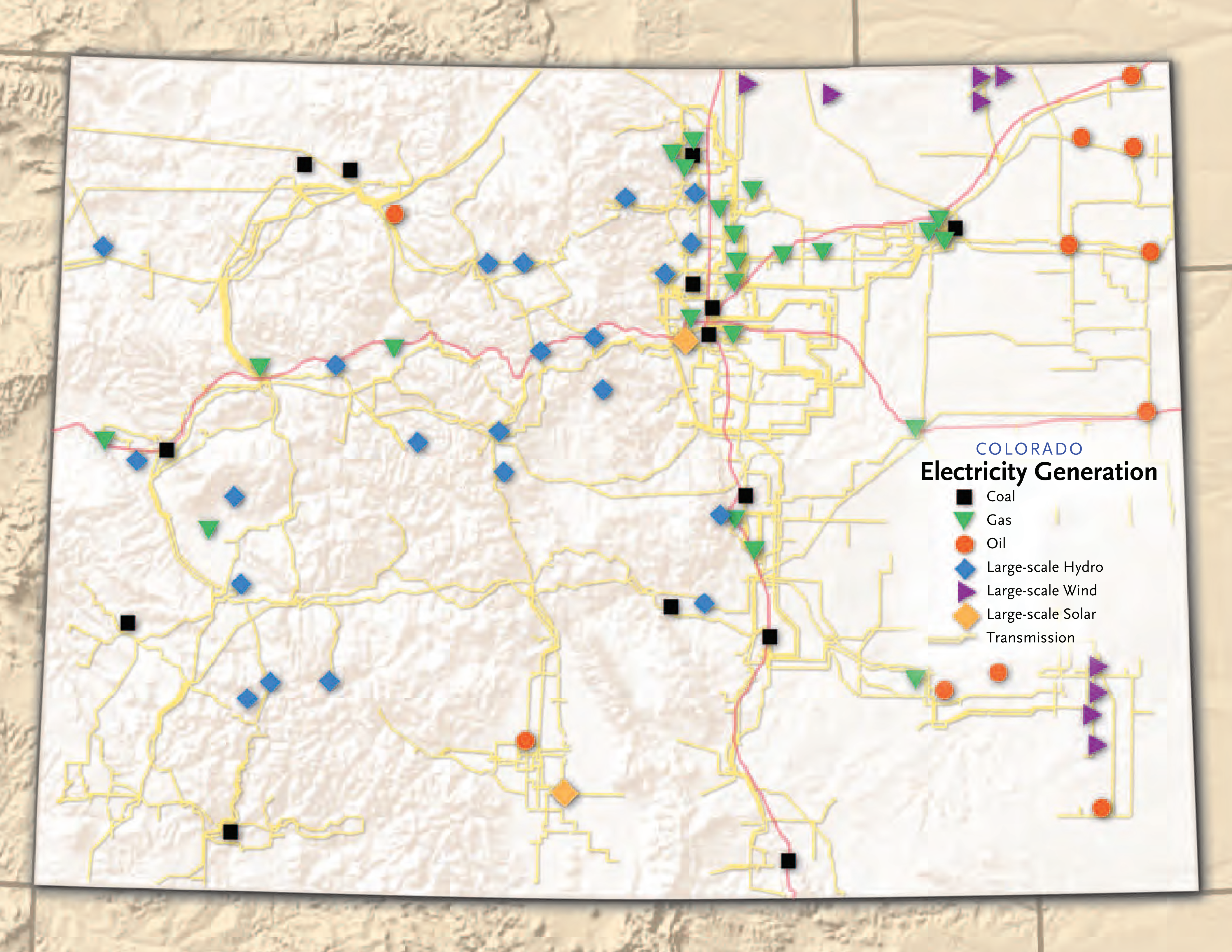
Some major conclusions from the CEF and DOE reports are as follows:

Growth in Demand: Colorado will need 4,900 MW of new generation resources by 2025, tempered by the success of energy conservation measures. This will require a mix of resources.

Renewables: About 3,300 MW of wind and 200 MW of solar must be developed to meet Colorado's minimum RES requirements by 2025. While some renewable additions will meet load growth, an additional 3,700 MW to 4,500 MW of additional generating resources (including conventional, additional renewable supplies, efficiency, and conservation) will be needed to serve Colorado's load by 2025.

Resource Mix: Colorado's generation resource mix has shifted over the past decade from a coal-dominated mix to one in which natural gas generating capacity is nearly equivalent that of coal-fired generation, with renewables (excluding hydro) growing rapidly, but less than 10%.

Transmission: Colorado has a number of "very limited connections" in its transmission system, particularly as it relates to serving new generation resources in Wyoming and Eastern Colorado to meet load growth. Both new transmission lines and upgrades of existing lines will be required to meet load growth, access remote resources including wind and solar, and increase reliability, at a cost approaching $2 billion.


COLORADO
Electricity Generation
Coal
Gas
Oil
Large-scale Hydro
Large-scale Wind
Large-scale Solar
Transmission

Summarizing the Electricity Market for Colorado's Renewable Resource Development

■ *Most of the capacity on each transmission path has been fully-subscribed. There is insufficient capacity to accommodate the addition of new generating resources.*

To determine the best course of action, it is important to recognize the complex context for utility-scale renewable energy development in Colorado. The following summarizes some of the key points, explained in greater detail in the Appendix:

Colorado is located on the eastern edge of the western power system known as the Western Interconnection (WI). In 2005 the installed electrical generating capacity for the WI was 156 GW, of which 7% was located in the Rocky Mountain Power Area, which includes Colorado and Wyoming. The WI is one of the four electrical interconnection regions into which the North American Electric Reliability Corporation has divided the United States, Canada, and parts of Mexico.[xxxix] The electrical differences and miniscule linkages between these four regions effectively restrict markets for power to within each region. All Colorado electric utilities are subject to oversight by the Western Electric Coordinating Council,[xl] one of eight regional reliability councils established to improve the reliability of the bulk power system.

The transmission capacity between the WECC control areas that manage the distribution of bulk power transfers is limited by the voltage of the interconnecting transmission lines and the extent to which they interact and are impacted by transmission lines between other control areas. Since minimal new transmission capacity has been added in WECC in the past decade, most of the capacity on each transmission path has been fully-subscribed and as such, there is insufficient capacity to accommodate the addition of new generating resources. The transmission capacity between the two Colorado control areas and adjoining control areas is severely limited by line voltages, capacity commitments, and by the lack of interconnections to other control areas. In effect, Colorado is largely an island in the WECC transmission grid.

The renewable component of the electrical generating capacity mix has increased by 1,075 MW (a 110% increase) for the five-state area since 2005 based on information compiled by the Interwest Energy Alliance. The vast majority of the increase occurred in the wind sector of the renewable energy industry, with by far the largest gains made by Colorado which has enjoyed a four-fold increase in installed renewable generation capacity since 2005.

Colorado's average price of electricity in July 2007 was 7.54¢ per kilowatt hour (i.e., $75.40/MWh) as compared to a national average of 9.49¢ per kilowatt hour and a Pacific Coast average of 12.51¢ per kilowatt hour. This is due largely to the proximity to low-cost generating resources within Colorado and Wyoming.

Since renewables, particularly wind resources, are generally not considered as "dispatchable" generation resources (i.e., they, for the most part, cannot be dispatched on demand and must be used when they are available), they do not fit easily into the traditional categories. Concentrated solar thermal power may be an exception to this.

Notwithstanding the foregoing, wind generation has very low marginal costs which move them forward in the dispatch sequence and as such, they are positioned to be dispatched before fossil generation resources, thereby assuring their full use in the dispatch process to the extent that they can be integrated into the balance of the system, given their variability. With the advent of RES requirements, the application of renewable subsidies in the form of Production Tax Credits (PTCs), competitive economics (in the case of some wind resources), and continued advances in renewable generation technology, renewables will increase their role in the dispatch sequence which, in some instances, will cause the displacement of dispatchable resources, particularly gas-fired resources which have high marginal costs.

In the event that carbon taxes are ultimately applied to fossil generation sources, coal and gas, that will add to their marginal costs setting the stage for large-scale penetrations of renewables into the dispatch sequence. As such, there is a future scenario where substantial amounts of renewables will be dispatched ahead of fossil resources in order to meet load – a radical departure from the traditional approach to dispatching generating resources. This will impose a wide range of operational challenges on utility system and dispatch operators to integrate the two classes of resources, particularly given the additional generation variability and predictability of renewables.

■ *Colorado's ability to ensure continued affordable, reliable electricity and to build a vibrant economy depends on sufficient transmission capability.*

Colorado Transmission

2006 Transmission Task Force

In 2006 the Colorado General Assembly passed HB06-1325, which created the Transmission Task Force. The Task Force was charged with analyzing transmission in Colorado and make recommendations to the General Assembly meant to improve transmission development. The Task Force met in the summer and fall of 2006, and reported their findings to the General Assembly in November 2006. One recommendation suggested during the Task Force meetings was a policy establishing renewable energy resource zones and requiring utilities to construct transmission to those zones.

The Executive Summary states: "The subject matter of electric transmission infrastructure is complex and highly technical. In addition, Colorado's ability to ensure continued affordable, reliable electricity and to build a vibrant economy depends on sufficient transmission capability. Today the system is strained and, if current trends continue, there will not be adequate transmission to meet the needs. The Task Force concurs that action needs to be taken at a multitude of levels including changes in policy, legislation, and in the electric utility industry's relationship with state and local government. After Task Force deliberations and consideration the following recommendations were forwarded to the Governor and the General Assembly:

Transmission Cost Recovery Rider. The Task Force recommends that a Transmission Cost Recovery Rider be established to provide a mechanism for an annual automatic adjustment of Construction Work in Progress (CWIP) charges for an electric utility to recover the investments in and expenses related to eligible new transmission facilities. Follow up: this led directly to the passage of SB07-100, described later in this report.

Identify Renewable Generation Resource Development Areas. In order to develop economic, safe, reliable, and low-cost renewable generated electric power for consumers, the Task Force recommends that the State identify renewable generation resource development areas that have potential to support competition among renewable energy developers for development of renewable resource generation projects. Follow up: this recommendation led directly to the passage of SB07-091.

Governmental involvement with organizations like the Colorado Coordinated Planning Group. The Task Force supports increased communication to local government officials on the electric transmission activities. Therefore, the Task Force supports municipal and county government involvement with organizations like the Colorado Coordinated Planning Group (CCPG) to focus on transmission activities throughout the state.

Appropriate adequate funding for PUC to actively participate in regional electricity transmission planning, reliability and regulatory forums. The Task Force recognizes that transmission is a regional reliability issue. Therefore, the Task Force recommends that as a matter of state policy the Colorado State Legislature appropriate adequate funding for the PUC to actively participate in regional electricity transmission planning, reliability and regulatory forums." The PUC has increased its participation in regional planning meetings, as has the GEO.

Senate Bill 07-100- Identifying Resource Zones and Transmission Needs

As part of broad based efforts to diversify Colorado generation portfolios, SB07-100 was also enacted in 2007, signed by Governor Ritter at the same time that he signed HB07-1281 that doubled the RES. The new law requires IOUs to map energy resource zones to identify opportunities for bringing renewable energy resources to markets. The law also provides IOUs with economic incentives they requested to expand their transmission investments, as this will be required to meet the larger RES goals. Diversity provides risk mitigation for consumers by spreading reliance for electric supplies among more types of generators, different owners and managers, diverse locations and technologies, and fuel resources. Shortfalls in the adequacy of service to bring cost effective resources to the markets also provided a basis for the new legislation.

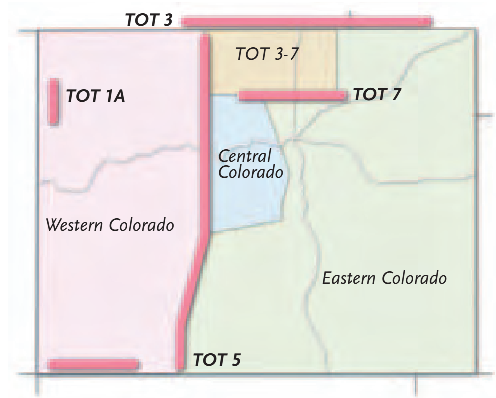
The law requires IOUs to identify transmission-constrained "energy resource zones" in filings to the PUC every odd numbered year. These filings must outline how utilities plan to address their transmission constraints, and the PUC then has 180 days in which to review and rule on the utilities' plans. Once plans are approved, the IOUs may apply for current cost recovery for prudent transmission investments. Aquila Colorado[xli] and Public Service Company of Colorado (PSCo)[xlii] filed their SB07-100 transmission plans with the PUC on October 31, 2007. The filings are posted on the Rocky Mountain Area Office website.[xliii]

Future Transmission Plans

See page 58 in the Appendix for more information on these proposed transmission expansion plans

Transmission Constraints

Power flows within Colorado and to adjoining states are measured at key points know as TOTs: a shorthand reference to the total of the power flows across the lines which comprise a given transmission path. The maximum power flows for each of the five TOT affecting Colorado summarized in the table that follows. The three paths that connect to adjoining states are ranked among the top 15 most constrained paths of the 79 transmission paths in WECC, while the two in-state paths are less constrained. These constraints limit the extent to which Colorado can take advantage of resources from adjoining states and its ability to participate in regional import/export markets.



Colorado Transmission Constraints
(Source: CEF)

Colorado's Major Transmission Paths

Path Name	1A	2A	3	5	7
WECC Path No.	30	31	36	39	40
Capacity (MW)	650	690	1,605	1,675	890
Flow Direction	E-to-W	N-to-S	N-to-S	W-to-E	N-to-S
Usage	Export	Export	Import	In-State	In-State
No. of Lines	3	3	6	10	3
WECC Constraint Rank	5	15	6	NA	NA

SB07-091 Task Force Report
“Connecting Colorado’s Renewable Resources to the Market”
Errata Sheet

Critical features on four figures in the report were inadvertently omitted and should be replaced with the following versions:

Colorado Transmission Constraints (Page 36)

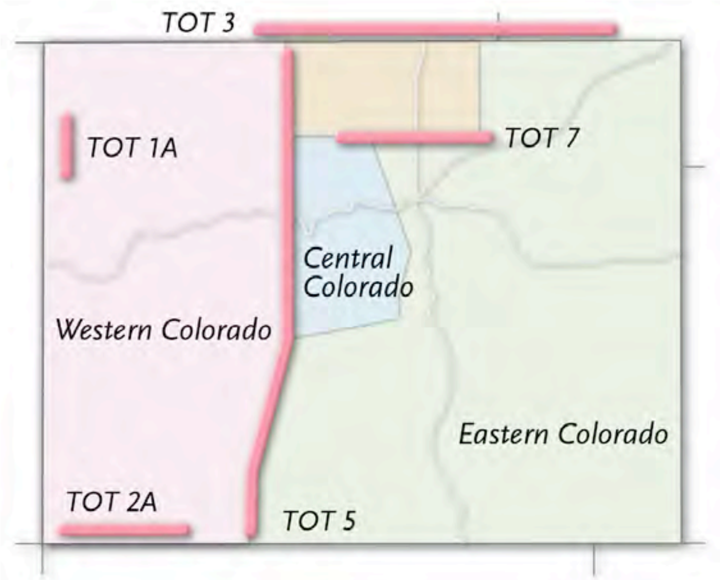


Figure 2-8: Daily (by Hour) and Annual (by Month) Load Profiles (Page 49)

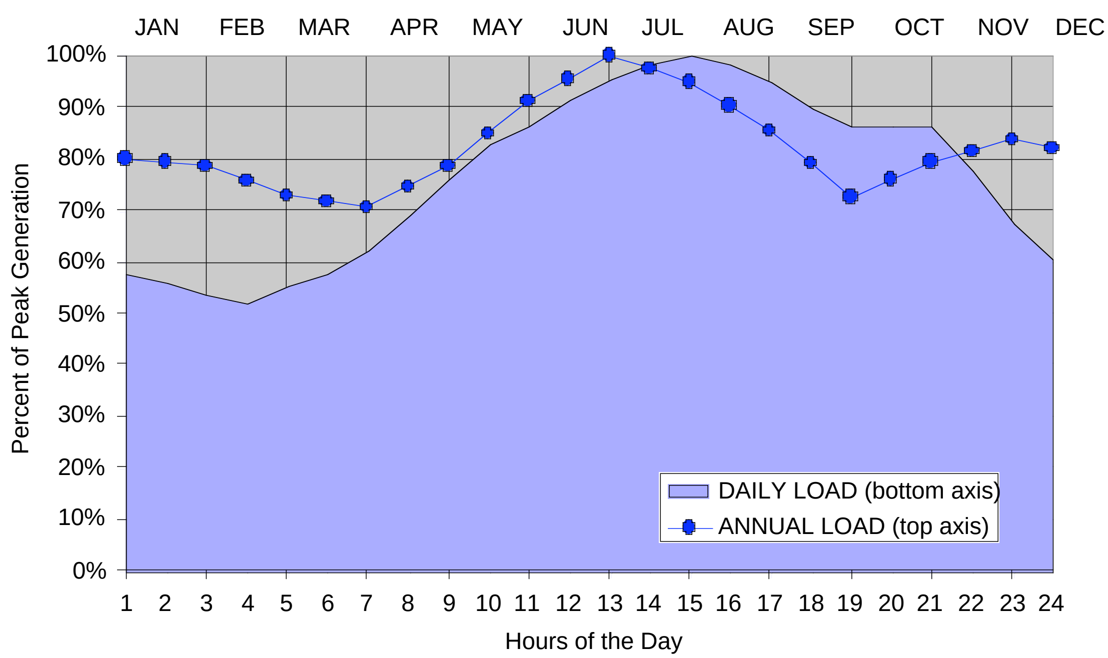


Figure 2-13: All-in Generation Costs - $2006 (Page 56)

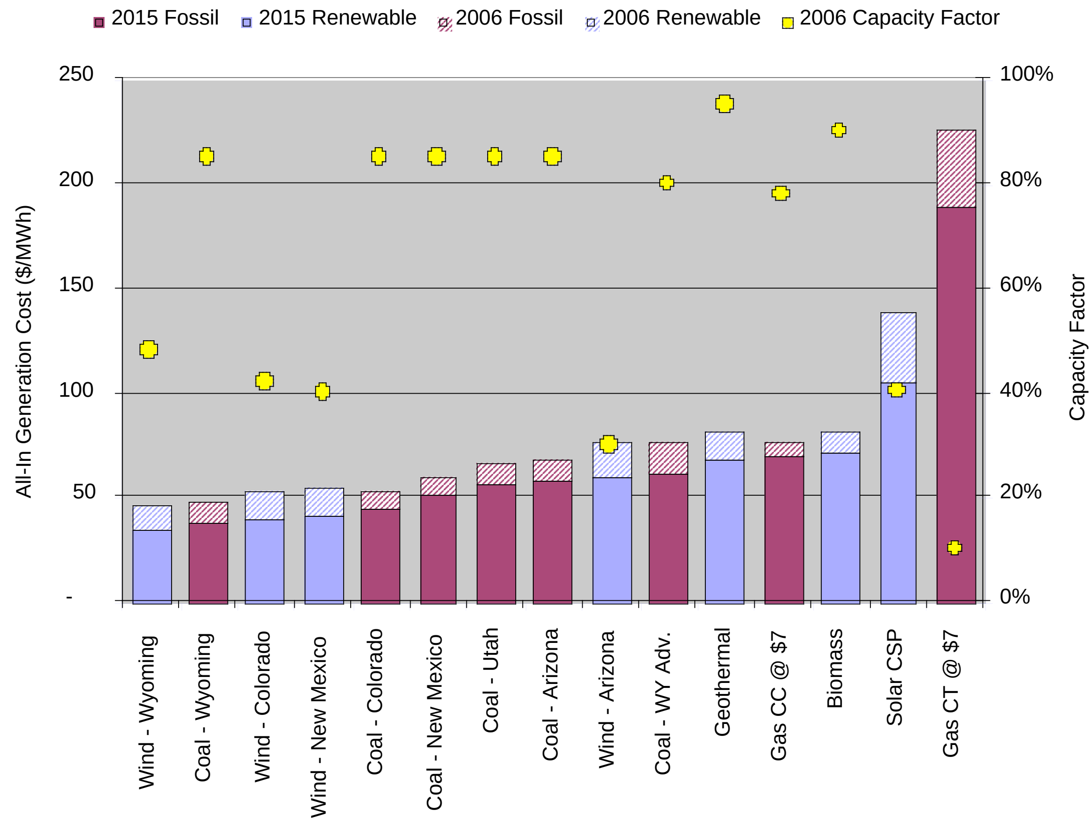
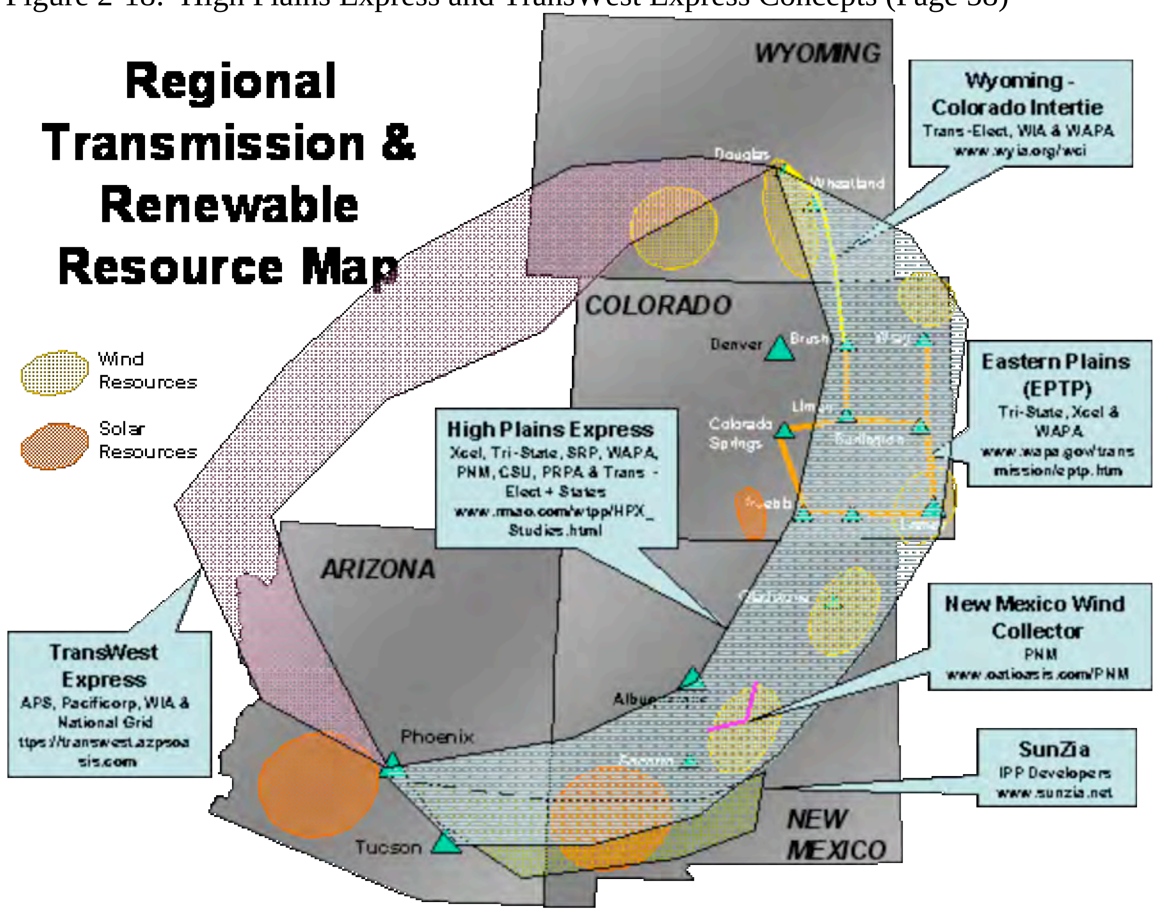


Figure 2-18: High Plains Express and TransWest Express Concepts (Page 58)



Colorado's Electric Utility Industry

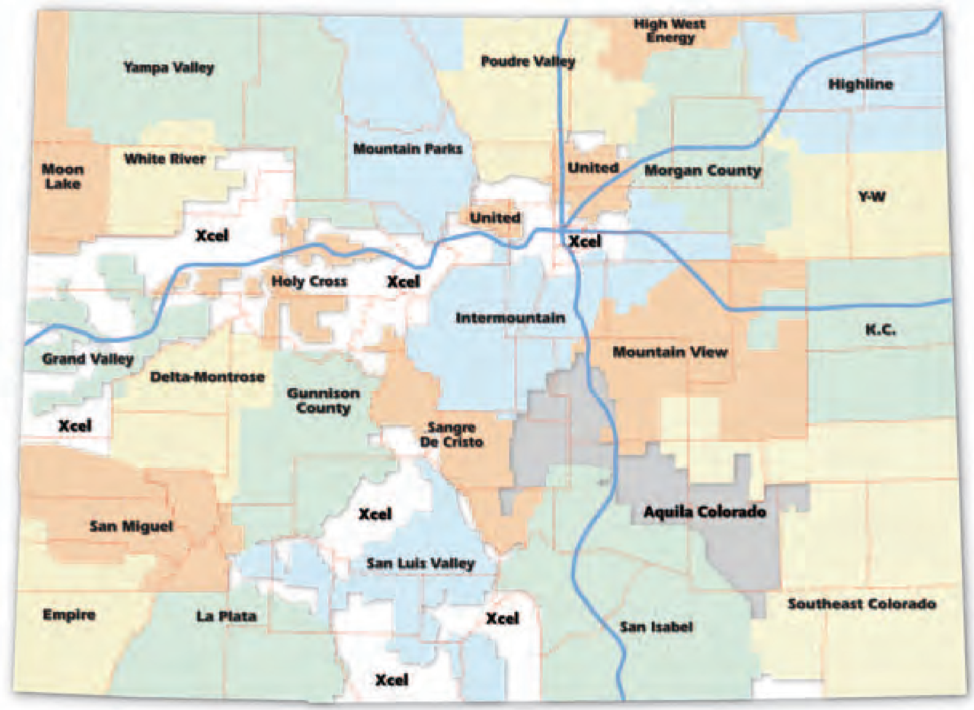
The Colorado Energy Forum characterizes the state's electric utility industry as follows:

"Depending on where they live, Colorado retail customers buy electricity from either an IOU (like Xcel Energy's Public Service Company of Colorado), a rural electric cooperative (like Intermountain REA) or a municipal utility (like Colorado Springs Utilities).

In addition to these three types of electric utilities, which sell electricity directly to retail customers, there are other entities that only generate, transmit and sell power, at the wholesale level, to other utilities, but that do not sell directly to retail customers. These include consumer-owned generation and transmission associations, municipal power agencies, the Western Area Power Administration (WAPA) and non-utility generators. Tri-State Generation and Transmission Association is the only consumer-owned generation and transmission association operating in Colorado. It is a wholesale power supplier owned by 44 RECs in four states.

Two municipal power agencies in Colorado (Platte River Power Authority and Arkansas River Power Authority) provide generation and transmission services to their respective municipal utility members. They are governed by boards of directors appointed by the member municipalities.

Colorado Electric Service Territories



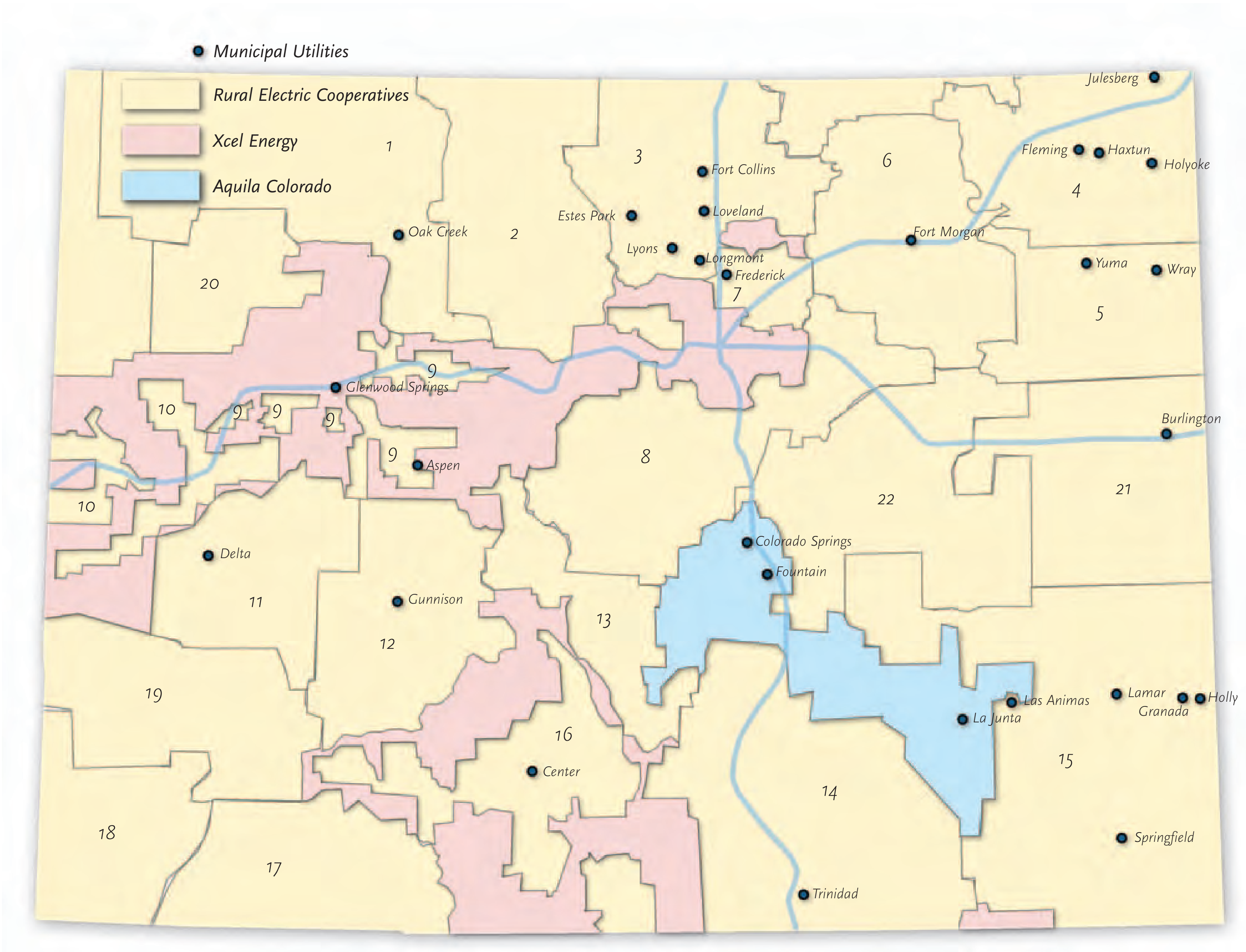
WAPA is one of four federal power marketing agencies that sell power and transmission services to a wide variety of wholesale customers. WAPA serves in 15 Western states over a 1.3 million square mile area, including municipal utilities and RECs in Colorado. WAPA is not subject to the jurisdiction of either state or federal regulators.

The category of non-utility generators includes independent power producers, exempt wholesale generators and qualifying facilities (usually cogeneration arrangements). In general, non-utility generators are not subject to state or federal regulation.

In one way or another, all of the distribution utilities are regulated in Colorado. The two IOUs in Colorado are regulated as monopolies by the PUC and serve the majority of the customers in the state. There are 29 municipal electric systems in Colorado that are regulated by their governing boards. Additionally, there are 22 rural electric distribution cooperatives serving wholly in Colorado (18 of which purchase their power from Tri-State G&T and four that purchase power from Xcel Energy and WAPA). These distribution cooperatives are regulated by their member boards."

Renewable Energy, Energy Efficiency, and Net Metering Programs

Net metering and incentives for customers who install renewable energy generation to their premises provide important incentives. The map represents service territories for RECs, municipal electric utilities, and IOUs in Colorado. The following chart displays preliminary information regarding renewable energy and energy-efficiency policies reported by Colorado's utilities, as of December 2007. "No response" indicates that the utility did not respond to GEO's information request. Modification of this preliminary information is in progress.

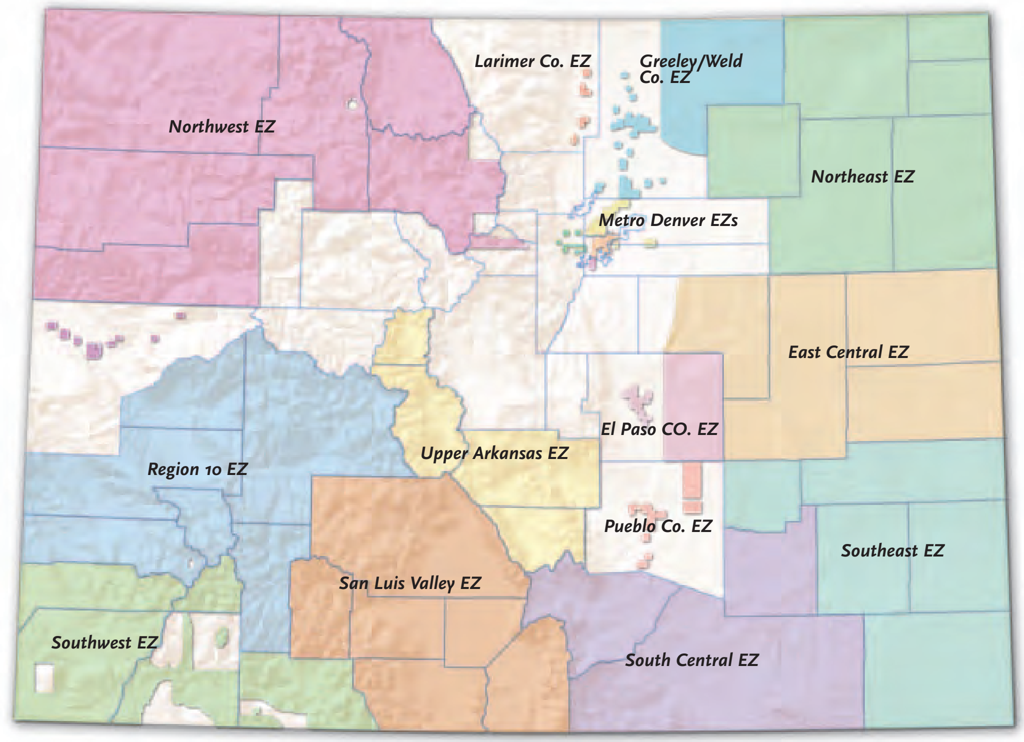


Map#	Utility	Renewable Energy and Energy Efficiency Program(s) Reported	Net Metering Program(s) Reported
	Aquila Colorado	$4.50 PV rebate for customers $2.50 REC purchase for non-customers within service territory	<10 kW limit = single meter, >10 kW limit = dual meter compensated at avoided cost, annual reconciliation; 20 customers
	Aspen Municipal Electric	75% RE in base rate; residential and commercial EE	6 kW limit, single meter, compensated at retail, annual: 2 customers
	Burlington Municipal Light and Power	No response	No response
	Center Municipal Gas, Light and Power	None offered	None offered
	Colorado Springs Utilities	Multiple RE and EE incentives	10 kW limit for residential, 25 kW limit for commercial; single meter, annual reconciliation; 23 customers
	Delta Municipal Light and Power	None offered	None offered
11	Delta-Montrose Electric Association	Multiple RE and EE incentives	25 kW limit, single meter, perpetual credit system; 30 customers
18	Empire Electric Association, Inc.	http://eea.coop/services1.html Multiple RE and EE incentives	10 kW limit, single meter, annual reconciliation, pays at average wholesale; 7 customers
	Estes Park Light and Power Department	None offered	None offered
	Fleming Electric Light Department	None offered	None offered
	Fort Collins Utilities	http://www.fcgov.com/utilities/green-power.php and 1% surcharge to all customers for RE purchases	25 kW limit, single meter, pays at retail, annual reconciliation; 13 customers (25 max in pilot program)
	Ft. Morgan Electric Light Department	None offered	None offered
	Fountain Department of Utilities	4% RE in rate base, Net Metering Tariff	10kW limit, single dual register, avoided, monthly, 1 customer
	Frederick Municipal Light System	see United Power	see United Power
	Glenwood Springs Electric System	None offered	25 kW limit, single meter on single, dual on 3-phase, perpetual credit; 5 customers.
	Granada Utilities	No response	No response
10	Grand Valley Rural Power Lines, Inc.	TOU rates, wind power blocks, net metering	25 kW limit, single meter, pays at retail, annual reconciliation; 7 customers.

Map#	Utility	Renewable Energy and Energy Efficiency Program(s) Reported	Net Metering Program(s) Reported
	City of Gunnison Public Works	No response	No response
12	Gunnison County Electric Association, Inc.	www.gcea.coop/Member_Information/ Multiple RE and EE incentives	Pilot project, 10 kW limit, annual reconciliation, pays at average wholesale; 16 customers.
	Town of Haxtun Electric	None offered	None offered
4	Highline Electric Association	www.hea.coop Multiple RE and EE incentives	25 kW limit, single meter, variable carryover & payment; 2 customers.
	Holly Light and Power	None offered	None offered
9	Holy Cross Energy	No response	No response
	Holyoke Municipal Light and Power	No response	No response
8	Intermountain Rural Electric Association	No response	No response
	Julesburg Municipal Electric	None offered	None offered
21	KC Electric Association	Multiple RE and EE incentives	14.4/24.9, single meter, pays at avoided cost; 0 customers
	La Junta Municipal Utilities	EE audit program, no RE	None offered
17	La Plata Electric Association, Inc.	Multiple RE and EE incentives	25 kW limit, single, Carryover, avoided cost - 37 customers
	Lamar Light and Power	Residential and commercial EE, no RE	None offered
	Las Animas Municipal Light and Power	None offered	None offered
	Longmont Power and Communications	www.ci.longmont.co.us/lpc	50 kW limit, single meter, annual reconciliation, pays at retail; 0 customers
	City of Loveland Power Operations	http://www.ci.loveland.co.us/wp/power/Conservation/main.htm	None offered
	Lyons Municipal Light and Power Dept.	No response	No response
6	Morgan County Rural Electric Association	Multiple RE and EE incentives	No response
2	Mountain Parks Electric Association	Multiple RE and EE incentives TOU, industrial peak shaving	25 kW limit, single meter dual register, annual reconciliation, pays at avoided cost; 2 customers.
22	Mountain View Electric Association	Multiple RE and EE incentives	Single meter; pays at wholesale rate

Map#	Utility	Renewable Energy and Energy Efficiency Program(s) Reported	Net Metering Program(s) Reported
	Oak Creek Municipal Utilities	No response	None offered
3	Poudre Valley Rural Electric Association, Inc.	Multiple RE and EE incentives	10 kW limit residential, 25 kW limit net billing, annual, wholesale; 13 customers
14	San Isabel Electric Association, Inc.	Multiple RE and EE incentives	No response
16	San Luis Valley Rural Electric Cooperative, Inc.	Multiple RE and EE incentives	25 kW limit, single meter, annual reconciliation, pays at avoided cost; 4 customers
19	San Miguel Power Association, Inc.	Multiple RE and EE incentives	25kW limit, single dual register meter, retail paid for generation below total consumption, annual average cost of power paid for excess power generated.
13	Sangre De Cristo Electric Association, Inc.15	Multiple RE and EE incentives	No response
	Southeast Colorado Power Association	Multiple RE and EE incentives	Yes, but detail not provided
	Springfield Municipal Utilities	None offered	None offered
	Trinidad Municipal Power and Light	None offered	None offered
7	United Power, Inc.	www.unitedpower.com Multiple RE and EE incentives	25 kW limit, single meter, annual reconciliation, paid at average wholesale; 12 customers
20	White River Electric Association	Multiple RE and EE incentives	25 kW limit, single & dual meters, annual reconciliation, paid at average wholesale; 0 customers
	City of Wray	None offered	None offered
	Xcel Energy	Multiple EE and RE incentives	Multiple programs for various size systems. See: http://www.xcelenergy.com/XLWEB/CDA/0,3080,1-1-2_735_25709-23075-2_171_282-0,00.html
1	Yampa Valley Electric Association		25kW, single dual register meter, retail paid for generation below total consumption, annual average cost of power paid for excess power generated.
	Yuma Municipal Light Department	No response	None offered
5	Y-W Electric Association, Inc.	Multiple RE and EE incentives	25 kW limit, dual meters, annual reconciliation, paid at actual wholesale; 0 customers

Enterprise Zones



Senate Bill 07-091 specifically references Enterprise Zones. The Task Force offers the following information on this topic:

Enterprise zones (EZ) in Colorado offer a variety of tax incentives to businesses for qualifying activities, including state tax credits for new employees and investment. Manufacturing equipment used both within and outside an EZ qualifies for a statewide exemption from state sales and use tax. However, the exemption is broader when such equipment is used solely and exclusively in an EZ. While the majority of incentives offered in EZ may be applicable to the renewable energy industry, nothing specifically designed to promote the renewables in these regions currently exists.

The Colorado Economic Development Commission has the authority to designate or terminate areas as EZ. In order to be considered for EZ status, an area must meet at least one of the following three criteria:

- Unemployment rate at least 25 percent above the state average; or
- Per capita income less than 75 percent of the state average; or
- Population growth less than 25 percent of the state average.

In addition, the total population residing within an enterprise zone boundary cannot exceed 80,000 people in urban or 100,000 in rural EZ.

Each year, the Office of Economic Development and International Trade and the Department of Local Affairs create an annual report that summarizes documentation provided by the individual EZ concerning their efforts to achieve their respective economic development objectives. According to the most recent report (2006), most zones reported that the EZ program was an important tool in bringing economic development to their regions. During fiscal year 2006, 5,032 businesses certified one or more potential EZ tax credits. These businesses created 6,400 new jobs and retained more than 122,650 jobs. When compared to the statewide average, employment in rural EZ counties has been growing at a healthy pace. Additionally, since 2002 unemployment in rural EZ counties has been below the state average and the urban EZ county average. Overall, EZ tax credits claimed with the Department of Revenue in 2006 totaled $33.9 million.

Colorado Demographic Data

The following information provides baseline statistics. According to the most recent census data, the population of Colorado is 4,301,261. The state population has increased at a rate of 10% since 2000; 4.1% faster than national population growth. The average Colorado household contains 2.52 individuals. Median household income is $52,015, while median individual income is $27,750. 12% of the population is below the poverty line. There are 2,095,235 housing units in Colorado. 68.7% are owner occupied. There is an 11.8% vacancy rate. The median value of an owner occupied unit Colorado is $232,900. Median rent ranges from $500 - $749. 60.2% of the housing stock was built before 1980. 74.9% of the housing stock uses utility gas for heating purposes, 16.1% uses electricity for heating.

According to the U.S. Census 86.9% of the population has achieved a high school degree or higher, and 32.7% have a bachelors degree or higher. Colorado ranks fourth in the nation in attainment of higher education. 70% of residents 16 and older are in the labor force. The state unemployment rate in 2006 was 3%; however, this varies widely across the state, with many rural communities experiencing higher rates of unemployment. The education, health, and social services sector is the largest employer in the state, accounting for 17% of the work force. 11.8% work in retail, and 11.7% work in professional, scientific, management, administrative, and waste management services. Other statistical details for Colorado can be found at the Colorado Department of Local Affairs at www.dola.state.co.us.

Conclusion

As quantified in this report's maps and narrative, Colorado has abundant renewable resources that can provide increased opportunities to improve the state's energy, economic, and environmental condition. The state has moved quickly over the past few years to expand the penetration of renewable energy into Colorado's electric power marketplace. Colorado will continue to benefit by adding more renewable energy and expanding its limited transmission infrastructure to serve its population and what may evolve as a regional electric power marketplace.

The Task Force identifies a key challenge — the expansion of high voltage transmission to the areas of Colorado that have significant renewable potential. The Task Force report demonstrates that Colorado's existing transmission system has very limited capability to connect our substantial renewable resources to the market. The resolution of these constraints will strengthen and improve Colorado's electric infrastructure and citizens. We commit to work together on these common objectives so that Colorado will achieve the objectives of the New Energy Economy.

Acknowledgements

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American Wind Energy Association
Colorado Association of Municipal Utilities
Colorado Counties, Inc.
Colorado Department of Local Affairs
Colorado Energy Forum
Colorado Geological Survey
Colorado Governor's Energy Office
Colorado Municipal League
Colorado Office of Economic Development and International Trade
Colorado Public Utilities Commission
Colorado Renewable Energy Society
Delta Montrose Electric Association
Governor's Energy Office
Independent Bankers of Colorado
Interwest Energy Alliance
National Renewable Energy Laboratory
Platte River Power Authority
Rocky Mountain Farmers Union
SunEdison
Trans-Elect Development Company LLC
Tri-State Generation and Transmission Association
Western Resource Advocates
Xcel Energy

Dave Skiles, GEO geographic information system contractor
John Boak, graphic design, www.boakart.com

Questions, corrections, or comments: morey.wolfson@state.co.us

Endnotes

i — http://www.colorado.gov/energy/utilities/sb91-taskforce.asp
ii — PUC Resource Planning Rules at 4 CCR723-3
iii — http://www.nrel.gov/gis/maps.html#resource_atlas
iv — http://www.eere.energy.gov/windandhydro/windpoweringamerica/maps_template.asp?stateab=co
v — http://www1.eere.energy.gov/windandhydro/wind_research.html
vi — http://www.interwest.org/projects/default.aspx
vii — http://www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/workshops/2006_summit/wind.pdf
viii — http://www.c-bed.org/
ix — http://www.eere.energy.gov/windandhydro/windpoweringamerica/filter_detail.asp?itemid=617
x — http://www.westgov.org/wga/initiatives/cdeac/index.htm
xi — www.iso-rto.org
xii — http://www.uwig.org/opimpactsdocs.html
xiii — http://www.nrel.gov/learning/re_photovoltaics.html
xiv — http://www.solaralliance.org/fourpillars.html#utility#utility
xv — http://www.xcelenergy.com/XLWEB/CDA/0,3080,1-1-1_41994_42118_45645-27104-0_0_0-0,00.html
xvi — http://www.xcelenergy.com/XLWEB/CDA/0,3080,1-1-1_41994_45385-42116-0_0_0-0,00.html
xvii — htp://www.epa.gov/cleanenergy/egrid/
www.small-hydro.com www.eren.doe.gov/repis
http://www.inl.gov/scienceandtechnology/energy/
http://www.nrel.gov/programs/wind_hydro.html
http://www.usbr.gov/power/
http://www.platts.com/infostore/index.php
xviii — For hydro plants in Colorado. see: www.eren.doe.gov/repis
For annual hydro production, see:
www.eia.doe.gov/cneaf/solar.renewables/page/hydroelec/hydroelec
xix — www.eia.doe.gov/cneaf/solar.renewables/page/hydroelec/hydroelec (annual hydro production)
xx — www.colorado.edu/engineering/energystorage/files
xxi — http://www.colorado.edu/engineering/energystorage/files.html
xxii — http://ceri-mines.org/renewableenergystorage.htm
xxiii — http://hydropower.id.doe.gov/prospector/index.shtml
xxiv — http://www.nrel.gov/learning/re_geo_elec_production.html
xxv — http://www.colorado.gov/energy/in/uploaded_pdf/ColoradoGeothermalDevelopmentStratPlan.pdf
xxvi — http://www.dora.state.co.us/puc/presentations/InformationMeetings/GeoThermal/GeoThermalCIM10-10-07.htm
xxvii — http://www.colorado.gov/energy/renewables/geothermal.asp and http://geosurvey.state.co.us/Default.aspx?tabid=484
xxviii — http://www.fleci.org/docs/WhereWoodWorks-Online.pdf
xxix — www.nrel.gov/analysis/repis
xxx — http://www.eere.energy.gov/afdc/fuels/ethanol_what_is.html
xxxi — http://www.eere.energy.gov/afdc/fuels/biodiesel_alternative.html
xxxii — http://www.westernresourceadvocates.org/ http://www.energyatlas.org/contents/default.asp
xxxiii — http://www.colorado.gov/energy/utilities/clean-energy-development-authority.asp
xxxiv — http://www.colorado.gov/energy/policy/index.asp#EOrders
xxxv — http://www.colorado.gov/energy/in/uploaded_pdf/ColoradoClimateActionPlan_001.pdf
xxxvi — www.epa.gov/cleanenergy/egrid/
xxxvii — http://www.dora.state.co.us/puc/energy/ColoradoElectricPowerUtilities.pdf
xxxviii — www.coloradoenergyforum.org
xxxvix — www.nerc.com
xl — www.wecc.biz
xli — Aquila Colorado PUC Docket is 07A-422E
xlii — http://www.dora.state.co.us/puc/DocketsDecisions/DocketFilings/EnergyFilings11-15-07CWMmatrix.pdf
xliii — http://www.rmao.com/wtpp/SB100.html
xliv — http://www.dola.state.co.us/

Appendix

The Electricity Context for Colorado Renewable Resource Development

Colorado renewable energy projects that produce electricity have but one market to which they can provide their product: utilities. A single buyer in a market is called a "monopsony" and if you create electricity for sale, you must sell it to a utility buyer. Accordingly, the context for renewable energy development depends on the relationship between the seller (the project developer) and the buyers (the utility).

National and Regional Electricity Industry

On a national basis, electric utilities are generally subject to oversight by the Federal Energy Regulatory Commission (FERC: www.ferc.gov) depending on the extent to which they participate in wholesale and interstate power markets or seek reciprocal status to trade in these markets with utilities that FERC regulates.

Colorado is located on the eastern edge of the Western Interconnection – one of the three very large electrically interconnected grids, each of which operates separate from the others. These are the Western, Eastern, and Texas (Electric Reliability Council of Texas) regions. In addition, the North American Electric Reliability Corporation has divided North America into reliability regions for the purpose of requiring utilities to keep the lights on. (NERC; www.nerc.com) (Figure 2-1). The electrical differences and miniscule linkages between the grid regions effectively restrict markets for power to within each region. Electrical planning, operations, and management standards within the Western Interconnection are established and administered by the Western Electric Coordinating Council (WECC; www.wecc.biz) – one of eight regional reliability councils established to improve reliability of the bulk power system. As such, all Colorado utilities (to varying degrees) are subject to NERC, FERC, and WECC oversight.

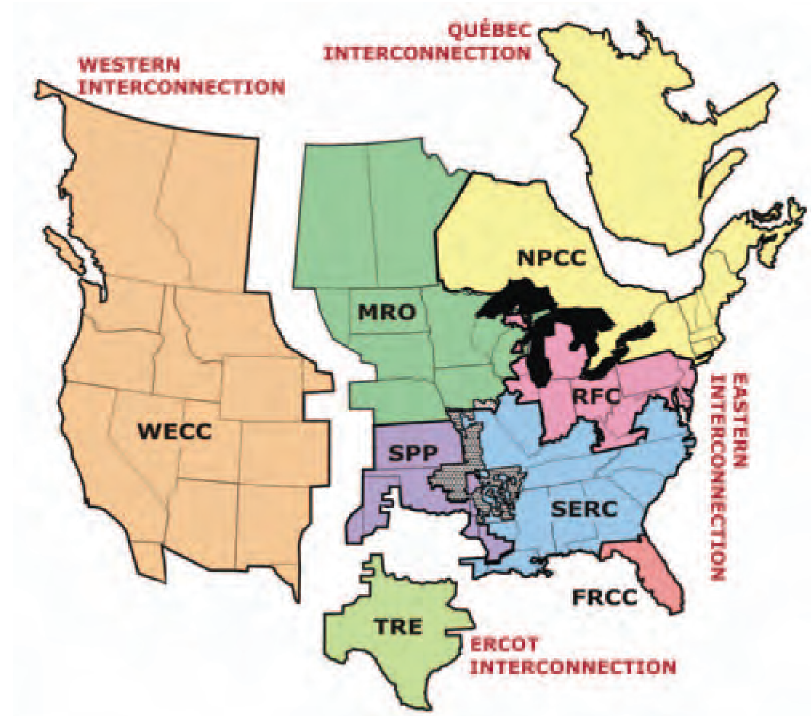


Figure 2-1: North American Electrical Interconnection Regions

(Source: NERC website)

WECC is further subdivided into sub-regions. Colorado is located within the Rocky Mountain Power Area along with eastern Wyoming – the area to which it is best connected via the regional transmission grid (Figure 2-2). In its January 1, 2006 "Summary of Estimated Loads and Resources" report, WECC summarized historical and projected peak electrical generation requirements (measured MW of capacity) and electrical energy requirements (measured in MW hours or MWh) for each WECC sub-region for 1995, 2005, and 2015. As shown in Figure 2-2, in 2005 the installed electrical generating capacity for WECC was 156,815 MW, of which 7% was located in the Rocky Mountain Power Area. Such information provides a context for evaluating Colorado's position within WECC and the region.

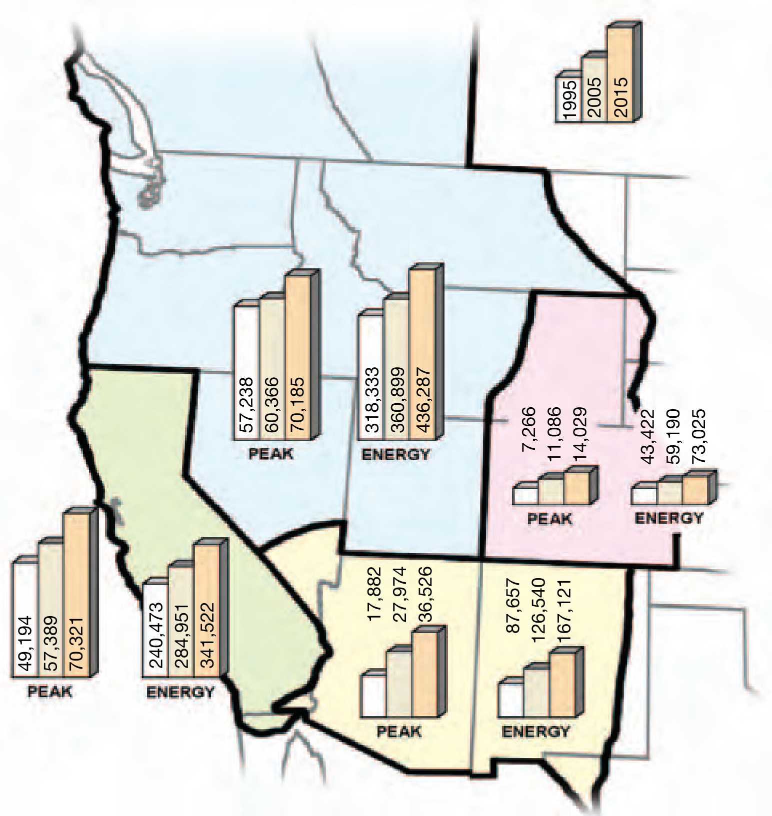


Figure 2-2: WECC Historical and Projected Electrical Capacity and Energy

(Source: WECC)

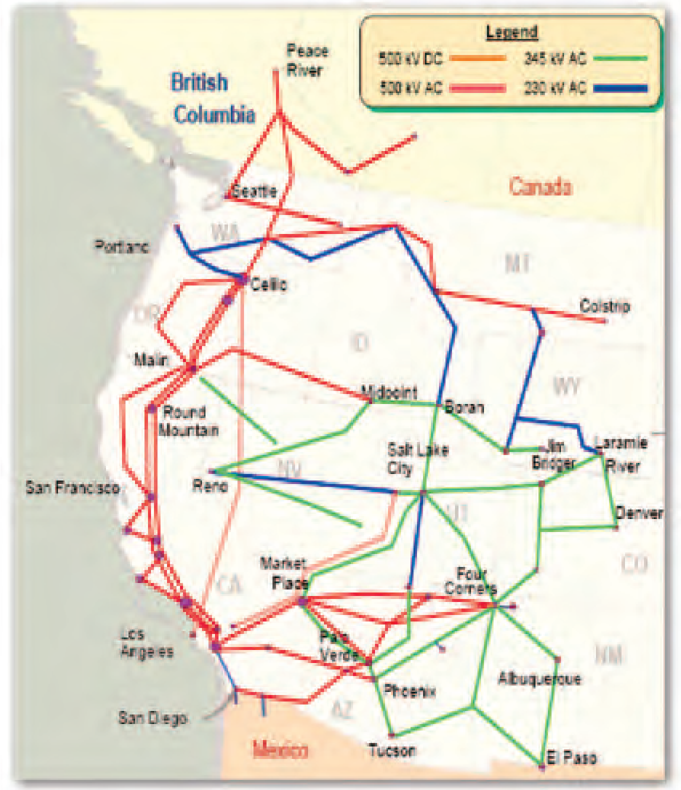


Figure 2-3: Primary Components of the WECC Transmission Grid

(Source: Rob Kondziolka, Salt River Project)

The WECC transmission grid is comprised of a network of high-voltage transmission lines that link generation (some of which is located in remote areas) to loads (generally located in urban areas). This use of this grid and its development has evolved over time from serving individual utilities to improving reliability of electric deliveries and more recently, to serve growing markets for bulk power deliveries. However, Colorado is largely isolated from markets for bulk deliveries because it is mostly electrically self sufficient and has few transmission interties with adjacent states.

Major WECC transmission lines shown on Figure 2-3 illustrate that the grid is comprised of 500 kilovolt (kV high) voltage lines over much of the West, with the exception of the easternmost part of WECC in the areas of Wyoming, Colorado, and New Mexico. This is a deficiency which has inhibited the development of regional power markets and improved reliability in those areas. Lower voltage 230 kV and 345 kV transmission lines are found throughout Rocky Mountain States (including Colorado) and underlying the 500 kV system throughout WECC, although they are not shown on Figure 2-3.

Transmission capacity between the WECC control areas that manage distribution of bulk power transfers is limited by voltages of interconnecting transmission lines and the extent to which they interact and are impacted by transmission lines between and among other control areas. Since minimal new transmission capacity has been added in WECC in the past decade, most capacity on each transmission path has been fully-subscribed and as such, there is insufficient capacity to accommodate the addition of new generating resources. As shown in Figure 2-4, transmission capacity between the two Colorado control areas and adjoining control areas is severely limited: by line voltages, capacity commitments, and by lack of interconnections to other control areas. In effect, Colorado is largely a box canyon in the WECC transmission grid.

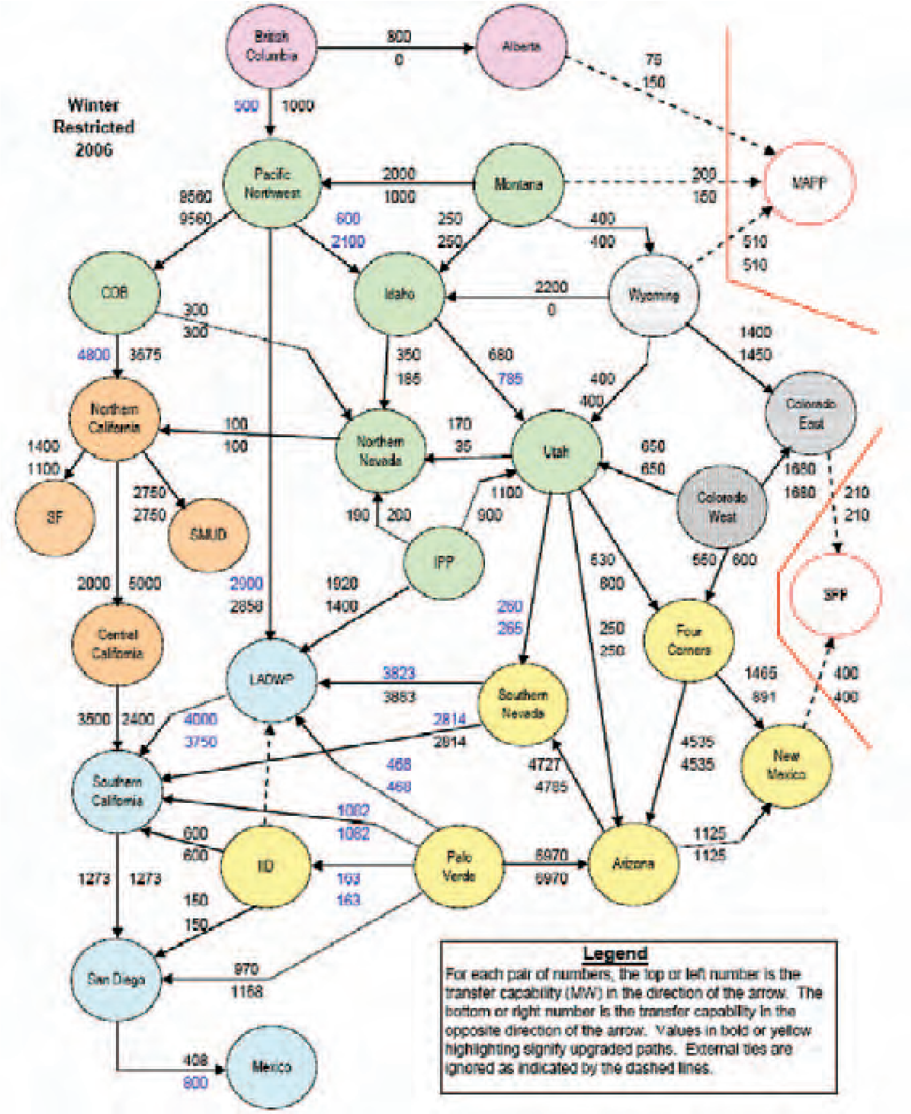


Figure 2-4: Transmission Capacity between WECC Control Areas

(Source: WECC)

The Energy Information Administration (EIA/DOE (www.eia.doe.gov) provides information regarding the mix of electrical generation resources for each state, with 2005 statistics for Colorado and its adjoining Rocky Mountain states, the most recent year for which data are available, shown in Table 2-5. It demonstrates that renewables (exclusive of hydroelectric) comprise only about 2% of the generation capacity in the five-state area and only 1% of the electrical energy generated in 2005. Fossil resources, particularly coal and gas, constitute 83% and 86% of the capacity and generation, respectively. The data compiled on the last few lines of Table 2-5 are indicative of Colorado's isolation from regional power markets. As shown, its in-state generation nearly matches its in-state use, while the adjoining states are much more involved in import/export markets.

CAPACITY (MW)	WYOMING	UTAH	COLORADO	NEW MEXICO	ARIZONA	TOTAL	MARKET SHARE
Coal	5,847	4,891	4,928	3,957	5,430	25,053	45%
Gas & Oil	166	1,358	4,706	2,031	12,647	20,908	38%
Nuclear	0	0	0	0	3,875	3,875	7%
Hydroelectric	303	255	652	82	2,720	4,012	7%
Renewables	287	24	238	410	16	975	2%
TOTAL	6,707	6,528	11,087	6,480	24,904	55,706	100%
GENERATION (MWH)							
Coal	43,345,685	35,970,405	35,570,135	29,947,248	40,143,310	184,976,783	69%
Gas & Oil	367,277	1,218,410	11,940,338	4,224,127	28,936,475	46,686,625	17%
Nuclear	0	0	0	0	25,807,446	25,807,446	10%
Hydroelectric	808,375	784,463	1,415,296	164,993	6,410,064	9,583,191	4%
Renewables	717,264	188,751	810,561	799,274	73,995	2,589,845	1%
TOTAL	45,567,307	38,165,131	49,614,265	35,135,642	101,478,655	269,961,000	100%
CAPACITY FACTOR							
Coal	85%	84%	82%	86%	84%	84%	
Gas & Oil	25%	10%	29%	24%	26%	25%	
Nuclear	NA	NA	NA	NA	76%	76%	
Hydroelectric	30%	35%	25%	23%	27%	27%	
Renewables	29%	90%	39%	22%	53%	30%	
AVERAGE	78%	67%	51%	62%	47%	55%	
IN-STATE USE							
Megawatt Hours	14,137,727	25,000,498	48,353,236	20,638,951	69,390,686	177,521,098	
% of Generation	31%	66%	97%	59%	68%	66%	
AVE. PRICE (¢/KWH)	5.16	5.92	7.64	7.51	7.79	7.24	

Table 2-5: 2005 Electric Statistics

(Source: DOE)

The renewable component of the electrical generating capacity mix has increased by 1,075 MW (110% increase) for the five-state area since 2005 based on information compiled by the Interwest Energy Alliance (www.interwest.org) (Table 2-6). The vast majority of the increase occurred in the wind sector of the renewable energy industry, with by far the largest gains made by Colorado, which has enjoyed a four-fold increase in installed renewable generation capacity since 2005.

The DOE's Information Administration provides an annual summary of historical and projected energy supplies, costs, and consumption statistics in its Annual Energy Outlook series which includes substantial information regarding the electricity sector of the energy industry that are accessible via the following EIA website links: www.eia.doe.gov/oiaf/aeo/pdf/trend_3.pdf; www.eia.doe.gov/fuelelectric.html. The most recent information available from EIA/DOE regarding electricity prices for Colorado and adjoining states is presented in Table 2-7. Colorado's average price of electricity in July 2007 was 7.54¢ per kilowatt hour (i.e., $75.40/MWh) as compared to a national average of 9.49¢ per kilowatt hour and a Pacific Coast average of 12.51¢ per kilowatt hour, due largely to its proximity to low-cost generating resources within Colorado and Wyoming.

	WY	UT	CO	NM	AZ	TOTAL
WIND	318.6	19.9	1,169.3	496.6	0.0	2,004.4
GEOTHERMAL	0.0	26.0	0.0	0.0	0.0	26.0
SOLAR	0.0	0.0	8.2	0.0	11.8	20.0
BIOMASS	0.0	0.0	0.0	0.0	0.0	0.0
2007 TOTAL (IEA)	318.6	45.9	1,177.5	496.7	11.8	2,050.4
2005 TOTAL (DOE)	287.0	24.0	238.0	410.0	16.0	975.0
CHANGE	31.6	21.9	939.5	86.7	-4.2	1,075.4
% CHANGE	11%	91%	395%	21%	-26%	110%

Table 2-6: Renewable Generating Capacity for Select Rocky Mountain States (MW)

(Source: Interwest Energy Alliance and DOE)

	Residential	Commercial	Industrial	Total
Mountain	9.94	7.94	6.21	8.29
Idaho	6.97	5.39	4.25	5.28
Wyoming	8.06	6.20	4.12	5.30
Utah	8.86	6.80	5.31	7.19
Colorado	9.03	7.10	5.97	7.54
New Mexico	9.32	7.62	5.83	7.63
Montana	9.32	8.34	5.34	7.67
Arizona	10.35	8.89	6.42	9.34
Nevada	12.12	10.12	10.28	11.08

Table 2-7: July-07 Retail Electricity Prices (¢/kWh) – Mountain Region

(Source: EIA/DOE)

Operational Considerations

Utilities dispatch power from their different supply source options to cost-effectively (on the basis of marginal costs) and reliably serve customer demand and to maintain stable operating conditions throughout their transmission and distribution systems. These requirements vary on an hourly and seasonal basis, as indicated in Figure 2-8.

Generation resources have traditionally been considered in three progressively higher-cost categories for purposes of dispatching generators to meet load: baseload, intermediate, and peaking (Figure 2-9). The use of each dispatch category on this diagram is represented by a "load duration curve" which is a different approach to showing annual load from that shown on Figure 2-7. In the Colorado example shown in Figure 2-8, baseload resources (generally hydroelectric and coal-fired generation) provide 65% of the energy needed to meet annual load, with the vast majority of the rest supplied by intermediate resources (typically, gas-fired facilities). As Colorado faces carbon constraints, acquiring and dispatching low carbon resources will become a key planning and operating criteria, joining with continued concern for reliable, low cost electric service. Carbon constraints have the potential to change very substantially both how electric systems are planned and how they are operated.

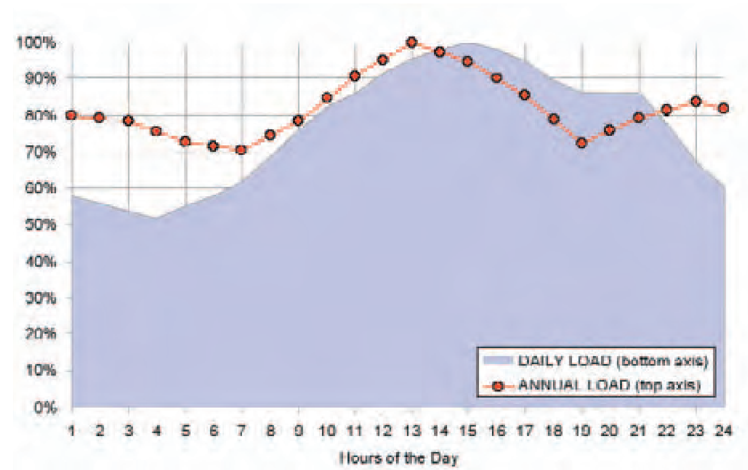


Figure 2-8: Daily (by Hour) and Annual (by Month) Load Profiles

(Sources: PSCo 2006 wind integration study & WECC-RMPA, respectively)

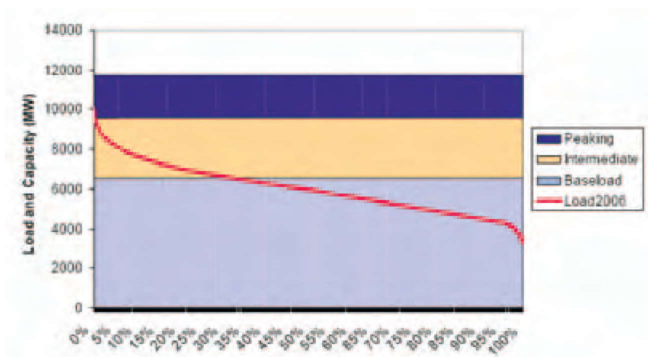


Figure 2-9: 2006 Colorado Resource Mix vs. Load Duration Curve

(Source: Colorado Energy Forum)

Renewables, particularly wind resources, are generally not considered "dispatchable" generation resources. For the most part, they cannot be dispatched on demand and must be used when they are available. But they are like electric loads that are driven by weather: hot or cold days cause more power to be consumed. Concentrated solar thermal power that involves storage or gas-fired equipment that can be dispatched may provide an exception. Wind generation has very low marginal costs, so control area operators will take as much low cost wind power as is available, using it to offset higher cost generation that can be turned down or turned off whenever wind is available.

Renewable resources are poised to increase their share of generation in Colorado, due to high natural gas prices that have the potential for very substantial, unanticipated price fluctuations, expansion of state-level renewable energy standard requirements, and Production Tax Credits (PTCs) that equalize the competitive position of renewable energy resources with subsidies enjoyed by fossil and nuclear resources. Large wind plants show currently competitive economics. Continued advances in renewable generation technology and potential for large scale economies of manufacturing production for renewable generation equipment suggest that renewables will increase their role among generation choices. In some instances, these new resources will cause the displacement of older, less efficient fossil resources, particularly smaller coal plants and gas-fired resources which have high marginal costs and are unable to flexibly match variable output from renewable sources.

In the event that carbon taxes are ultimately applied to fossil generation sources, coal and gas, that will add to their marginal costs setting the stage for large-scale penetrations of renewables into generation portfolios. As such, there is a future scenario where substantial amounts of renewables will be dispatched ahead of fossil resources in order to meet load – a radical departure from traditional approaches to dispatching generating resources. This will impose certain operational challenges on utility system and dispatch operators to integrate the two classes of resources. Fortunately, European system operators are meeting these challenges and providing important lessons that can be adapted to North American circumstances. See www.uwig.org for information from utility sources about how integration challenges are being met.

Colorado Generation

The following chart is the most recent listing available for electric generating units in Colorado. The source document is eGRID, a database developed by the U.S. Environmental Protection Agency with information regarding electric power generation in the United States. A description of acronyms, details on assumptions and use of data, and other pertinent information is available from the source: www.epa.gov/cleanenergy/egrid/

Generator Status:
OP = Operating
SB – Stand-by
RE – Retired

Prime Mover Type:
IC – Internal Combustion
GT – Gas Turbine
ST – Steam
CT – Combustion Turbine
HY – Hydroelectric
PS – Pumped Storage
WT – Wind Turbine

Fuel:
DFO – Diesel Fuel Oil
NG – Natural Gas
WAT – Water
BIT- Bituminous Coal
SUB – Sub-bituminous Coal
WND – Wind

PLANT NAME	GENERATOR STATUS	PRIME MOVER TYPE	FUEL	GENERATOR NAMEPLATE CAPACITY (MW)	GENERATOR ANNUAL NET GENERATION (MWH)	GENERATOR: YEAR ON-LINE
Airport Industrial	OP	IC	DFO	2.5	0	2002
Airport Industrial	OP	IC	DFO	2.5	0	2002
Airport Industrial	OP	IC	DFO	2.5	0	2002
Airport Industrial	OP	IC	DFO	2.5	0	2002
Alamosa	OP	GT	DFO	16.5	0	1973
Alamosa	OP	GT	DFO	16.5	0	1977
American Gypsum Cogeneration	SB	IC	DFO	1.6	0	1990
American Gypsum Cogeneration	SB	IC	DFO	1.6	0	1990
American Gypsum Cogeneration	OP	GT	NG	3.2	0	1990
American Gypsum Cogeneration	OP	GT	NG	3.2	0	1990
Ames Hydro	OP	HY	WAT	3.6	13302	1906
Arapahoe	RE	ST	BIT	44.0	0	1950
Arapahoe	RE	ST	BIT	44.0	0	1951
Arapahoe	OP	ST	SUB	48.0	199035	1951
Arapahoe	OP	ST	SUB	112.0	805901	1955
Arapahoe Combustion Turbine Project	OP	GT	NG	71.1	0	2000
Arapahoe Combustion Turbine Project	OP	GT	NG	71.1	0	2000
Arapahoe Combustion Turbine Project	OP	ST	NG	51.7	27112	2002
BCP	OP	CT	NG	37.0	215670	1994
BCP	OP	CA	NG	37.0	245678	1994
Big Thompson	OP	HY	WAT	4.5	10522	1959
Blue Mesa	OP	HY	WAT	43.2	0	1967
Blue Mesa	OP	HY	WAT	43.2	0	1967
Blue Spruce Energy Center	OP	GT	NG	234.0	0	2003
Blue Spruce Energy Center	OP	GT	NG	234.0	0	2003
Boulder Canyon Hydro	OP	HY	WAT	10.0	10829	1911

PLANT NAME	GENERATOR STATUS	PRIME MOVER TYPE	FUEL	GENERATOR NAMEPLATE CAPACITY (MW)	GENERATOR ANNUAL NET GENERATION (MWH)	GENERATOR: YEAR ON-LINE
Boulder City Betasso Hydroelectric Plant	OP	HY	WAT	3.0	12478	1987
Boulder City Silver Lake Hydro	OP	HY	WAT	3.3	9566	2000
Brush IV	SB	GT	NG	55.0	0	1999
Brush IV	SB	GT	NG	55.0	0	1999
Burlington	SB	GT	DFO	64.7	0	1977
Burlington	SB	GT	DFO	64.7	0	1977
Cabin Creek	OP	PS	WAT	150.0	0	1967
Cabin Creek	OP	PS	WAT	150.0	0	1967
Cameo	OP	ST	BIT	22.0	172350	1957
Cameo	OP	ST	BIT	44.0	298761	1960
Cherokee	SB	IC	DFO	2.7	0	1967
Cherokee	SB	IC	DFO	2.7	0	1967
Cherokee	OP	ST	SUB	125.0	698868	1957
Cherokee	OP	ST	SUB	125.0	630164	1959
Cherokee	OP	ST	SUB	170.4	1017561	1962
Cherokee	OP	ST	SUB	380.8	2621744	1968
Colorado Green Holdings LLC	OP	WT	WND	162.0	63136	2003
Colorado Power Partners	OP	CT	NG	25.0	0	1990
Colorado Power Partners	OP	CT	NG	25.0	0	1990
Colorado Power Partners	OP	CA	NG	38.0	2726	1990
Comanche	OP	ST	SUB	382.5	1717479	1973
Comanche	OP	ST	SUB	396.0	2584669	1975
Craig	OP	ST	SUB	446.4	3532840	1980
Craig	OP	ST	SUB	446.4	3103654	1979
Craig	OP	ST	SUB	446.4	3334532	1984
Crystal	OP	HY	WAT	28.0	3816	1978
Delta	OP	IC	NG	0.8	0	1945
Delta	OP	IC	NG	0.4	0	1939
Delta	OP	IC	DFO	0.1	0	1938
Delta	OP	IC	DFO	0.1	0	1937

PLANT NAME	GENERATOR STATUS	PRIME MOVER TYPE	FUEL	GENERATOR NAMEPLATE CAPACITY (MW)	GENERATOR ANNUAL NET GENERATION (MWH)	GENERATOR: YEAR ON-LINE
Delta	OP	IC	DFO	0.1	0	1937
Delta	OP	IC	NG	1.2	0	1949
Delta	OP	IC	NG	2.1	0	1956
Dillon Hydro Plant	OP	HY	WAT	1.8	9400	1987
Estes	OP	HY	WAT	15.0	0	1950
Estes	OP	HY	WAT	15.0	0	1950
Estes	OP	HY	WAT	15.0	0	1950
Flatiron	OP	HY	WAT	43.0	0	1954
Flatiron	OP	HY	WAT	43.0	0	1954
Flatiron	OP	PS	WAT	8.5	-137	1954
Foothills Hydro Plant	OP	HY	WAT	3.1	4798	1985
Fort Lupton	OP	GT	NG	39.2	0	1972
Fort Lupton	OP	GT	NG	39.2	0	1972
Fort St Vrain	OP	CA	NG	342.6	1387252	1998
Fort St Vrain	OP	CT	NG	130.0	0	1996
Fort St Vrain	OP	CT	NG	135.0	0	1999
Fort St Vrain	OP	CT	NG	135.0	0	2001
Fountain Valley Power Facility	OP	GT	NG	38.0	0	2001
Fountain Valley Power Facility	OP	GT	NG	38.0	0	2001
Fountain Valley Power Facility	OP	GT	NG	38.0	0	2001
Fountain Valley Power Facility	OP	GT	NG	38.0	0	2001
Fountain Valley Power Facility	OP	GT	NG	38.0	0	2001
Fountain Valley Power Facility	OP	GT	NG	38.0	0	2001
Frank Knutson	OP	GT	NG	77.1	0	2002
Frank Knutson	OP	GT	NG	77.1	0	2002
Front Range Power Project	OP	CT	NG	154.0	0	2003
Front Range Power Project	OP	CT	NG	154.0	0	2003
Front Range Power Project	OP	CA	NG	233.0	250787	2003
Fruita	OP	GT	NG	18.6	77	1973
George Birdsall	OP	ST	NG	17.6	275	1953

PLANT NAME	GENERATOR STATUS	PRIME MOVER TYPE	FUEL	GENERATOR NAMEPLATE CAPACITY (MW)	GENERATOR ANNUAL NET GENERATION (MWH)	GENERATOR: YEAR ON-LINE
George Birdsall	OP	ST	NG	17.6	253	1954
George Birdsall	OP	ST	NG	23.5	377	1957
Georgetown	OP	HY	WAT	0.7	0	1906
Georgetown	OP	HY	WAT	0.7	0	1908
Green Mountain	OP	HY	WAT	13.0	0	1943
Green Mountain	OP	HY	WAT	13.0	0	1943
Hayden	OP	ST	SUB	190.0	1510325	1965
Hayden	OP	ST	SUB	275.4	1984764	1976
Hillcrest Pump Station	OP	HY	WAT	2.0	5800	1993
Holly	OP	IC	DFO	2.2	0	2002
Holly	SB	IC	DFO	0.7	0	1993
Holly	RE	IC	NG	0.2	0	1950
Holly	RE	IC	NG	0.2	0	1950
Holly	SB	IC	DFO	0.4	0	2000
Julesburg	SB	IC	DFO	0.9	0	1951
Julesburg	SB	IC	DFO	0.9	0	1949
Julesburg	SB	IC	DFO	0.3	0	1945
Julesburg	SB	IC	DFO	1.3	0	1964
Julesburg	SB	IC	DFO	0.3	0	1946
La Junta	RE	IC	DFO	0.6	0	1939
La Junta	SB	IC	DFO	0.7	0	1939
La Junta	SB	IC	DFO	0.4	0	1939
La Junta	SB	IC	DFO	1.0	0	1942
La Junta	RE	IC	DFO	1.2	0	1950
La Junta	SB	IC	DFO	3.0	0	1958
La Junta	SB	IC	DFO	3.5	0	1962
La Junta	SB	IC	DFO	3.5	0	1962
La Junta	SB	IC	DFO	5.1	0	1970
Lamar Plant	SB	IC	DFO	1.0	0	1949
Lamar Plant	SB	IC	DFO	1.0	0	1946
Lamar Plant	OP	WT	WND	4.5	0	2004
Lamar Plant	OP	WT	WND	1.5	0	2004
Lamar Plant	OS	ST	NG	25.0	13823	1972
Lamar Plant	OP	GT	NG	4.2	0	2001
Las Animas	OP	IC	DFO	0.3	0	1941
Las Animas	OP	IC	DFO	0.3	0	1941
Las Animas	OP	IC	DFO	1.0	0	1951
Las Animas	OP	IC	DFO	1.0	0	1951
Las Animas	OP	IC	DFO	3.0	0	1967
Limon Generating Station	OP	GT	NG	77.1	0	2002
Limon Generating Station	OP	GT	NG	77.1	0	2002
Lower Molina	OP	HY	WAT	4.8	14798	1962
Manchief Electric Generating Station	OP	GT	NG	150.0	0	2000
Manchief Electric Generating Station	OP	GT	NG	150.0	0	2000
Manitou Springs	OP	HY	WAT	2.5	0	1939
Manitou Springs	OP	HY	WAT	2.5	0	1927
Martin Drake	OP	ST	BIT	50.0	311147	1962
Martin Drake	OP	ST	BIT	75.0	504833	1968
Martin Drake	OP	ST	BIT	132.0	877380	1974
Marys Lake	OP	HY	WAT	8.1	30713	1951
McPhee	OP	HY	WAT	1.2	2655	1992
Metro Wastewater Reclamation Dist.	SB	IC	OBG	2.0	0	1985
Metro Wastewater Reclamation Dist.	SB	IC	OBG	2.0	0	19
Metro Wastewater Reclamation Dist.	SB	IC	OBG	2.0	0	1985
Metro Wastewater Reclamation Dist.	SB	IC	OBG	2.0	0	1985
Metro Wastewater Reclamation Dist.	OP	GT	OBG	3.5	0	2000
Metro Wastewater Reclamation Dist.	OP	GT	OBG	3.5	0	2000
Morrow Point	OP	HY	WAT	86.6	0	1970
Morrow Point	OP	HY	WAT	86.6	0	1971
Mount Elbert	OP	PS	WAT	100.0	0	1981

PLANT NAME	GENERATOR STATUS	PRIME MOVER TYPE	FUEL	GENERATOR NAMEPLATE CAPACITY (MW)	GENERATOR ANNUAL NET GENERATION (MWH)	GENERATOR: YEAR ON-LINE
Mount Elbert	OP	PS	WAT	100.0	0	1984
North Fork Hydro Plant	OP	HY	WAT	5.5	17700	1988
Nucla	OP	ST	BIT	79.3	0	1991
Nucla	OP	ST	BIT	11.5	746072	1959
Nucla	OP	ST	BIT	11.5	0	1959
Nucla	OP	ST	BIT	11.5	0	1959
Palisade	OP	HY	WAT	1.5	0	1932
Palisade	OP	HY	WAT	1.5	0	1932
Pawnee	OP	ST	SUB	552.3	3519296	1981
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Plains End Generating Station	OP	IC	NG	7.1	0	2002
Pole Hill	OP	HY	WAT	38.2	173181	1954

PLANT NAME	GENERATOR STATUS	PRIME MOVER TYPE	FUEL	GENERATOR NAMEPLATE CAPACITY (MW)	GENERATOR ANNUAL NET GENERATION (MWH)	GENERATOR: YEAR ON-LINE
Ponnequin	OP	WT	WND	9.0	0	2001
Ponnequin	OP	WT	WND	15.4	0	1999
Ponnequin Phase 1	OP	WT	WND	5.2	10870	1998
Pueblo	OP	IC	DFO	2.0	0	1964
Pueblo	OP	IC	DFO	2.0	0	1964
Pueblo	OP	IC	DFO	2.0	0	1964
Pueblo	OP	IC	DFO	2.0	0	1964
Pueblo	OP	IC	DFO	2.0	0	1964
Pueblo	OP	ST	NG	7.5	459	2001
Pueblo	OP	ST	NG	15.0	500	1949
Rawhide	OP	GT	NG	89.3	0	2002
Rawhide	OP	GT	NG	89.3	0	2002
Rawhide	OP	GT	NG	89.3	0	2002
Rawhide	OP	GT	NG	89.3	0	2004
Rawhide	OP	ST	SUB	293.6	2252742	1984
Ray D Nixon	OP	GT	NG	35.8	0	1999
Ray D Nixon	OP	GT	NG	35.8	0	1999
Ray D Nixon	OP	ST	BIT	207.0	1706723	1980
Redlands Water & Power	OP	HY	WAT	1.4	5	1931
Ridge Crest Wind Partners	OP	WT	WND	29.7	78301	2001
Rifle Generating Station	OP	CT	NG	15.3	0	1987
Rifle Generating Station	OP	CT	NG	15.0	0	1987
Rifle Generating Station	OP	CT	NG	39.0	0	1987
Rifle Generating Station	OP	CA	NG	39.0	30577	1987
Rocky Ford	OP	IC	DFO	2.0	0	1964
Rocky Ford	OP	IC	DFO	2.0	0	1964
Rocky Ford	OP	IC	DFO	2.0	0	1964
Rocky Ford	OP	IC	DFO	2.0	0	1964
Rocky Ford	OP	IC	DFO	2.0	0	1964
Rocky Mountain Energy Center	OP	CT	NG	185.0	0	2004

PLANT NAME	GENERATOR STATUS	PRIME MOVER TYPE	FUEL	GENERATOR NAMEPLATE CAPACITY (MW)	GENERATOR ANNUAL NET GENERATION (MWH)	GENERATOR: YEAR ON-LINE
Rocky Mountain Energy Center	OP	CT	NG	185.0	0	2004
Rocky Mountain Energy Center	OP	CA	NG	322.0	801499	2004
Ruedi	OP	HY	WAT	5.0	11044	1985
Ruxton Park	OP	HY	WAT	1.2	55	1925
Salida	OP	HY	WAT	0.7	0	1929
Salida	OP	HY	WAT	0.5	0	1908
Shoshone	OP	HY	WAT	7.2	0	1909
Shoshone	OP	HY	WAT	7.2	0	1909
Strontia Springs Hydro Plant	OP	HY	WAT	1.0	6200	1986
Sugarloaf Hydro Plant	OP	HY	WAT	2.5	2558	1985
Tacoma	OP	HY	WAT	2.2	0	1906
Tacoma	OP	HY	WAT	2.2	0	1905
Tacoma	OP	HY	WAT	3.5	0	1949
Taylor Draw Hydroelectric Facility	OP	HY	WAT	2.3	10261	1993
TCP 272	OP	CT	NG	58.5	0	1994
TCP 272	OP	CT	NG	58.5	0	1994
TCP 272	OP	CT	NG	58.5	0	1994
TCP 272	OP	CT	NG	58.5	0	1994
TCP 272	OP	CT	NG	58.5	0	1994
TCP 272	OP	CA	NG	47.0	70250	1994
TCP 272	OP	CA	NG	47.0	55924	1994
Tesla	OP	HY	WAT	27.6	54039	1997
Thermo Greeley	OP	GT	NG	37.0	200759	1996
Thermo Power & Electric	OP	CT	NG	47.2	0	1988
Thermo Power & Electric	OP	CT	NG	47.2	0	1988
Thermo Power & Electric	OP	CA	NG	16.4	12649	1988
Towaoc	OP	HY	WAT	11.4	16271	1993
Trigen Colorado Energy	OP	ST	BIT	7.5	75152	1976
Trigen Colorado Energy	OP	ST	BIT	7.5	74977	1977
Trigen Colorado Energy	OP	ST	BIT	20.0	143200	1983
Trigen Colorado Energy	OP	ST	BIT	0.4	44	1997
Trinidad	OS	ST	BIT	3.7	0	1950
Trinidad	SB	IC	NG	1.9	0	1966
Trinidad	SB	IC	NG	1.9	0	1966
Trinidad	OP	IC	DFO	1.8	0	1999
Trinidad	OP	IC	DFO	1.8	0	1999
Trinidad	OP	IC	DFO	1.8	0	1999
University of Colorado	OP	CT	NG	16.0	0	1992
University of Colorado	OP	CT	NG	16.0	0	1992
University of Colorado	OP	CA	NG	1.0	4126	1992
Upper Molina	OP	HY	WAT	8.6	25606	1962
Vallecito Hydroelectric	OP	HY	WAT	0.8	0	1989
Vallecito Hydroelectric	OP	HY	WAT	2.5	0	1989
Vallecito Hydroelectric	OP	HY	WAT	2.5	0	1989
Valmont	OP	ST	SUB	191.7	1354402	1964
Valmont	OP	GT	NG	45.2	478	1973
Valmont Combustion Turbine Project	OP	GT	NG	71.1	0	2000
Valmont Combustion Turbine Project	OP	GT	NG	71.1	0	2001
W N Clark	OP	ST	BIT	18.7	112018	1955
W N Clark	OP	ST	BIT	25.0	173923	1959
Williams Fork Hydro Plant	OP	HY	WAT	3.0	7900	1959
Williams Ignacio Gasoline Plant	OP	ST	NG	6.1	32471	1984
Yuma	SB	IC	DFO	0.1	0	1937
Yuma	SB	IC	DFO	0.1	0	1937
Yuma	SB	IC	DFO	0.3	0	1938
Yuma	SB	IC	DFO	0.5	0	1948
Zuni	OP	ST	NG	40.2	-661	1948
Zuni	OP	ST	NG	75.0	-532	1954

Economics of Electricity

Electricity generation and delivery system are relatively straight-forward processes involving generation, transmission, and distribution (Figure 2-10). The breakdown of costs for these components, absent any tax subsidies, is shown in Figure 2-11. As shown, generation costs comprise the largest component in electricity costs.

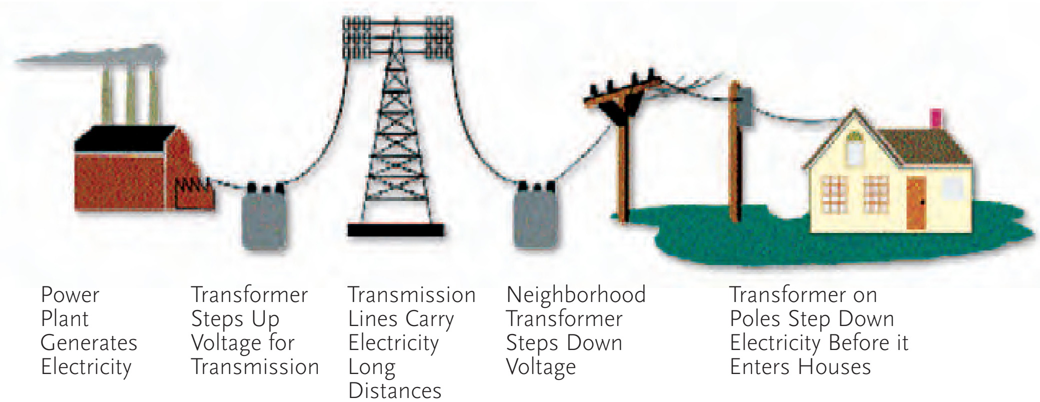


Figure 2-10: Electricity Generation & Delivery System

(Source: EIA/DOE)

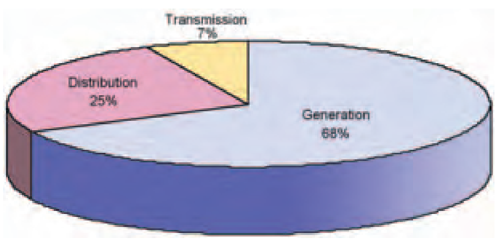


Figure 2-11: Electricity Cost Breakdown

(EIA, Annual Energy Outlook 2007)

Generation Costs

The cost of generation varies between different generating resources, locations, and stage of technology development, which in the case of fossil fuels, is largely influenced by the cost of fuel used to generate electricity. Such costs are also influenced by the installed cost of generation facilities, as well as the efficiency and utilization of those facilities. Recent Western U.S. public stakeholder venues to develop consensus projections of the levelized all-in costs for the different electricity generation technologies are summarized in Table 2-12 and Figure 2-13, separated into renewable and fossil categories for 2006 and 2015 installations . As shown, there is an expectation that technology will improve and costs will decline over the next decade for different generation technologies.

All-in costs for gas-fired plants shown in the preceding illustrations assume an average natural gas price of $7/mmBtu. However, in recent years dramatic increases in average natural gas prices, inability to predict gas prices, particularly over the long term, and unanticipated price volatility (Figure 2-14) has affected gas-fired power plants' competitive position in the generation dispatch sequence. High costs are reflected in relatively low capacity factors experienced in those plants (Table 2-12). In the event that natural gas prices continue to rise, or continue to vary unpredictably, gas-fired facilities will become less competitive in the generation portfolios, all else remaining equal. The trading price of natural gas is available at Bloomberg:
http://www.bloomberg.com/markets/commodities/cfutures.html

Plant Type	Capacity Factor	Tons CO_2/MWh	Year Installed ($/MWh) 2006	2015
Coal - Arizona	85%	0.89	68	58
Coal - Colorado	85%	0.99	54	45
Coal - New Mexico	85%	0.89	61	51
Coal - Utah	85%	0.89	66	56
Coal - Wyoming	85%	0.99	48	38
Coal - Wyoming Advanced	80%	0.15	76	62
Gas Combined Cycle @ $7	78%	0.40	77	71
Gas Combustion Turbine @ $7	10%	0.54	226	190
Biomass	90%	0	82	71
Geothermal	95%	0	82	68
Solar Concentrating	40%	0	138	105
Wind - Arizona	30%	0	77	60
Wind - Colorado	42%	0	53	40
Wind - New Mexico	40%	0	55	42
Wind - Wyoming	48%	0	47	36

Table 2-12: All-In Generation Costs - $2006

(Adapted from the Frontier Line FEAST Input Assumptions)

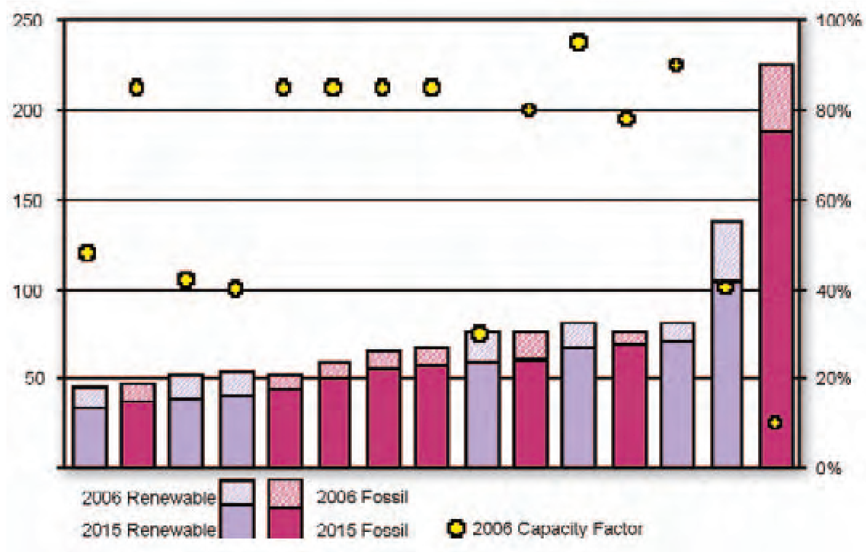


Figure 2-13: All-In Generation Costs - $2006

(Adapted from the Frontier Line FEAST Input Assumptions)

Figure 2-14: Price of Gas for Electricity ($/mmBtu)

(Source: EIA/DOE)

Imposition of CO2 penalties (Greenhouse gas adders or GHG adders) would have a material impact on all-in costs of generation for fossil-fired power plants and would not affect costs for most renewable generation (Figure 2-13). Impacts of each dollar per ton of CO2 penalty for fossil generation range downward from nearly $1/MWh for conventional coal-fired generation, to 40¢/MWh for combined cycle gas, to 15¢/MWh for advanced coal technology with carbon separation and sequestration as a reflection of each of their CO2 emission rates are shown in Table 2-15.

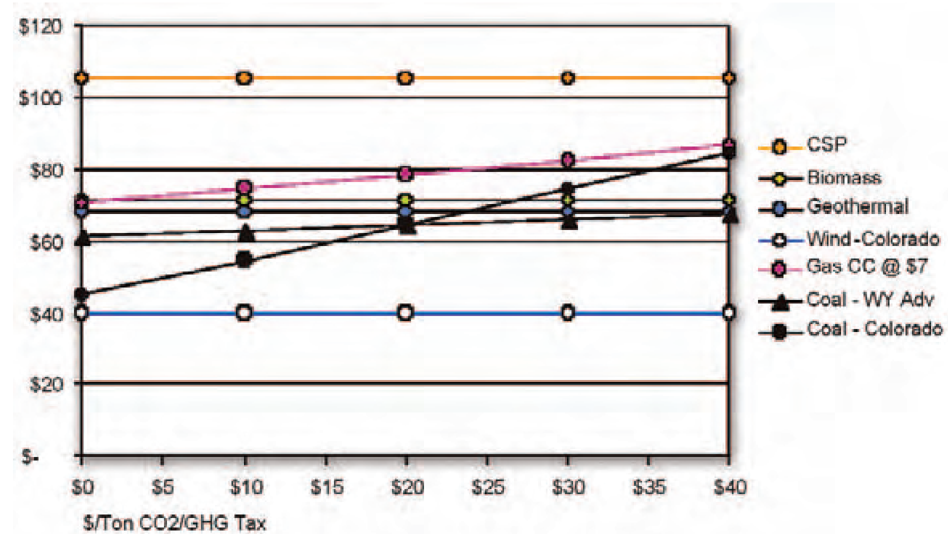


Figure 2-15: Generation Costs for Different CO2 Penalty Scenarios

(Based on FEAST Input Assumptions)

While GHG adders have not yet been applied, values as high as $40/ton have been discussed in public policy circles as we move inexorably towards a carbon-constrained world. The extent to which such penalties are applied will affect both the role of various resources in generation portfolios as well as the dispatch sequence of different generation resources, potentially moving renewables towards the front of the dispatch order. However, since renewables cannot be dispatched to meet loads, which is particularly important during peak load periods, (nor is electricity generated from them "storable,") there will still be a significant role for fossil generation that can be dispatched when needed to meet load requirements.

Transmission Costs

While transmission doesn't comprise a major part of overall electricity costs, typically only about 8%, it is the key link between power plants and the utility distribution system, particularly in the case of power plants located far from load: coal, wind, and central solar generation facilities. Such costs apply to the higher voltage transmission lines; typically in excess of 69 kV although in some instances the distinction may be at 115 kV. Rule-of-thumb costs and capacities for the typical voltages used in transmission lines are summarized in Table 2-16, taking into account recent increases in such costs.

			MILES - APPROX. INSTALLED COST ($MM)				
Voltage	$000/Mile	Other*	100	200	300	400	500
230	$750	30%	$98	$195	$293	$390	$488
345	$1,000	30%	$130	$260	$390	$520	$650
500	$1,500	30%	$195	$390	$585	$780	$975

		MILES - APPROXIMATE $/MW				
Voltage	Capacity (MW)	100	200	300	400	500
230	400	$244	$488	$731	$975	$1,219
345	750	$173	$347	$520	$693	$867
500	1,500	$130	$260	$390	$520	$650

* Substations, SVC, Series Compensation, Phase Shifters, etc.

Table 2-16: Approximate Overhead Transmission Line Costs

(Source: Trans-Elect LLC)

While Colorado's transmission system is largely comprised of 230 kV and 345 kV lines, many new lines are being planned at 500 kV which is the voltage used over much of the remainder of WECC and is much more cost-effective provided that there is a requirement for the larger capacities involved (Figure 2-16).

Transmission services are sold on the basis of capacity, primarily in the form of "firm" and "non-firm" rates, with most power delivered via the former. Transmission rates vary among utility ownership classes and utilities, depending on the size of their service territories footprints and the vintage of construction. Since transmission is sold on the basis of capacity expressed in $/kW-mo, effective transmission rates in terms of $/MWh are a function of the extent to which that capacity is used. Differentials in effective transmission rates for different utilization levels and resource mixes shipped are shown in Figure 2-17. As shown, a renewables-only transmission line results in much higher transmission rates than a line that delivers a mix of resources.

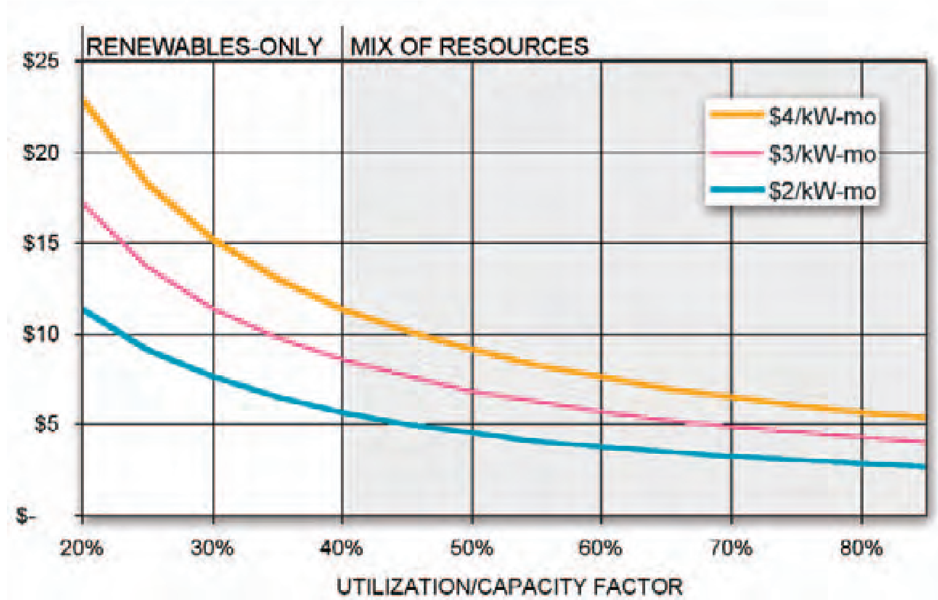


Figure 2-17: Transmission Rates Vary Depending on Utilization

(Source: Trans-Elect LLC)

There has been minimal investment in transmission over the past decade as building gas-fired power plants at load has been the preferred generation supply option. However, as gas costs have dramatically increased, more remotely-sited generation options and associated transmission are being considered, particularly to access renewable resources. Some of the new transmission projects that are being developed in the region that would involve Colorado are summarized on the following pages.

Future Transmission Plans

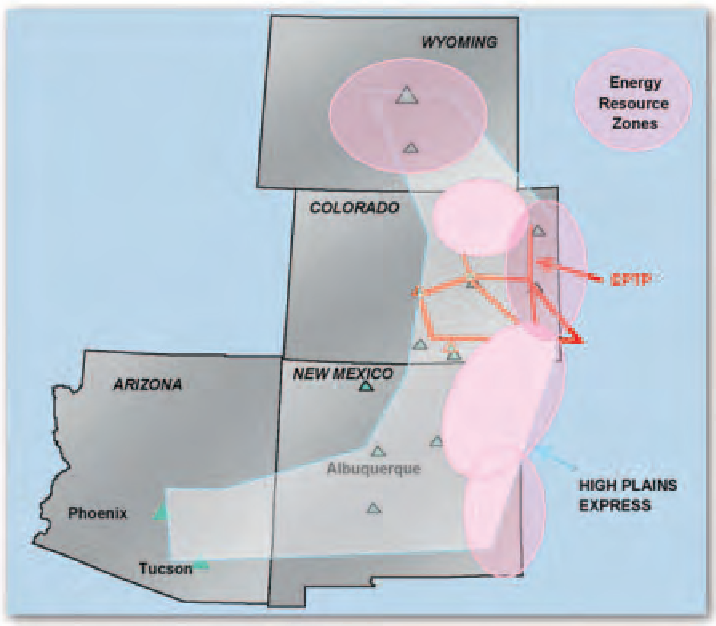


Figure 2-18: High Plains Express Transmission Project

High Plains Express (HPX)

Project Sponsor/Partners: Xcel/PSCo, Tri-State G&T, WAPA, Platte River Power Authority, Colorado Springs Utilities, Public Service of New Mexico (PNM), Salt River Project, and Trans-Elect. The transmission authorities of Wyoming and New Mexico are also participating. Colorado's Clean Energy Development Authority may soon participate.

Website Link: http://www.rmao.com/wtpp/HPX_Studies.html

Project Summary: The HPX is a 500 kV "master plan" for transmission grid expansion and reinforcement in Wyoming, Colorado, New Mexico and Arizona. The goal is to develop a high-voltage, backbone transmission system that will enhance reliability and increase access to renewable and other diverse generation resources within regional energy resource zones. The initial phase of feasibility studies will be completed in early 2008 (Figure 2-18).

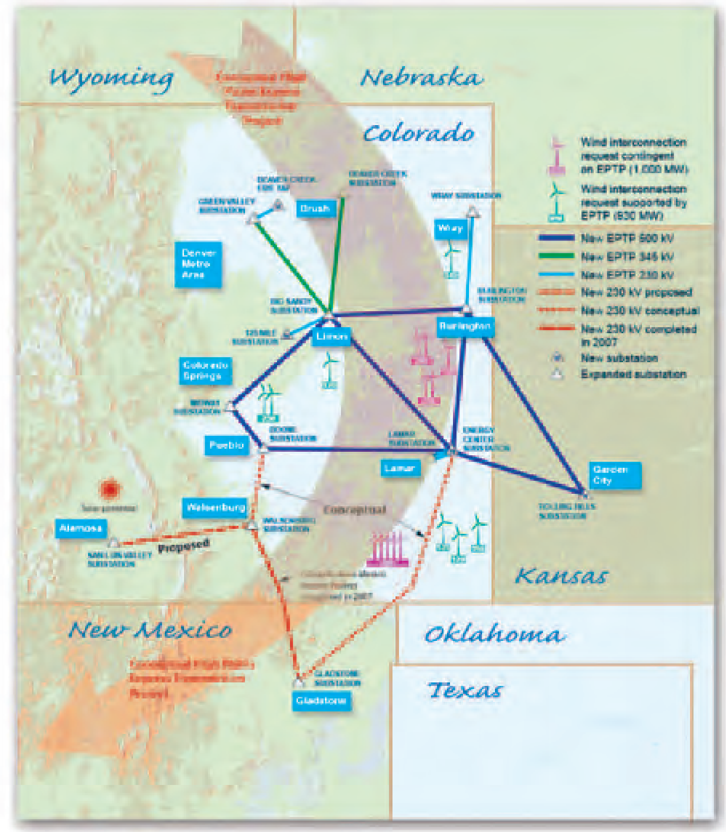


Figure 2-19: Eastern Plains Transmission Project

Eastern Plains Transmission Project (EPTP)

Project Sponsor/Partners: Tri-State G&T with WAPA & PSCo

Website Link: http://www.wapa.gov/transmission/eptp.htm

Project Summary: EPTP is a proposed new transmission project that would include about 1,000 miles of new high-voltage transmission lines and related facilities in eastern Colorado and western Kansas, expansions at existing substations and construction of new substations, access roads and fiber optic communication facilities. As currently planned, the EPTP would be one of the largest transmission additions in the United States in the past five years (Figure 2-19). EPTP can be considered as a component of HPX.

Transmission development coming out of EPTP has resulted in over 1900 MW of renewable energy interconnection requests for EPTP segments and associated transmission. Each project that interconnects to this system equates to additional economic development and revenue in counties and for landowners, on whose property these projects will be sited. The project may rest on assumptions about development of new coal fired power plants in Colorado and Kansas, which have been delayed or rejected for air permits.

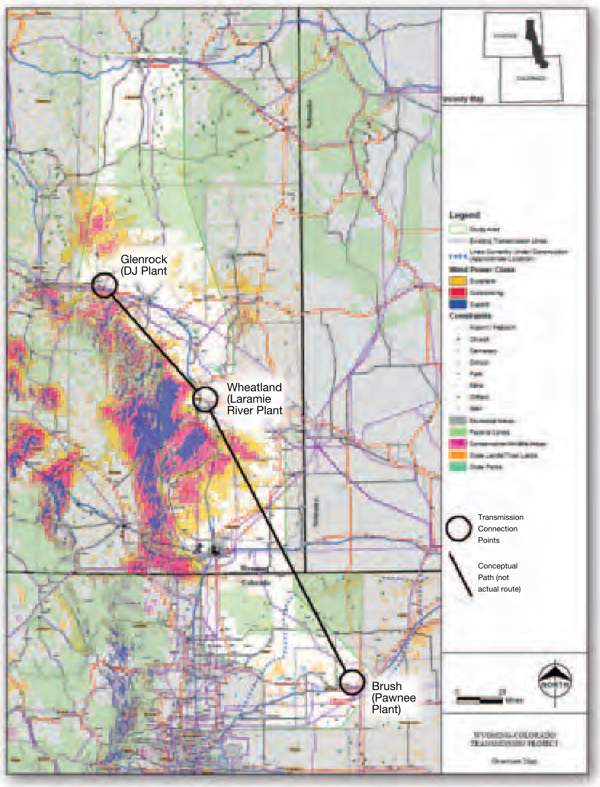


Figure 2-20: Wyoming-Colorado Intertie Project

Wyoming-Colorado Intertie Project (WCIP) (TOT3)

Project Sponsor/Partners: Wyoming Infrastructure Authority, Trans-Elect, and Western Area Power Administration (WAPA).

Website Link: www.wyia.org/wci

Project Summary: The WCI is a new transmission line that would add capacity to a long-standing bottleneck (known as TOT 3 or Path 36) in the region's transmission system and which was recommended for development in the Rocky Mountain Area Transmission Study. It is a 180 mile long 345 kV line that would link SE Wyoming to the Fort Morgan, CO area for delivering 900 MW of low-cost, clean power (primarily wind) to Colorado Front Range markets. Capacity on the line will be auctioned in early 2008 for a 2013 on-line date (Figure 2-20). WCI is being considered as a component of HPX and as such, may be "overbuilt" to 500 kV and initially operated at 345 kV.

Xcel Solar Power Plan Catching On

Denver Business Journal
November 26, 2007

Xcel Energy Inc., Colorado's largest utility, connected its 1,000th small-solar customer to the grid on Monday. Xcel's "Solar*Rewards" program, which gives customers rebates to help cover the cost of buying and installing solar panels on their homes and small businesses to generate electricity, has grown rapidly in the last 18 months.

To date, Xcel has handed out $19.5 million in rebates and payments for "Renewable Energy Credits" for customers offering solar power for use in their homes, businesses and to the utility. The money comes from a special charge on every Xcel customers' bill in Colorado. Currently, customers pay an extra 0.6 percent, or roughly 36 cents on a $60 monthly electricity bill. The charge currently brings Xcel $13 million a year, a spokeswoman said.

Last week Xcel asked the Colorado Public Utilities Commission to raise the charge to 2 percent of a customer's monthly bill — the maximum allowed by the Legislature.

Raising the charge from 0.6 to 2 percent would bring Xcel an additional $33 million a year to spend on new, bigger renewable energy programs. Xcel said in early 2008 the company will issue three requests for proposals: large, on-site solar power systems that can generate between 100 kilowatts and 2 megawatts of power; a second RFP for up to 25 megawatts of solar-generated power from a single location; and a third RFP for 300 megawatts of wind-generated power.

In Xcel's Solar*Rewards program, customers receive $2 per watt of solar panels installed on their property, up to 10 kilowatts. Xcel also buys, for $2.50 per watt, the "renewable energy credits" generated by the solar systems. Xcel uses the credits to count toward its state-mandated goal of getting 20 percent of its electricity from renewable resources by 2020. Xcel said a common size for residential photovoltaic systems in Colorado is 2 to 3 kilowatts, and total payments to customers for this size would be in the $9,000 to $13,500 range. This would cover approximately half of the installation cost, since typical photovoltaic systems are priced at $8,000 to $10,000 per kilowatt.

"This program not only helps us meet the Renewable Energy Standard, it also adds emissions-free electricity to our grid," said Tim Taylor, president and CEO, of Xcel's Colorado arm, Public Service Company of Colorado. "To date, we have added more than 4.3 megawatts of power to our system through this program. We look forward to adding a number of other customers to the program." Xcel said it will continue to expand the program to meet Colorado's Renewable Energy Standard, 20 percent of sale from renewable energy sources by 2020. The company said it is wants to have an additional 29 megawatts of customer owned, on-site solar power added to the system by 2015.

Analysis of Generation Development Areas for Wind and Concentrating Solar Power

David Hurlbut and Donna Heimiller, National Renewable Energy Laboratory

This analysis, conducted by NREL for the Colorado Senate Bill 91 Renewable Resource Generation Development Area Task Force, assesses the production potential of generation development areas (GDAs) identified by the Task Force for wind power and concentrating solar power (CSP). Aside from large-scale hydroelectric projects, these are the two predominant technologies for utility-scale electric generation from renewable energy.

A similar analysis was not done for community-scale and small-scale wind, solar, geothermal, hydroelectric, biomass, and landfill gas resources because these electricity resources are functionally different from utility-scale power plants in ways that make resource clustering less meaningful. First, a utility-scale power plant need not be located near the load it will serve. Second, utility-scale power plants entail major transmission investment, the cost of which is normally recovered from customers through the utility's rate base, and which usually involves the exercise of eminent domain to acquire easements. Third, the burden of permitting, financing, and building new transmission lines and the need to reduce overall cost through economies of scale make resources that are geographically concentrated more valuable to ratepayers than those that are not. By contrast, analysis of community-scale and small-scale resources does not involve large transmission investment. Moreover, the geographic concentration of small-scale resources within a particular area on a map is not a crucial factor affecting the decision by a community, business or individual to purchase equipment. Therefore, the fact that these resources have not been analyzed in the same way as wind and CSP reflects the dispersed, localized nature of these resources and their economic drivers, not their potential or need.

Once the Task Force delineated the boundaries of all the GDAs on a map, NREL developed standard supply curves to quantify the resource potential within each. The supply curves indicate how much capacity the GDA can theoretically accommodate, and the relative cost of developing it. Costs were calculated as the levelized cost of energy (LCOE) over the life of the project under standard economic assumptions.

The supply curves describe the number and quality of siting options for development within the GDA based on natural resource endowment. They are not intended to suggest the total amount of wind power or CSP that would be developed in a GDA. For example, the CSP supply curve for the San Luis Valley indicates a potential of 240 GW. A precise and practical interpretation of this number is that if a developer wanted to build a 100 MW CSP plant somewhere in the San Luis Valley, there are there are potentially 2,400 sites with similar development costs that would produce roughly the same amount of electricity.

Supply curves for wind GDAs

The boundaries of the eight wind GDAs generally follow wind classes, which categorize locations on a scale of one to seven based on average annual wind speed and the related wind power potential. The wind GDAs identified by the Task Force generally comprise areas that are Class 4 or better.

NREL applied its geographic information system (GIS) tools and data to the GDAs to determine the total area for each wind class. Field experience indicates that a typical utility-scale wind farm can optimally accommodate 5 MW of generating capacity for every square kilometer covered; this factor was used to convert square kilometers of area into an estimate of the capacity (in megawatts) that could be installed in a GDA to take advantage of a particular wind class. Screens were applied to exclude wilderness areas, national parks, towns and airports.

The analysis then applied a generic capacity factor to each wind class contained within the GDA. A capacity factor indicates the extent to which a generating unit is used to its full potential. A capacity factor near 100% indicates a unit runs near maximum capacity all the time; a unit running at full capacity half of the time, and half capacity the rest of the time, would have a capacity factor of 75%. Weaker and more intermittent wind reduces a turbine's capacity factor, resulting in less total output and higher average cost of electricity. The capacity factors applied to various wind classes are as follows:

Wind class	Primary location	Capacity factor	Cost per MWh
Class 7	Wyoming border, west of Pueblo	49.6%	$33-$39
Class 6		43.6%	$38-$45
Class 5		39.8%	$42-$49
Class 4	eastern Colorado	33.8%	$51-$59
Fossil Fuel Benchmark			$57
($6/mmBtu natural gas price ¥ 9 mmBtu/MWh heat rate + 5% O&M adder)			

The next step was to estimate the LCOE of wind power assuming the capacity factor corresponding to each wind class. The economic assumptions used to derive the cost per MWh estimates were taken largely from the most recent similar analysis of cost, which was conducted by Black & Veatch for three Arizona utilities and completed in September 2007. The assumed values and their directional sensitivities are as follows:

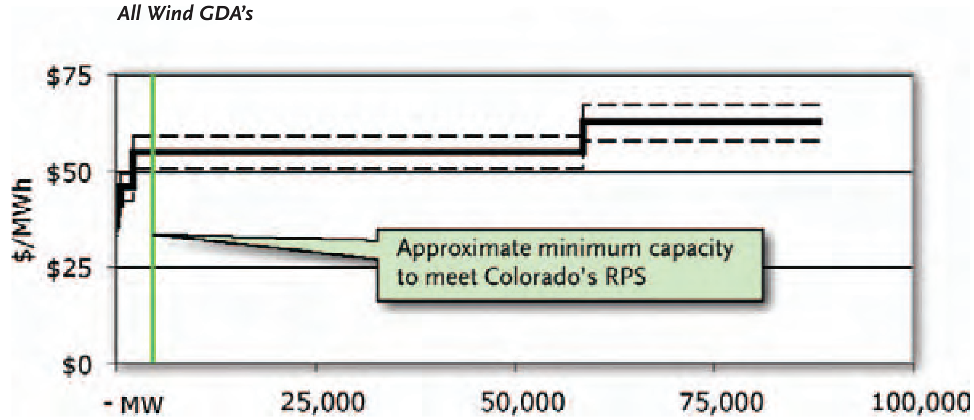
Variable	Assumed Value	If actual value is higher levelized cost will be
Capacity factor	see previous table	lower
Capital cost	$1.6 million - $1.9 million/MW	higher
Debt financing	70%	higher
Debt term	15 years	lower
Debt interest	8%	higher
Fixed O&M	$28,000 per MW per year	higher
Variable O&M	$8/MWh	higher
Federal income tax	35%	lower
Colorado income tax	4.63%	lower
Accelerated depreciation	5 years (mid-year convention)	NA
Production tax credit	$20/MWh for 10 years	lower
Project life	20 years	lower
Discount rate	10%	lower

The net cost for each year was calculated as the annualized capital cost plus operating and maintenance (O&M) costs, less production tax credits and accelerated depreciation benefits, divided by the expected annual electrical output. A 10% discount rate was applied to the cost stream over the economic life of the project.

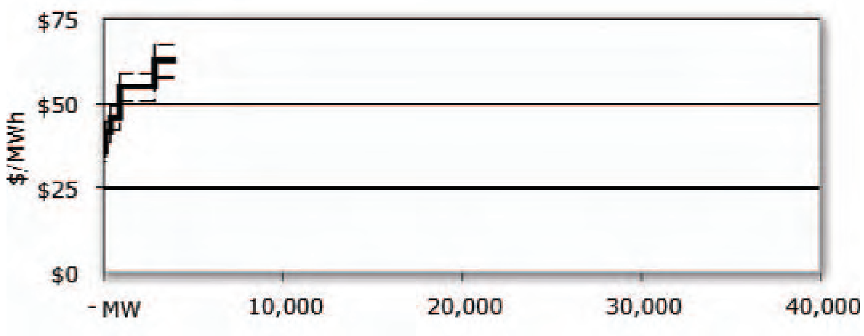
To approximate possible variations in the assumptions listed above, the analysis calculated LCOE under high and low capital cost assumptions for capital costs. The dashed lines on the following charts show the LCOE under high and low assumptions; the dark solid line indicates the midpoint. With the remaining values held constant, the only factor causing LCOE to change is the capacity factor associated with each wind class.

The following chart depicts the combined capacity potential of all eight GDAs taken together (Class 3 wind or better). The potential capacity at sites with Class 4 wind or better is roughly 12 times what would be needed to fully satisfy Colorado's RPS in 2020. About 4% of that potential is Class 5 or better.

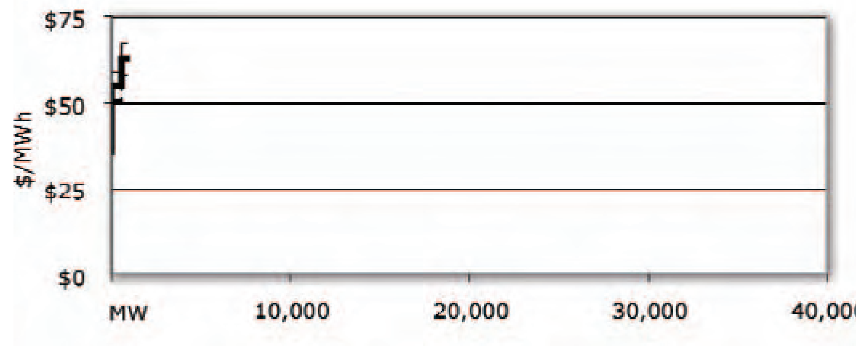
All Wind GDA's



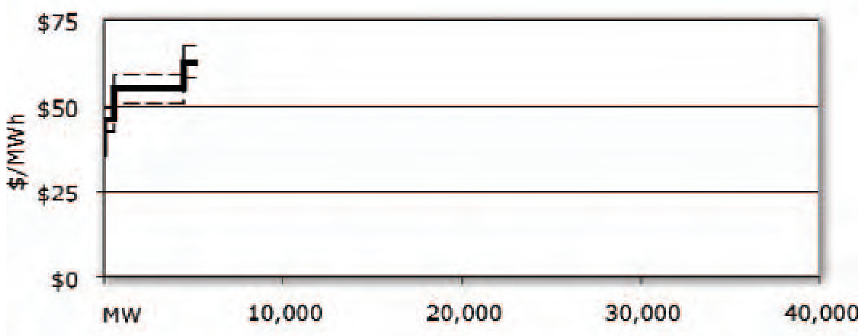
Wind GDA 1 – North-central



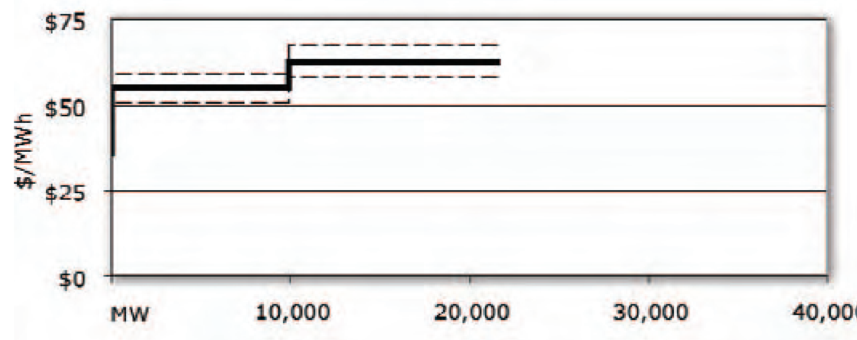
Wind GDA 4 – East-central



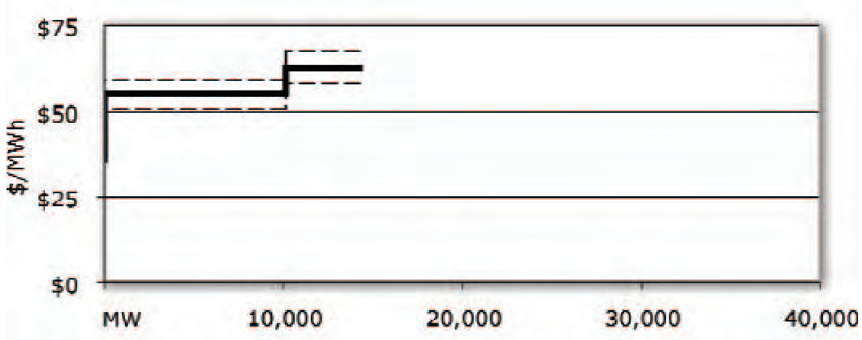
Wind GDA 2 – North-east



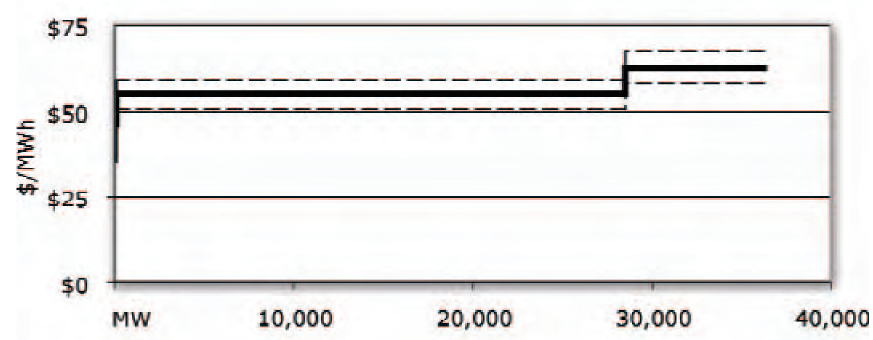
Wind GDA 5 – East-central



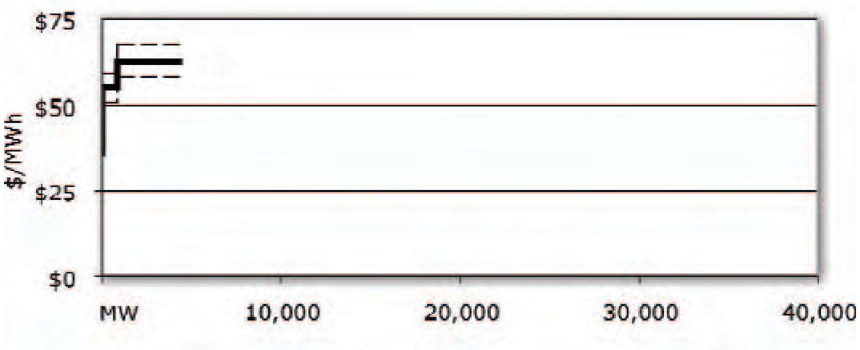
Wind GDA 3 – North-east



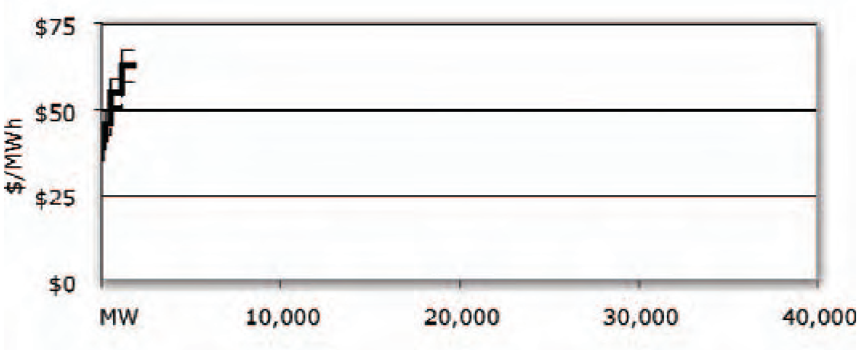
Wind GDA 6 – South



Wind GDA 7 – Front-east



Wind GDA8 – Walsenburg



The location of each wind GDA identified by the Task Force is shown on the map on on page 9. As indicated in the legend, shading indicates the different wind classes 50 meters above the ground.

The supply curves for each GDA are shown in the following charts. The GDA-specific curves show that while the largest wind power potential is in southeastern Colorado (wind GDA 6), the least-cost potential sites are mostly along the eastern Colorado-Wyoming border (wind GDAs 1 and 2).

Supply curves for concentrating solar power GDAs

The CSP supply curves were obtained using the Solar Advisor Model (SAM) developed by NREL, Sandia National Laboratory, and the U.S. Department of Energy's Solar Energy Technology Program (SETP). SAM was designed to evaluate several types of financing (from residential to utility-scale) and a variety of technology-specific cost models for several and, eventually, all SETP technologies. The SETP technologies currently represented in SAM include CSP parabolic trough systems, and photovoltaic (PV) flat plate and concentrating technologies. Other technologies to be added once validated include dish collectors, Stirling engines, power towers, and solar heating (primarily solar residential hot water).

SAM is available for download via the Internet at https://www.nrel.gov/analysis/sam/, and will run on a standard personal computer. Site-specific solar radiation data may be obtained via a Google Earth tool at https://rpm.nrel.gov/rpmentry/; downloaded data are in a format that enables direct import to SAM. With these two tools, the reader may recalculate the LCOE for CSP under scenarios with assumptions different from those used here.

This analysis used a parabolic trough system with thermal storage capabilities as a representative CSP technology. The economic assumptions used to derive the cost estimates for the two CSP areas are as follows:

Variable	Assumed Value	If actual value is higher levelized cost will be
Parabolic trough	100 MWe	NA
Molten salt storage	6 hours	NA
Solar field cost	$225-$275/m2	higher
Capital cost	$4.2 million - $4.8 million per MW	higher
Debt financing	70%	higher
Debt term	20 years	lower
Debt interest	8%	higher
Fixed O&M	$65,000 per MW per year	higher
Variable O&M	$0.70/MWh	higher
Federal income tax	35%	lower
Colorado income tax	4.63%	lower
Accelerated depreciation	5 years (mid-year convention)	NA
Investment tax credit	10%	lower
Project life	30 years	lower
Discount rate	10%	lower

Note that the costs resulting from the analysis described above do not attempt to optimize the financial structure associated with the project. Nor does it account for the capital cost reductions associated with the current 30% investment tax credit (ITC). The current 30% ITC is set to expire at the end of 2008 although there is significant pressure being applied to Congress to extend the 30% ITC through 2016. The analysis also assumes a reference 100MW plant rather than the 200MW plant recently announced in Xcel's integrated resource plan. Economies of scale in both capital and O&M costs would likely reduce the LCOE of the plant. Finally, this analysis assumes current costs and does not account for future cost reductions. Such gains are likely if there is a significant CSP build out in the Southwest or elsewhere prior to a build out in Colorado.

The SAM interface has no portal to specify direct normal insolation (DNI) values as shown in the legend to the CSP maps developed by the Task Force. To approximate those values, this analysis used the Google Earth tool to obtain data from a point corresponding to the highest DNI shown for San Luis Valley, and another from a point corresponding to the lowest value shown for the valley. LCOE was calculated using these two values, with LCOEs for intermediate values interpolated as a linear trend using a standard spreadsheet.

The GDAs for CSP identified by the Task Force are shown in the map on page 13.

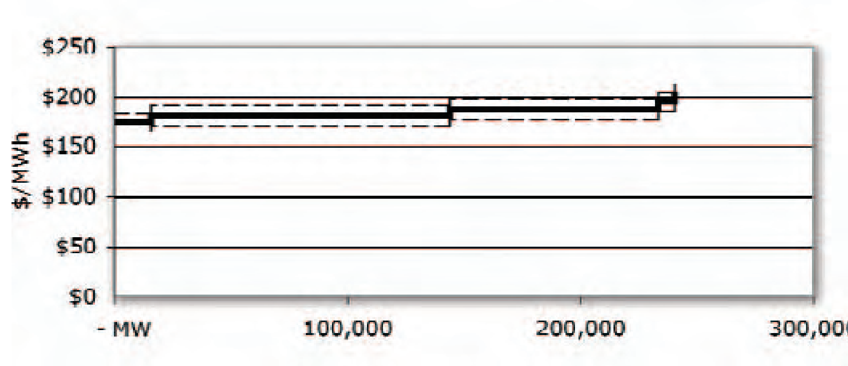
Within these two areas, a GIS screen was applied to exclude areas with a land slope of more than 1%. While CSP may be developed on land with a greater slope, the effect of applying this screen was to increase the homogeneity of likely development costs for areas with comparable DNI. As with the wind GDAs, other GIS screens excluded wilderness areas, national parks, towns and airports.

The CSP supply curves for the San Luis Valley and the area south and east of Pueblo are shown below. Note that while the perimeter of the latter is greater than that of the San Luis Valley GDA, more area inside the eastern area was screened out of the analysis. Consequently, the effective capacity potential for the GDA south and east of Pueblo is much less than that identified for the San Luis Valley.

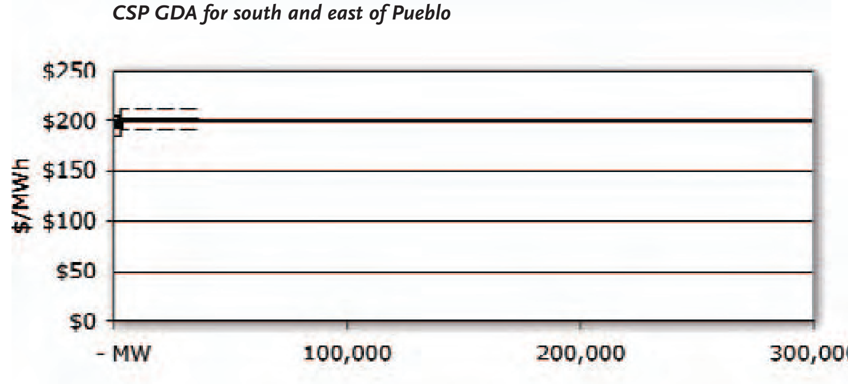
The analysis identified a technical potential of 240 GW for prime-location CSP in the San Luis Valley, with an average cost of $181 to $202 per MWh for current technology. The technical potential for the area south and east of Pueblo was 35 GW, with an average cost for current technology of $190 to $211 per MWh. (Costs are calculated using nominal dollars, not adjusted for future inflation.) In other words,

- in the San Luis Valley there are 2,400 potential sites for a 100 MW CSP plant, with likely costs of between $181 and $202 per MWh; and
- in the area south and east of Pueblo there are potentially 350 sites for a 100 MW CSP plant, with likely costs of between $190 and $211 per MWh.

CSP GDA for San Luis Valley



CSP GDA for south and east of Pueblo



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