US Department of the Interior
Bureau of Land Management
Uncompahgre Field Office, Colorado

Resource Management Plan Revision and Environmental Impact Statement

RENEWABLE ENERGY POTENTIAL REPORT

MAY 2010

TABLE OF CONTENTS

Chapter Page

1. INTRODUCTION 1-1

1.1 Purpose of this Report 1-1
1.2 Renewable Energy-Related BLM Policies and Regulations 1-1
1.3 How to Read This Document ..... **Error! Bookmark not defined.**

2. GEOTHERMAL ENERGY 2-1

2.1 What is Geothermal Energy? 2-1
2.1.1 Direct Use 2-1
2.1.2 Indirect Use 2-2
2.2 How is Geothermal Energy Developed? 2-2
2.2.1 Flash Steam Power Plants 2-2
2.2.2 Binary-cycle Power Plants 2-2
2.2.3 Dry Steam Power Plants 2-2
2.2.4 Emerging Technologies 2-3
2.3 What BLM Actions are Involved in Geothermal Energy Development? 2-4
2.3.1 Geothermal Leasing Laws and Regulations 2-4
2.3.2 Available and Unavailable Lands for Geothermal Leasing 2-4
2.3.3 Leasing Process, Rights, and Limitations 2-5
2.4 How are Potential Levels Defined for Geothermal Energy? 2-7
2.5 Geothermal Potential 2-8
2.5.1 Data Sources 2-8
2.5.2 Geothermal Potential Data Used in this Report 2-9
2.6 Potential Areas within the Uncompahgre RMP Planning Area 2-9
2.7 Reasonable Foreseeable Development Scenario 2-10

3. SOLAR ENERGY 3-1

3.1 What is Solar Energy? 3-1
3.2 How is Solar Energy Developed? 3-1
3.2.1 Photovoltaic Systems 3-2
3.2.2 Concentrating Solar Power Systems 3-3
3.2.3 Thermal Energy Storage 3-4
3.2.4 Emerging Technologies 3-4
3.3 What BLM Actions are Involved in Solar Energy Development? 3-4
3.4 How are Potential Levels Defined for Solar Energy? 3-5
3.5 Solar Potential 3-6
3.5.1 Data Sources 3-6
3.5.2 Solar Potential Data Used in This Report 3-8
3.6 Potential Areas within the Uncompahgre RMP Planning Area 3-8
3.7 Reasonable Foreseeable Development Scenario 3-8

TABLE OF CONTENTS *(continued)*

Chapter Page

4. WIND ENERGY 4-1

4.1 What is Wind Energy? 4-1
4.2 How is Wind Energy Developed? 4-1
4.3 What BLM Actions are Involved in Wind Energy Development? 4-2
4.4 How are Potential Levels Defined for Wind Energy? 4-3
4.5 Wind Potential 4-4
4.5.1 Data Sources 4-4
4.5.2 Wind Potential Data Used in this Report 4-6
4.6 Potential Areas within the Uncompahgre RMP Planning Area 4-6
4.7 Reasonable Foreseeable Development Scenario 4-6

5. BIOMASS 5-1

5.1 What is Biomass? 5-1
5.2 How is Energy Produced from Biomass? 5-1
5.2.1 Direct-firing 5-1
5.2.2 Co-firing 5-2
5.2.3 Gasification 5-2
5.2.4 Pyrolysis 5-2
5.2.5 Anaerobic Digestion 5-2
5.3 What BLM Actions are Involved in Biomass Projects? 5-2
5.4 How are Potential Levels Defined for Biomass-producing Areas? 5-3
5.5 Biomass Productivity 5-3
5.5.1 Data Sources 5-3
5.5.2 Biomass Productivity Data Used in this Report 5-4
5.6 Biomass Productivity within the Uncompahgre RMP Planning Area 5-6
5.7 Reasonable Foreseeable Development Scenario 5-4

6. REFERENCES 6-1

FIGURES

Page

Figure 1-1 Uncompahgre RMP Planning Area 1-3
Figure 2-1 Federal Mineral Estate 2-11
Figure 2-2 Geothermal Potential Area in the UFO ..... **Error! Bookmark not defined.**
Figure 2-3 Geothermal Heat Flow Contours 2-14
Figure 3-1 Solar Energy Potential 3-9
Figure 3-2 Developable Areas for Concentrating Solar Power 3-13
Figure 4-1 Wind Potential 4-7
Figure 5-1 Biomass Productivity 5-5

TABLES

Page

Table 4-1 Classes of Wind Power Density at 10 Meters and 50 Meters 4-5

ACRONYMS AND ABBREVIATIONS

	Full Phrase
BLM	United States Department of the Interior, Bureau of Land Management
CFR	Code of Federal Regulations
DOE	Department of Energy
EIS	Environmental Impact Statement
GIS	Geographic Information System
kWh/m^2/day	kilowatt-hour per square meter per day
NDVI	normalized difference vegetation index
NREL	National Renewable Energy Laboratory
ROW	right-of-way
UFO	Uncompahgre Field Office
US	United States

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CHAPTER 1
INTRODUCTION

1.1 PURPOSE OF THIS REPORT

The purpose of this report is to identify the potential for development and potential location of renewable energy on lands administered by the United States (US) Department of the Interior, Bureau of Land Management (BLM) within the Uncompahgre Field Office (UFO) Resource Management Plan planning area. The planning area encompasses 675,700 acres of public (BLM-administered) land in six Colorado counties: Montrose, Delta, Mesa, Gunnison, Ouray and San Miguel (**Figure 1-1**). It excludes the Gunnison Gorge and Dominguez-Escalante National Conservation Areas. Renewable energy addressed in this report includes geothermal, solar, wind, and biomass. In the case of solar, wind, and biomass energy, lands considered are all BLM-administered public lands in the planning area (675,700 acres). In the case of geothermal energy, lands considered are both BLM-administered public lands, as well as additional lands under other surface ownership (such as US Forest Service, private, or State lands) where the BLM controls the mineral estate ("split estate" lands). In total, lands considered for geothermal energy include 2.2 million acres of federal (subsurface) mineral estate.

1.2 RENEWABLE ENERGY-RELATED BLM POLICIES AND REGULATIONS

At the time of writing of this report, the BLM's renewable energy policy is directed by the regulations and executive orders listed below. The policies and procedures cited in this report are applicable at the time of writing but are expected to evolve over the timeframe of the RMP. Also at this time of writing, a new BLM solar energy policy is in preparation but was not completed in time for incorporation into this report. The right-of-way (ROW) authorization process, which is particularly important for solar and wind projects, is also expected to change over time.

As of 2010, the BLM's renewable energy policy is directed by the following regulations and executive orders:

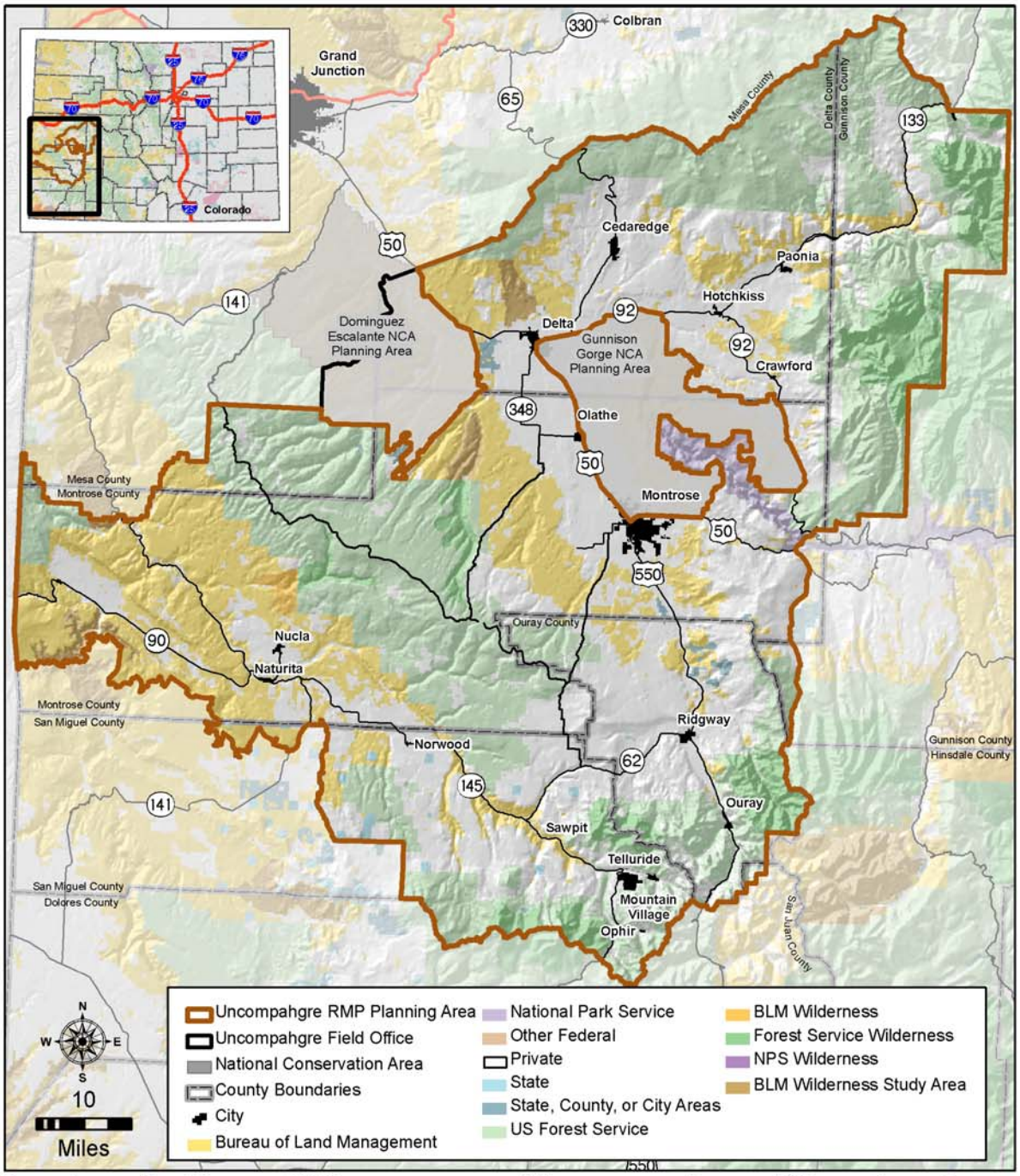
- The Geothermal Steam Act of 1970, as amended, designates the BLM as being responsible for leasing Federal lands and reviewing permit applications for geothermal development. This authority encompasses about 570 million acres of

BLM land, National Forest System lands (with concurrence of the Forest Service), and other Federal lands, as well as private lands where the mineral rights have been retained by the Federal Government.

- The Energy Policy Act of 2005 (Title II, Sec. 211), which requires the US Department of the Interior to approve at least 10,000 megawatts of renewable energy on public lands by 2015;
- The Energy Policy Act of 2005 (Title II, Sec. 222(d)), which requires that all future forest plans and RMPs in areas of geothermal resource potential consider geothermal leasing and development;
- The Energy Policy Act of 2005 (Title II, Sec. 223), which gives the Secretary of Interior authority to identify areas that could be leased exclusively for direct use of geothermal resources;
- Executive Order 13212, Actions to Expedite Energy-Related Projects, which requires federal agencies to expedite review of energy project applications; and
- Secretarial Order 3285, which requires the US Department of the Interior to identify and prioritize specific locations best suited for large-scale renewable energy production.

Additionally, the BLM has specific guidance for certain types of renewable energy. These are discussed in the respective energy-specific sections of this report. The main Instruction Memoranda are summarized here:

- 43 CFR 3200 provides the **Geothermal** Resource Leasing Rules and Regulations for the BLM.
- Instruction Memorandum 2009-022, **Geothermal** Leasing under the Energy Policy Act of 2005 (BLM 2009a), provides guidance for geothermal leasing.
- Instruction Memorandum 2007-097, **Solar** Energy Development Policy (BLM 2007), establishes policy for the processing of right-of-way (ROW) applications for solar energy development projects on BLM-administered lands and evaluating the feasibility of installing solar energy systems on BLM administrative facilities and projects.
- Instruction Memorandum 2006-216, **Wind** Energy Development Policy (BLM 2006), provides guidance on implementing the Record of Decision for the Programmatic Environmental Impact Statement (EIS) on Wind Energy Development (BLM 2005) and processing ROW applications for wind energy projects on BLM-administered lands; Instruction Memorandum 2009-043, Wind Energy Development Policy (BLM 2009b), provides updated guidance on processing ROW applications for wind energy projects on BLM-administered lands.



Source: Bureau of Land Management 2010

Uncompahgre Planning Area

Datum: NAD 83
Projection: UTM, Zone 13

The Bureau of Land Management (BLM) attempts to use the most current and complete geospatial data available. No warranty is made by the BLM as to the accuracy, reliability, or completeness of this data. Using this map for other than its intended purpose may yield inaccurate or misleading results.

Figure 1-1

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- Instruction Memorandum 2004-227, **Biomass** Utilization Strategy (BLM 2004), updated in July 2005, provides sets of goals to help focus and increase utilization of biomass from BLM lands. In June 2005, the final rule in the *Federal Register* revised the authority of 48 Code of Federal Regulations (CFR) Part 1452 by adding 1452.237-71, which is a new contract clause for removal and utilization of woody biomass generated as a result of land management service contracts whenever ecologically and lawfully appropriate. The BLM issued Instruction Memorandum 2009-120 in May 2009, which updated the contract clause for utilization for woody biomass.

Solar, wind, and some aspects of geothermal projects are authorized via the right-of-way (ROW) process. Right-of-way applications for development on BLM lands must be accompanied by a processing fee as set forth in 43 CFR 2804.14. Right-of-way applications are generally accepted and processed on a first-come, first-served basis. The ROW regulations (43 CFR 2804.23[c]) provide authority for offering public lands under competitive bidding procedures for ROW authorizations. The BLM initiates a competitive process if a land use planning decision has specifically identified an area for competitive leasing. The BLM may also consider other public interest and technical factors in determining whether to offer lands for competitive leasing. Competitive bidding follows procedures required by 43 CFR 2804.23(c).

1.3 How to Read This Document

This report contains separate chapters for each of the four types of renewable energy considered: geothermal, solar, wind, and biomass. Each chapter contains a flow of information designed to provide a basic understanding of the energy type, the technologies used to harness that energy, the process of developing (making use of) that energy, and the BLM action involved. Each chapter then describes how potential levels are commonly defined for each energy type, including an overview of scientific terminology and units. Each chapter explains the major resource assessments that are commonly used to assess potential within an area and defines which source data is used for conducting the assessment in this report. Each chapter provides an overview of the potential energy levels across planning area lands (and, for geothermal, on split-estate lands) and estimates where development is likely to occur in the next 15 to 20 years through the presentation of a reasonable foreseeable development scenario.

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CHAPTER 2
GEOTHERMAL ENERGY

2.1 WHAT IS GEOTHERMAL ENERGY?

Geothermal energy is energy derived from the natural heat of the earth. Geothermal resources are typically underground reservoirs of hot water or steam created by heat from the earth, but geothermal resources also include subsurface areas of dry hot rock. In cases where the reservoir is dry hot rock, the energy is captured through the injection of cool water from the surface, which is then heated by the hot rock and extracted as fluid or steam. Geothermal steam and hot water can naturally reach the earth's surface in the form of hot springs, geysers, mud pots, or steam vents. Geothermal reservoirs of hot water are also found at various depths beneath the earth's surface. By drilling wells down into a geothermal reservoir, heat can be brought to the surface and be used either directly (direct use) for heating applications or indirectly (indirect use) to produce electricity.

According to the 43 CFR 3200, Geothermal Resource Leasing Rules and Regulations, the BLM is allowed to lease "geothermal steam and associated geothermal resources," which are defined as 1) all products of geothermal processes, including indigenous steam, hot water, and hot brines; 2) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations; 3) heat or other associated energy found in geothermal formations; and 4) any byproducts.

2.1.1 Direct Use

Geothermal reservoirs of low- to moderate-temperature water—68 degrees Fahrenheit to 302 degrees Fahrenheit (20 degrees Celsius to 150 degrees Celsius)—provide numerous opportunities for direct use. Direct use means utilization of geothermal resources for commercial, residential, agricultural, public facilities, or other energy needs other than the commercial production of electricity (43 CFR 3200.1). Direct use includes using heat energy from naturally occurring hot water or using other technology to capture the heat from the earth (e.g., heat pumps). Modern hot water direct-use systems access geothermal reservoirs by drilling into them from the surface to develop a steady stream of hot water. The water is brought up through the well, and a mechanical system consisting of piping, a heat exchanger, and controls

delivers the heat directly for its intended use. A disposal system then either injects the cooled water underground or disposes of it on the surface.

2.1.2 Indirect Use

Commercial electrical generation from geothermal resources is also called indirect use. Electrical generation uses geothermally heated fluid to produce steam, which turns a turbine connected to a generator. As discussed below, the fluid may be the naturally occurring steam or water in the geothermal reservoir or another fluid that has the geothermal heat transferred through a heat exchange system.

2.2 HOW IS GEOTHERMAL ENERGY DEVELOPED?

Geothermal power plants can be small (300 kilowatts to 10 megawatts), medium (10 to 50 megawatts) or large (50 megawatts and higher). Generation capacity is guided by the number of turbines within a plant. In general, commercial electrical generation requires hot geothermal reservoirs with a water temperature above 200 degrees Fahrenheit (93 degrees Celsius); however, new technologies have proven that lower-temperature water (e.g., 165 degrees Fahrenheit [74 degrees Celsius]) can also be used for electrical generation.

Three types of geothermal power plant systems—flash steam, binary-cycle, and dry steam—are commonly used to generate electricity depending on temperature, depth, and quality of the water and steam in the area. These plants can also be hybridized by including elements of the different technologies at a single location. All three methods re-inject the remaining geothermal fluid back into the ground to replenish the reservoir and recycle the hot water.

2.2.1 Flash Steam Power Plants

Flash steam power plants use hot water above 360 degrees Fahrenheit (182 degrees Celsius) from geothermal reservoirs. The high pressure underground keeps the water in the liquid state, although it is well above water's boiling point at standard atmospheric pressure. As the water is pumped from the deep, pressurized reservoir to the power plant at atmospheric pressure, the drop in pressure causes the water to convert, or "flash," into steam to power the turbine. Any water not converted into steam is injected back into the reservoir for reuse. Flash steam plants, like dry steam plants, emit small amounts of gases and steam.

2.2.2 Binary-cycle Power Plants

Binary-cycle power plants typically use cooler fluids than flash steam plants (165 to 360 degrees Fahrenheit [74 to 182 degrees Celsius]). The hot fluid from geothermal reservoirs is passed through a heat exchanger, which transfers heat to a separate pipe containing fluids with a much lower boiling point. These fluids, usually isobutane or isopentane, are vaporized to power the turbine. The advantage of binary-cycle power plants is their lower cost and increased efficiency. These plants do not emit any excess gas and, because they use fluids with a lower boiling point than water, are able to use lower-temperature geothermal reservoirs, which are much more common.

2.2.3 Dry Steam Power Plants

Dry steam power plants use very hot (greater than 455 degrees Fahrenheit [235 degrees Celsius]) geothermal reservoirs that exist primarily in the form of steam. The steam is routed to

the surface via a well and used to turn a turbine. The turbine drives a generator that produces electricity. While this is the rarest form of power plants, it was both the first type of geothermal reservoir used to produce electricity (at Lardarello, Italy, in 1904) and is the reservoir type being used at the world's largest geothermal production site, The Geysers in northern California. Dry steam power plants emit only excess steam and very minor amounts of gases. Geothermal sources with dry steam generation capability are very rare.

2.2.4 Emerging Technologies

The technologies described above are those that are in use as of the writing of this report. Leading up to 2010, there has substantial private and government investment into the development of new geothermal technologies to allow for the capture of heat from the earth at deeper temperatures and in locations where heat is present but water and fractured rock are not. The following paragraphs discuss emerging technologies known at the time of this writing. It is expected that further technological advancements will be made over time timeframe of the RMP.

Geothermal Energy from Oil and Gas Production

Oil and gas wells are typically thousands of feet deep and often produce very hot fluid. Along with the oil and gas, wells produce water that must be separated from the oil and gas and usually reinjected deep below domestic aquifers. The Rocky Mountain Oilfield Testing Center, located in the Teapot Dome Oilfield near Casper, Wyoming, is demonstrating the use of warm reservoir fluids from oil and gas production to produce electricity that can be used to power the oil and gas pumps (Rocky Mountain Oilfield Testing Center produced water cut (NREL 2006). Because the electricity is used on site, there is no need to purchase additional electricity, which eliminates the need for power lines to be run to oil and gas facilities. This technology could be applied at many oil and gas facilities throughout the West.

Enhance Geothermal Systems

Enhanced geothermal systems are engineered reservoirs created to produce energy from geothermal resources deficient in water and/or permeability (US Department of Energy 2006, 2007). With enhanced geothermal systems, a developing reservoir is targeted within a volume of rock that is hot and tectonically stressed. Through a combination of hydraulic, thermal, and chemical processes, the reservoir can be stimulated, causing fractures to open, extend, and interconnect. This creates a fluid-conductive fracture network and an interconnected reservoir system. The process can extend the margins of existing geothermal systems or can create entirely new ones wherever optimal thermal and tectonic conditions exist (University of Utah Energy and Geoscience Institute 2007). Enhanced geothermal systems technology is relatively new in the geothermal field and has been found to have great potential for providing electrical power; one study found the potential for 100 gigawatts of power (US Department of Energy 2006). Until recently, lack of research and development funding, government policies, and lack of incentives had not favored the growth of enhanced geothermal systems, with most development occurring outside of the United States (US Department of Energy 2006). It is anticipated that there may be applications for research and development drilling on public and NFS lands in the future. Until it becomes a technically and economically proven technology, it is unlikely that it will be applied at a large scale in the western US within the next 20 years.

2.3 WHAT BLM ACTIONS ARE INVOLVED IN GEOTHERMAL ENERGY DEVELOPMENT?

2.3.1 Geothermal Leasing Laws and Regulations

A geothermal lease is for the heat resource of the earth where there is federal mineral estate. Unless specifically owned in fee, the federal government does not own the hot water commonly associated with the heat; this falls under state water laws. Geothermal developers must obtain the appropriate water rights and state permits in addition to the federal lease for the resource.

The BLM has the delegated authority to issue geothermal leases on federal lands. It is the policy of the federal government, consistent with Section 2 of the Mining and Mineral Policy Act of 1970 and Sections 102(a)(7), (8), and (12) of the Federal Land Policy and Management Act of 1976 (43 US Code 1701 et seq.), to encourage the development of mineral resources, including geothermal resources, on federal lands. The Geothermal Steam Act of 1970 (30 US Code Section 1001, et seq.), which was amended and supplemented by the Energy Policy Act of 2005, provides statutory guidance for geothermal leasing by the BLM. New federal geothermal development regulations (43 CFR Parts 3000, 3200, and 3280: Geothermal Resource Leasing and Geothermal Resources Unit Agreements) were made effective June 1, 2007 (72 *Federal Register* 24358, May 2, 2007) as a result of a directive provided in the Energy Policy Act of 2005. These statutes and regulations delineate lands that are available and unavailable for leasing.

All geothermal project applications are subject to environmental review in accordance with the requirements of the National Environmental Policy Act of 1969. Applications triggering environmental review are typically received at each of the following three phases of a geothermal development project: (1) exploration (seismic surveys and/or temperature gradient hole drilling); (2) drilling operations (full bore exploration well drilling and well testing); and (3) utilization (construction and utilization of power plants and transmission lines and ancillary facilities).

2.3.2 Available and Unavailable Lands for Geothermal Leasing

In accordance with the Geothermal Steam Act of 1970, as amended (30 US Code 1001) and the Geothermal Resources Leasing Rule (43 CFR 3201.10), the BLM may issue leases on the following "available" lands:

- Lands administered by the US Department of the Interior, including public and acquired lands not withdrawn from such use;
- Lands administered by the US Department of Agriculture with its concurrence;
- Lands conveyed by the US where the geothermal resources were reserved to the US; and
- Lands subject to Section 24 of the Federal Power Act, as amended (16 US Code 818), with the concurrence of the Secretary of Energy.

Conversely, the BLM is prohibited from issuing leases on the following statutorily closed federal lands as defined in the Geothermal Resources Leasing Rule (43 CFR 3201.11). Other lands administered directly by the BLM and US Department of Agriculture, Forest Service may also be closed through other authorities.

- Lands where the Secretary of the Interior has determined that issuing the lease would cause unnecessary or undue degradation of public lands and resources;
- Lands contained within a unit of the National Park System or that are otherwise administered by the National Park Service;
- Lands where the Secretary of the Interior determines after notice and comment that geothermal operations, including exploration, development, or utilization of lands, are reasonably likely to result in a significant adverse effect on a significant thermal feature within a unit of the National Park System;
- Lands within a National Recreation Area;
- Fish hatcheries or wildlife management areas administered by the Secretary of the Interior;
- Indian trust or restricted lands within or outside the boundaries of Indian reservations;
- The Island Park Geothermal Area (in Idaho and Montana); and
- Lands where Section 43 of the Mineral Leasing Act (30 US Code 226-3) prohibits geothermal leasing, including:
  - Wilderness areas administered by the BLM or other surface-management agencies;
  - Lands designated by Congress as Wilderness Study Areas, except where the statute designating the study area specifically allows leasing to continue; and
  - Lands within areas allocated for wilderness or further planning in Executive Communication 1504, Ninety-sixth Congress (House Document 96-119), unless such lands are allocated to uses other than wilderness by a land and resource management plan or are released to uses other than wilderness by an act of Congress.

2.3.3 Leasing Process, Rights, and Limitations

The BLM grants access to geothermal resources through a formalized leasing process based on the end use. For direct uses, an applicant can apply noncompetitively for a lease. For indirect use, such as commercial electrical generation, the BLM awards leases through a competitive bidding process. Historically, certain lands were designated as known geothermal resource areas. All lands designated within known geothermal resource areas were leased through a competitive bidding process. Until the passage of the Energy Policy Act of 2005, lands outside of known geothermal resource areas could be leased noncompetitively. Section 222 of the Energy Policy Act of 2005 modified the Geothermal Steam Act of 1970 to allow only competitive lease sales for all federal geothermal resources and their associated lands. The geothermal leasing regulations provide for four types of lands available for noncompetitive leasing:

- Parcels of land that did not receive bids in a competitive sale;
- Lands available exclusively for direct use;
- Lands subject to mining claim and a current plan of operation; and

- Lands for which a lease application was pending on August 8, 2005, if the applicant so chooses.

Blocks of land can either be nominated by the public or the BLM itself for inclusion in a lease sale. When the BLM receives a nomination, it is adjudicated and configured into lease parcels by the respective BLM state office. Lease parcels are then forwarded to the appropriate Field office where the Field Office determines whether the lease is in conformance with the applicable land use plan or plan amendment(s) and whether BLM can properly rely upon existing NEPA documents that analyze the potential impacts of geothermal leasing.

The four stages of geothermal resource development within a lease are exploration, drilling operations, utilization, and reclamation and abandonment. Each stage requires a permit from the BLM. Leasing geothermal resources by the BLM vests with the lessee a non-exclusive right to future exploration and an exclusive right to produce and use the geothermal resources within the lease area, subject to existing laws, regulations, formal orders, and the terms, conditions, and stipulations in or attached to the lease form or included as conditions of approval to permits. Lease issuance alone does not authorize any ground-disturbing activities to explore for or develop geothermal resources without site-specific approval for the intended operation. Such approval could include additional environmental reviews and permits. Also at each stage, the BLM can issue site-specific conditions of approval to protect resource values.

A lease is issued for a primary term of ten years and may be extended for two five-year periods. Each of these extensions is available provided the lessee meets the work commitment requirements or the lessee made payment in lieu of the minimum work requirements of each year. At any time a lease may receive a five- year drilling extension. Once commercial production is established, the lease may receive a production extension of up to 35 years and a renewal period of up to 55 years. The lease must continue to produce to remain in effect. The BLM may grant a suspension of operations and production on a lease when justified by the operator (refer to 43 CFR 3207).

Geothermal exploration and production on federal land conducted through leases is subject to terms and stipulations to comply with all applicable federal and state laws pertaining to various considerations for tribal interests, sanitation, water quality, wildlife, safety, cultural resources, and reclamation.

Exploration

The exploration phase focuses on finding potential sources of geothermal energy. The goal of geothermal exploration is to locate sites that can be used consistently into the future for the purpose of energy generation, and to evaluate the suitability of such sites for geothermal development.

There are various ways to conduct exploration, including satellite and air photo mapping, geologic and structural mapping, volcanological studies, gravity, magnetics, geochemical sampling, seismic exploration, and temperature gradient well creation.

During exploration, geologists must find areas that are consistently geologically active to justify the expense of establishing a power plant, and they must consider the environmental impact of

the energy production. In areas with limited water supplies, for example, dedicating water to geothermal production may not be feasible. Likewise, injecting water into the earth's crust can cause instability in the soil, which is not a desirable outcome. These factors all need to be taken account in geothermal exploration.

Drilling Operations

Drilling operations, which would include flow-testing wells that are drilled, would characterize the geothermal resources within the leased area to determine whether future development of geothermal resources would be feasible, and would determine whether drainage of the geothermal resource may be occurring.

If deep exploration encounters a geothermal resource, well testing would be conducted to define resource characteristics. The proponent would test each well to evaluate fluid flow and temperature and determine the potential for production as a viable geothermal energy resource. Flow testing involves using specialized equipment to measure temperature and flow rate.

Utilization

Once geothermal resources have been identified and deemed viable, the next phase focuses on building the power plant and ancillary facilities to both produce electricity and move it to the electrical power grid. This phase includes construction of the actual electrical generation facilities (power plant), roads, and transmission lines; developing the wells; and setting up the well field. This includes connecting wells to the power plant via pipelines and setting up pumping, where needed, to bring the geothermal resources to the surface and to re-inject cooled fluids.

Reclamation and Abandonment

Reclamation and abandonment activities occur after production ceases. During this phase, the site would be restored (reclaimed) to conform to BLM and FS standards. Typical activities during the reclamation phase include closure of all facilities and wells; removal of aboveground components and gravel from well pads, access roads (if not maintained for other uses), and other ancillary facility sites; recontouring the surface; and revegetation.

2.4 HOW ARE POTENTIAL LEVELS DEFINED FOR GEOTHERMAL ENERGY?

Geothermal potential is difficult to determine without site-specific exploration activities. Even in areas of supposed high potential, many exploration wells result in no viable resource. A viable resource requires high enough temperatures, the presence of water at that depth, and a sufficiently fractured geology so that the hot water can move through the rocks to the well.

At sufficient depth, sufficient heat can be found from any location on earth; however, because technical challenges and the cost of drilling increase with depth, economically and technically viable resources are those that occur closer to the earth's surface. Potential areas are those areas that are believed to (a) have temperatures high enough to either produce electricity (for indirect use) given current power plant technologies or to serve direct use functions at the surface, and (b) be at depths that are economically and technically feasible to drill, given current drilling technologies. Data collection to estimate potential areas come in the form of existing hot springs and other natural hydrothermal features, and are often combined with bottom-hole temperature data from oil, gas, water, and geothermal wells. Existing wells and their associated

data can be few and far between, particularly in remote areas, and so computer modeling has been used to develop potential maps that extrapolate this data to estimate the geographic extent of various temperatures at depth. A limited understanding of the subsurface environment renders these extrapolations fairly speculative and this is compounded in areas of sparse downhole temperature data.

Geothermal potential maps are often binary in nature, showing only potential versus non-potential. Unlike solar or wind resources where intensity of the resource is easily documented, the geothermal resource remains unknown until it is drilled into. As such, potential areas are usually identified as being inclusive of any form of usable geothermal resources. Once drilled into and evaluated, those resources are typically described as high, medium, or low temperature resources. These resource categories are typically described as follows:

- High: Greater than 300 degrees Fahrenheit.
- Medium: Between 195 and 300 degrees Fahrenheit.
- Low: Less than 195 degrees Fahrenheit.

Efficient electrical production requires a resource that is at least 40 degrees hotter than the temperature of the cooling medium used in the power plant. This medium can be air, surface water, or groundwater. Thus, hotter resources are required for areas with hotter weather. The lowest temperature resource being used for electrical generation is 153 degrees Fahrenheit, although this is being done in northern Alaska where the surface water used for cooling never rises above 45 degrees Fahrenheit.

Heat flow maps are a type of geothermal potential map that show heat flow values. Heat flow values are a measure of the heat flux moving from the earth's interior to the earth's surface. High heat flow values often indicate a high potential for geothermal development and are the result of various geologic situations such as: 1) an area of relatively thinner crustal rock above the mantle, 2) presence of an igneous pluton at depth, 3) resident heat from geologically recent volcanism or plutonic activity, or 4) upwelling of deep, heated groundwater.

2.5 GEOTHERMAL POTENTIAL

2.5.1 Data Sources

There are two main sets of geothermal resource data available: the Southern Methodist University-produced Heat Flow Map of North America (Blackwell and Richards 2004) and the Interpretive Geothermal Heat Flow Map of Colorado (Colorado Geological Survey 2008). The potential area for Colorado that was used in the Geothermal PEIS was provided by the Colorado Geological Survey and that data is discussed below. Additionally, the Geothermal PEIS includes a Reasonably Foreseeable Development scenario (RFD) for Colorado, which drew from the 2006 Western Governors' Association Geothermal Task Force Report. The 2006 report identified a total of 20 megawatts of anticipated near-term geothermal capacity over an estimated 9 sites across Colorado (Western Governors' Association 2006).

Heat Flow Map of North America

This map (Blackwell and Richards 2004) was developed using heat flow values. The map was produced from a compilation of various data sets of bottom-hole temperature data collected from oil, gas, geothermal, and water wells. Approximately 4,000 data points were used to create the map. Hot springs data were also included.

Heat flow data are not evenly distributed throughout Colorado. Small areas with clustered data surrounded by wide areas containing sparse data are characteristic of the heat flow map. As such, the contours are well constrained in areas of clustered data and more interpretive in areas of sparse data.

Interpretive Geothermal Heat Flow Map of Colorado

The Interpretive Geothermal Heat Flow Map of Colorado (Colorado Geological Survey 2008) was developed by the Colorado Geological Survey in 2007. The map shows areas of direct use or electrical power potential for Colorado. This map includes the area of all known hot spring locations along with oil and gas basins that have potential for geothermal resources by virtue of bottom-hole temperatures. Colorado geothermal heat flow and gradient data were also considered in creating the map. The Colorado Geological Survey produced a Geographic Information System (GIS) shape file boundary to define the area of geothermal potential for the Final Programmatic EIS for Geothermal Leasing in the Western US (Colorado Geological Survey 2007).

2.5.2 Geothermal Potential Data Used in this Report

The Colorado Geological Survey shape file for the Interpretive Geothermal Heat Flow Map of Colorado was used for this report because it is the most recent Colorado-specific assessment available, was produced in-state by State of Colorado geologists, and combines data from both bottom-hole temperatures and hot springs. Three maps are provided in this report: **Figure 2-1** shows the federal mineral estate across the planning area, highlighting those areas that are withdrawn from the Federal mineral estate, and those BLM- and Forest Service-administered lands that have no Federal mineral estate or an unknown Federal mineral estate status; **Figure 2-2** shows areas determined to have potential for direct or indirect use resources by the Colorado Geological Survey on lands that have Federal mineral estate within the planning area; this is the same area that was used in the Geothermal PEIS; and **Figure 2-3** shows the distribution of heat flow contours across the planning area; this data was provided by the Colorado Geological Survey and was used to determine the potential area shown in Figure 2-2, The electrical production RFD from the Geothermal PEIS, as based on the 2006 Western Governors' Association report, was also considered in this report.

2.6 POTENTIAL AREAS WITHIN THE UNCOMPAHGRE RMP PLANNING AREA

The Uncompahgre RMP decision area has 552,500 acres with Federal mineral estate and geothermal potential. Additionally, within the planning area there are:

- 1,202,300 acres of Forest Service lands that have Federal mineral estate;
- 27,100 acres of National Park Service lands that have Federal mineral estate;

- 220,000 acres of private land that have Federal mineral estate; and
- 6,300 acres of state land that have Federal mineral estate.

Additional acreages of land with Federal mineral estate and geothermal potential may be contained within the planning area on lands that have an unknown status with respect to Federal mineral estate. Of the lands within this category, 17,900 acres are on Forest Service land and 6,400 are BLM-administered. These lands are shown in Figure 2-1.

Aside from the westernmost portion, the entire planning area is considered to have geothermal potential. This is shown in Figure 2-2. Specific geothermal surface features within the planning area are limited to Orvis Hot Spring (126 degrees Fahrenheit) and Ouray Hot Spring (156 degrees Fahrenheit), which have the potential for expansion of both direct use and indirect (electrical) use applications for the communities near those resources. While neither of these hot springs are located on BLM-administered lands, such lands are nearby and could potentially be involved in future development of these geothermal resources.

2.7 REASONABLE FORESEEABLE DEVELOPMENT SCENARIO

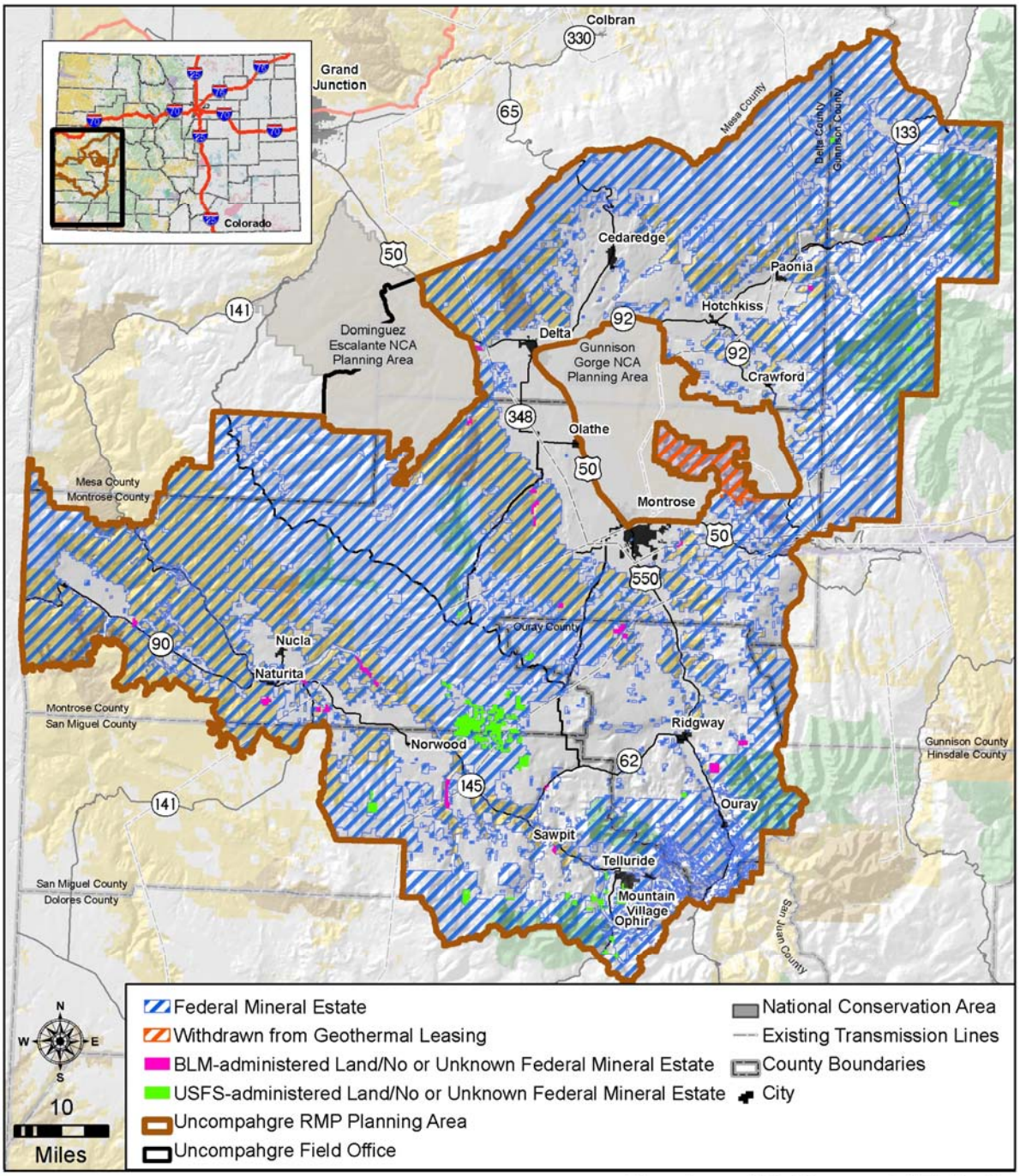
The likelihood of future development of geothermal projects in the Uncompahgre RMP planning area and BLM split-estate lands in the UFO can be estimated by considering the extent of existing geothermal resources and projects in the area, the number of pending lease applications within the UFO, the quality of geothermal resources in the UFO compared with other areas in the region, and expressions of interest by geothermal companies.

Three hot springs are in the southern part of the Uncompahgre RMP planning area; none are on BLM-administered lands:

- Orvis Hot Springs (126 degrees Fahrenheit) located approximately two miles south of the town of Ridgway on US Highway 550;
- Ouray Hot Spring (Radium Hot Spring) (156 degrees Fahrenheit) located less than one mile north of the city of Ouray on US Highway 550; and
- Lemon Hot Spring (91 degrees Fahrenheit) in the town of Placerville.

There are no geothermal facilities or pending applications for geothermal facilities in the UFO. As of March 2010, Colorado has three expressions of interest: two in the Gunnison Field Office and one in Royal Gorge Field Office near Mount Princeton. While there are no geothermal leases on BLM-administered lands anywhere in Colorado, the BLM geothermal program is relatively new and the time period leading up to and beyond year 2030 is expected to be a time of rapid expansion of renewable energy. BLM-administered lands do exist close to existing hot springs within the UFO.

The UFO is close to the Great Basin geologic unit, which extends from the western half of Utah, west to California, north into Idaho, and south into Mexico. The Great Basin is recognized as having some of the best geothermal resources in the world, and many projects are already operating or in various phases of planning of development in this region. Geothermal companies



Source: Bureau of Land Management 2010

Federal Mineral Estate

Datum: NAD 83
Projection: UTM, Zone 13

The Bureau of Land Management (BLM) attempts to use the most current and complete geospatial data available. No warranty is made by the BLM as to the accuracy, reliability, or completeness of this data. Using this map for other than its intended purpose may yield inaccurate or misleading results.

Figure shows all fluid minerals in the federal mineral estate on BLM-administered lands in the Uncompahgre RMP Planning Area regardless of current management constraints.

Figure 2-1

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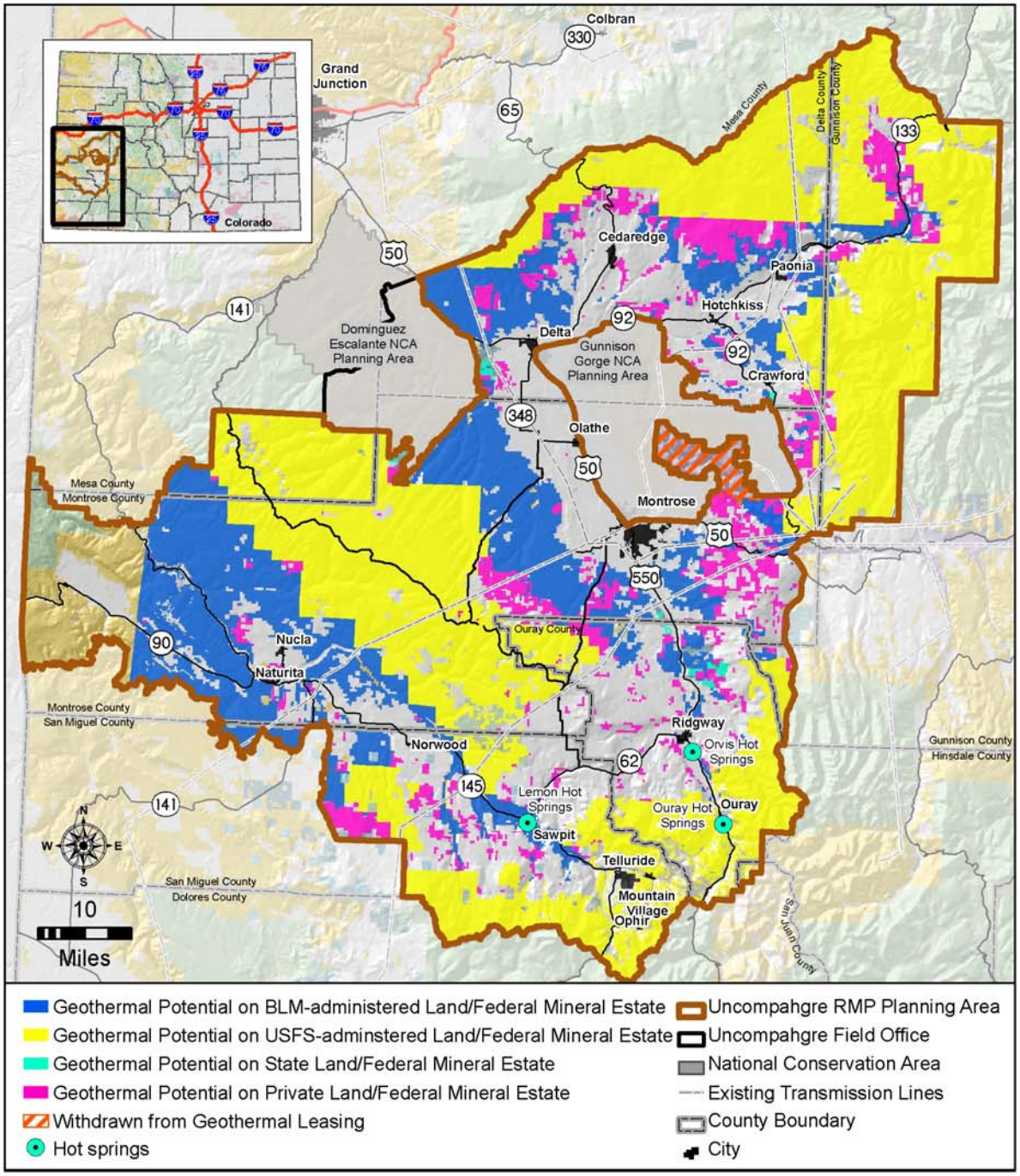

Source: Bureau of Land Management 2010, Colorado Geological Survey 2007

Geothermal Energy Potential on Federal Mineral Estate

Datum: NAD 83
Projection: UTM, Zone 13

The Bureau of Land Management (BLM) attempts to use the most current and complete geospatial data available. No warranty is made by the BLM as to the accuracy, reliability, or completeness of this data. Using this map for other than its intended purpose may yield inaccurate or misleading results.

Figure shows geothermal potential on federal mineral estate lands in the Uncompahgre RMP Planning Area regardless of current management constraints.

Figure 2-2

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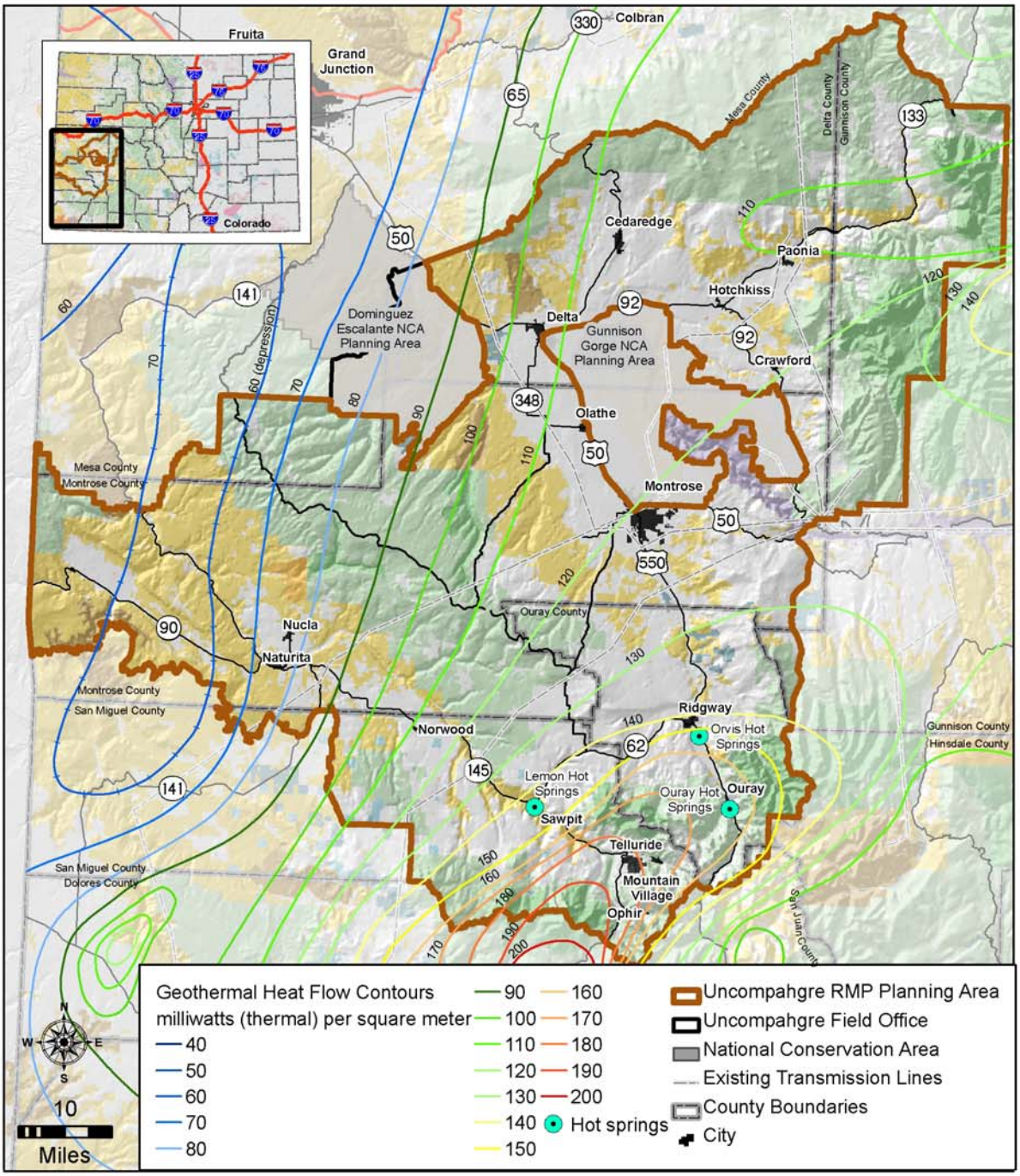

Source: Bureau of Land Management 2010, Colorado Geological Survey 2007

Geothermal Heat Flow Countours

Datum: NAD 83
Projection: UTM, Zone 13

The Bureau of Land Management (BLM) attempts to use the most current and complete geospatial data available. No warranty is made by the BLM as to the accuracy, reliability, or completeness of this data. Using this map for other than its intended purpose may yield inaccurate or misleading results.

Figure shows geothermal heat flow contours on BLM-administered lands in the Uncompahgre RMP Planning Area regardless of current management constraints.

Figure 2-3

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tend to develop in areas where the resources are well understood and where exploration will render the highest likelihood of finding a viable resource. This consideration further reduces the likelihood that a geothermal company would choose to invest in exploration funds in areas such as the UFO where resources are not proven.

Despite the many above-discussed factors that suggest a low level of geothermal development in the UFO planning area in the near future, longer term trends indicate that such development can be expected over the mid-to-long term. These factors include the ongoing national rapid expansion of renewable energy development and the possible future trend toward locally produced renewable energy. Given these longer-term trends, the BLM considers it to be reasonably foreseeable that one indirect use (electrical generation) project and two direct use projects would occur within the decision area by year 2030. The indirect use project would be assumed to have a capacity of 10 MW.

Given the proximity of the Ouray, Orvis and Lemon hot springs to existing communities, any direct use projects would be expected to occur in association with these hot springs in their respective communities of Ouray, Ridgway, and Placerville; however, other communities within the planning area could conduct exploratory drilling to seek geothermal resources for local direct use projects.

Given the heat flow patterns and the presence of existing transmission lines shown in Figure 2-3, the indirect use project is expected to occur either near Montrose or Paonia. BLM-administered lands occur in abundance to the east, south, and west of Montrose, and several transmission lines cross these areas as well. This same combination of factors exists around Paonia. While the highest temperatures are expected to occur in the southern portion of the planning area from Ridgway to the south, there is a lack of transmission lines to provide connection to the electrical grid.

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CHAPTER 3
SOLAR ENERGY

3.1 WHAT IS SOLAR ENERGY?

Solar energy is the energy produced in the sun's core through nuclear fusion. This energy reaches the earth in form of electromagnetic radiation, mostly in the visible and near-visible (ultraviolet and near-infrared) bands. The intensity of radiation striking the top of earth's atmosphere is 1,367 watts per square meter. This value varies by plus or minus three percent as the earth orbits the sun on an elliptical orbit (University of Oregon 2002). The amount of solar radiation that reaches earth's surface is known as insolation or "incident solar radiation." Insolation values are affected by location (latitude and elevation), season, time of day, local landscape, and local weather.

As solar radiation passes through the atmosphere, some of it is scattered, absorbed, and reflected by air molecules, water vapor, clouds, ozone, and other agents in the atmosphere. On a clear day at Noon, only about 25 percent or 1,000 watts per square meter of the incident direct radiation reaches the earth's surface. The solar radiation that reaches earth's surface directly without being scattered is called direct normal irradiance. The radiation that has been scattered before reaching the earth's surface is called diffuse solar radiation. The total solar radiation (sum of direct normal irradiance and diffuse solar radiation) projected onto a horizontal surface is called global radiation, which is sometimes referred to as global horizontal irradiance.

3.2 HOW IS SOLAR ENERGY DEVELOPED?

Solar radiation may be harnessed through various technologies and transformed to usable energy such as heat and electricity. It has small-scale applications such as powering solar vehicles and generating electricity or heating water for residences. It may also be used for large-scale commercial applications such as generating electricity in solar power plants.

Two basic solar energy technologies that produce electrical power are photovoltaic systems and concentrating solar power systems. These can be combined with natural gas or other fossil-fueled power technologies to form hybrid systems.

3.2.1 Photovoltaic Systems

Photovoltaic systems use solar cells, which are semiconductor materials similar to those used in computer chips, to capture the energy in sunlight and convert it directly into electricity. Photovoltaic systems must be scaled over a very large area in order to be effective for utility-scale applications. Due to the high cost of photovoltaic cell productions, large photovoltaic electrical generating systems are less likely to be used in commercial utility application. Photovoltaic systems are generally used to provide power to individual homes and small buildings. They are also found in rural areas on communication towers, water pumps, and road and traffic signs.

The process by which a photovoltaic cell converts sunlight into electricity is called the photoelectric effect. Through this process, the sunlight absorbed by the semiconductor material knocks electrons loose from their atoms, allowing them to flow through the material and generate electric current.

There are three main types of materials used for solar cells. Traditional solar cells are made from silicon. These cells are usually flat-plate and are the most efficient. The second type is thin-film solar cells made from amorphous silicon or non-silicon materials such as cadmium telluride. The third and newest type of solar cells is made from a variety of new materials besides silicon, including solar inks, solar dyes, and conductive plastics. Some new solar cells use plastic lenses or mirrors to concentrate sunlight onto high-efficiency photovoltaic materials. These systems are cost effective for use in utility-scale applications because they use less of more-efficient and expensive materials (National Renewable Energy Laboratory [NREL] 2009a).

Photovoltaic cells are connected together to form photovoltaic modules, which in turn are combined to make photovoltaic arrays. The size of an array depends on the amount of sunlight and the needs of the customer. For utility-scale electricity generation, hundreds of arrays are interconnected to form a single large system. Modules and arrays are often combined with other components such as those that convert the current within the cell material to usable electricity, batteries to store some of the electricity, and mounting structures that point them toward the sun. These components, referred to as the balance-of-system components, combined with modules and arrays create a complete photovoltaic system. There are two types of photovoltaic systems in use today: flat-plate systems and concentrated photovoltaic systems.

Flat-plate Photovoltaic Systems

The most common array designs use flat-plate photovoltaic panels, which can either be fixed in place or allowed to track the sun. These panels respond to both diffuse and direct solar radiation, making them useful even on cloudy days when the diffuse radiation accounts for nearly 100 percent of the total radiation. On a sunny day, an estimated 10 to 20 percent of the total solar radiation comes from the diffuse component of sunlight.

Generally, flat-plate photovoltaic panels are mounted on stationary structures with a tilt at a fixed angle determined by the latitude of the site, the requirement of the load, and the availability of sunlight. The fixed arrays are advantageous in that they are simple, inexpensive, and lightweight. However, because their orientation to the sun is fixed and at an angle often less than optimal, they receive less energy per unit area compared with a tracking array. The flat-

plate tracking arrays are primarily mounted on one-axis tracking structures, which are designed to track the sun from east to west.

Concentrated Photovoltaic Systems

Concentrated photovoltaic systems use lenses or mirrors to concentrate sunlight on solar cells. The concentration of sunlight allows for greater efficiency and reduction in size and number of cells. These systems must track the sun to keep light focused on the photovoltaic cells. They are primarily mounted on two-axis tracking structures, which are designed to track the sun's daily and seasonal course. One-axis tracking systems are also sometimes used.

Both reflectors and lenses have been used to concentrate light for photovoltaic systems. The most promising lens for concentrated photovoltaic application is the Fresnel lens, which uses a miniature sawtooth design to focus incoming light. The best lenses, however, can transmit only 90 to 95 percent (and in practice even less) of incident light. In addition, lenses cannot focus diffuse sunlight, which makes up nearly 10 to 20 percent of the radiation on a clear day.

While concentrated photovoltaic systems lower costs by reducing photovoltaic material needs, they require sophisticated tracking devices and expensive concentrating optics. High concentration ratios also introduce an excessive heat, which can decrease cell efficiencies and damage solar cells.

3.2.2 Concentrating Solar Power Systems

Concentrating solar power technologies use mirrors to concentrate sunlight onto receivers that convert it to heat. The thermal energy is then used to drive a generator via a steam turbine or heat engine to produce electricity. Concentrating solar power technologies are the most suitable solar technologies for large utility-scale applications. The three main types of concentrating solar power technologies are linear concentrator, dish/engine, and power tower systems.

Linear Concentrator Systems

Linear concentrating solar power systems use a large field of long, rectangular, U-shaped mirrors tilted toward the sun that capture and focus solar energy onto linear receiver tubes that run along the length of the mirrors. The receiver contains a fluid (oil or water/steam) that is heated by the sunlight and used to boil water in a steam-turbine generator to produce electricity.

The two major types of linear concentrating solar power systems are parabolic trough systems and linear Fresnel reflector systems. Parabolic trough systems are the predominant concentrating solar power systems currently in operation in the US. They use collectors in which the receiver tube is positioned along the focal line of each parabolic mirror. Currently the largest individual trough systems generate 80 megawatts of electricity.

In linear Fresnel reflector systems, the receiver tube is positioned above several flat or slightly curved mirrors that are mounted on tracking structures. Sometimes a small parabolic mirror may be added atop the receiver to further focus the sun's rays.

Dish/Engine Systems

The dish/engine system produces relatively small amounts of electricity (3 to 25 kilowatts) compared to other types of concentrating solar power technologies. It uses a parabolic mirrored dish similar to a large satellite to concentrate sunlight onto a thermal receiver. The thermal receiver, mounted at the focal point of the dish, absorbs and transfers the heat to an engine or generator. The most common type of heat engine used today in dish/engine systems is the Stirling engine. A Stirling engine uses the fluid heated by the receiver to move pistons and create mechanical power. Mechanical work turns a crankshaft, which drives a generator and produces electricity. To maximize the amount of solar energy captured by the dish/engine collectors, the dish assembly is mounted on a tracking structure that follows the sun across the sky.

Power Tower Systems

Power tower systems use a large field of flat, sun-tracking mirrors, known as heliostats, to focus sunlight onto a receiver, which is located atop a tower. A fluid in the receiver, either water/steam or molten nitrate salt, is heated and used to generate steam, which, in turn, is used in a conventional turbine generator to produce electricity. The molten nitrate salt has heat-transfer and energy-storage capabilities, which allows for production of electricity during cloudy weather and at night.

3.2.3 Thermal Energy Storage

Sunlight is an intermittent resource. No solar radiation is available at night, and cloud cover, smog, or haze can further limit generation from a solar power plant. In a concentrating solar power system, fossil fuel hybridizations provide a means to produce power during periods of low or non-existent solar radiation. In addition, heat energy storage is viable for power tower and parabolic trough technologies in which oil or molten salt is used as the heat-transfer medium.

Thermal energy storage technologies include two-tank indirect systems, two-tank direct systems, and single-tank thermocline systems. A two-tank direct thermal energy storage system stores the thermal energy in the same fluid that was used to collect it. A two-tank indirect thermal energy storage system uses different fluids to collect and store the heat. Both systems store the fluid in two separate tanks—one at high temperature and the other at low temperature. A single-tank thermocline system stores the thermal energy in a solid medium, most commonly silica sand, located in a single tank.

3.2.4 Emerging Technologies

The technologies described above are those that are in use at the time of this writing. Leading up to 2010, there has substantial private and government investment into the development of new solar technologies to allow for the cheaper and more efficient capture of solar energy. It is expected that further technological advancements will be made over time timeframe of the RMP.

3.3 WHAT BLM ACTIONS ARE INVOLVED IN SOLAR ENERGY DEVELOPMENT?

Solar energy development on BLM-administered lands is managed through ROW authorization under Title V of the Federal Land Policy and Management Act of 1976, 43 CFR 2800, and

current applicable BLM Instruction Memoranda. This guidance is expected to change over time and new IMs are expected to be developed.

A ROW grant is an authorization that allows for specific use of a piece of public land for a certain project. A solar energy development ROW authorizes all facilities on public lands including solar collectors, tower, turbine generator, fossil-fuel fired generator for hybrid systems, thermal storage, access roads, electrical and transmission facilities, and other testing and support facilities. Installation of a photovoltaic system as part of another authorized facility or use does not require a separate authorization. The ROW authorization contains appropriate stipulations relating to all aspects of project development including, but not limited to, road construction and maintenance; vegetation removal; natural, cultural, and biological resources mitigation and monitoring; and site reclamation. In addition, an approved plan of development for construction and operation of the solar facility must be completed prior to beginning construction.

Right-of-way applications for solar energy development projects are identified as a high-priority BLM Field Office workload, consistent with the President's National Energy Policy of 2001 and the Energy Policy Act of 2005. The term length of the authorization is not limited by regulation (43 CFR 2805.10[a][3]); however, it should recognize the overall costs and useful life of solar energy facilities (43 CFR 2805.11[b][3]). The term of the solar energy authorization for a commercial facility should not exceed the design life of the project, typically 30 years. The authorization may be renewed consistent with the provisions of the regulations (43 CFR 2807.22[a]). Other compatible uses may be authorized but are unlikely due to the intensive use of the site for photovoltaic or concentrating solar power facility equipment. All solar energy ROW authorizations are subject to annual rent, as established by the BLM, unless they are specifically exempt from rent by statute or regulation.

In addition, the solar energy development policy requires that all solar energy project ROW applications be subjected to environmental review in accordance with the requirements of the National Environmental Policy Act of 1969. The scope of the National Environmental Policy Act analysis and compliance requirements of the Endangered Species Act, Migratory Bird Treaty Act, National Historic Preservation Act, and other laws for a solar energy development ROW application should address the installation, maintenance and reclamation of solar collectors, water for steam generation and cooling purposes, oil or gas used by backup generators, thermal or electrical storage, turbines or engines, access roads, electrical inverters, and transmission facilities.

3.4 HOW ARE POTENTIAL LEVELS DEFINED FOR SOLAR ENERGY?

Solar energy potential is determined using solar insolation values measured in kilowatt-hours per square meter per day (kWh/m^2/day). Concentrating solar power solar resource potential is based on direct normal solar radiation values. Photovoltaic solar insolation values represent the resource available to a flat-plate collector, oriented due south, at an angle from horizontal equal to the latitude of the collector location.

In addition to solar insolation values, factors such as slope of the land, proximity to roads, transmission lines, water resources, and population centers, as well as average wind speeds and

vegetation concentration must be considered when determining a site's potential for solar development.

3.5 SOLAR POTENTIAL

3.5.1 Data Sources

The main source of solar potential data in the US is available through the US Department of Energy's (DOE) NREL. The NREL offers national 10-kilometer and 40-kilometer resolution maps of photovoltaic and concentrating solar power resources. The maps provide annual and monthly average daily totals for each resource type. For photovoltaic solar radiation, the insolation values represent the resource available to a flat-plate collector, oriented due south, at an angle from horizontal equal to the latitude of the collector location. The concentrating solar power solar radiation maps represent direct normal radiation values for receptors that track the sun throughout the day. In addition to direct normal irradiance maps, typical for concentrating solar power, and Latitude Tilt maps, typical for photovoltaic solar, the NREL provides global horizontal irradiance data, which represents total solar radiation (the sum of direct, diffuse, and ground-reflected radiation).

The 10-kilometer resolution maps are based on the State University of New York data, which use a model that incorporates hourly radiance images from geostationary weather satellites, daily snow cover data, and monthly averages of atmospheric water vapor, trace gases, and the amount of aerosols in the atmosphere to calculate the hourly total insolation falling on a horizontal surface. The 40-kilometer resolution maps are based on the Climatological Solar Radiation model, which used information on cloud cover, atmospheric water vapor and trace gasses, and the amount of aerosols in the atmosphere to calculate daily total insolation falling on a horizontal surface.

The NREL also provides a Dynamic Solar Atlas that provides resource information for any location in the US. It provides access to spreadsheets giving average monthly radiation values for 14 different types of solar collectors. Data for individual collectors are also available for fixed, flat-plate photovoltaic collectors on five different orientations. The dynamic map also accesses the monthly average Photovoltaic Watts calculator, a software program that calculates electrical energy produced by grid-connected photovoltaic systems.

The NREL provides additional concentrating solar power resource maps for the southwest on its Concentrating Solar Power Research page of its website (NREL 2010a). These maps of direct-normal solar radiation are filtered by solar resource and land availability and identify the most economically suitable lands available for deployment of large-scale concentrating solar power plants. There are two types of maps provided for each state: maps that exclude lands with slopes greater than one percent, and those that exclude lands with slopes greater than three percent. Major urban areas, potentially sensitive environmental lands, water features, and areas with less than one square kilometer are excluded from these maps.

The 10–kilometer resolution maps provide a higher level of detail on solar irradiance than the 40-kilometer resolution maps. Given the size of the planning area being considered in this

assessment, a higher resolution data set was considered more appropriate. Thus, the 10-kilometer State University of New York data were used for this analysis.

There are two major existing BLM assessments addressing solar resource potential on public lands in the US that utilize the NREL solar potential data. These include the BLM and DOE's Renewable Potential Energy Assessment (BLM and DOE 2003) and the Draft Solar Energy Development Programmatic EIS (BLM and DOE 2010).

BLM/DOE Renewable Potential Energy Assessment

In 2003, the BLM, in collaboration with the NREL, conducted an assessment (BLM and DOE 2003) of renewable energy resources including solar, biomass, geothermal, water, and wind energy on BLM lands in the western US. The objective of this assessment was to identify BLM lands with highest potential for renewable energy development.

This assessment used NREL 40-kilometer resolution solar data and developed screening criteria in order to analyze and assess the potential solar energy resources on public lands. The screening criteria for the concentrating solar power central generation technology were (in order of importance):

- Direct normal radiation of at least 5 kWh/m^2/day;
- Slope of the land less than 5 percent;
- Transmission availability within 50 miles (within the 69- to 435-kilovolt range) and transmission capacity availability;
- Minimum parcel size of 40 acres;
- Within 50 miles of roads or railroads; and
- BLM-compatible land use.

The screening criteria for large-scale photovoltaic development included:

- Direct normal radiation of at least 5 kWh/m^2/day;
- Transmission availability within 50 miles of transmission lines within the 115- to 345-kilovolt capacity range; and
- BLM-compatible land use.

Solar Energy Development Programmatic EIS

The Solar Energy Development Programmatic EIS (BLM and DOE 2010) is being prepared by the DOE's Energy Efficiency and Renewable Energy Program and the BLM to assess environmental impacts associated with the development of utility-scale solar energy in six western states (Arizona, California, Colorado, New Mexico, Nevada, and Utah). The Programmatic EIS will analyze potential impacts associated with utility-scale solar projects that can generate 10 megawatts or more of electricity to be put directly into the transmission grid. Trough, dish, and tower concentrating solar power, as well as flat-panel and concentrating photovoltaic technologies, will be included in the Programmatic EIS analysis.

Maps representing low, moderate, and high potential for concentrating and photovoltaic solar resources on BLM lands for the six states included in the analysis are included. The data for this analysis was obtained from the NREL 10- kilometer resolution database.

In the Programmatic Environmental Impact Statement, lands with excellent solar resources, suitable slope, proximity to roads and transmission lines, and containing at least 2,000 acres of BLM-administered lands were considered for solar energy study areas. Sensitive lands, wilderness, and other high-conservation-value lands, as well as lands with conflicting uses, were excluded. Solar energy study areas in Colorado include Antonio Southeast, De Tilla Gulch, Fourmile East, and Los Mogotes East. None of the study areas are in the Uncompahgre RMP planning area.

The Programmatic EIS has also committed to analyze lands with solar insolation levels greater than 6.5 kWh/m^2/day and slopes of less than 5 percent that exclude Wilderness Study Areas, National Conservation Areas, Areas of Critical Concern, and other sensitive lands. These areas must also be larger than one square kilometer to be considered for solar energy development. The maps for these areas are not yet available.

3.5.2 Solar Potential Data Used in This Report

All of the available assessments on solar radiation, including the solar Programmatic EIS, used either the 10-kilometer resolution State University of New York data or the 40-kilometer resolution Climatological Solar Radiation model data, are available through the NREL GIS database. Both data sets include maps of resource potentials for photovoltaic and concentrating solar power solar radiation nationwide, which were integrated into the US Atlas of Renewable Resources (NREL 2010b). In this interactive resource map, layers representing 10-kilometer resource data from 1998 through 2005 for Direct Normal, Global Horizontal, and Latitude Tilt data are available. The 40-kilometer resolution solar layer representing data sets gathered from 1961 to 1990 only for flat-plate tilted south at latitude are available.

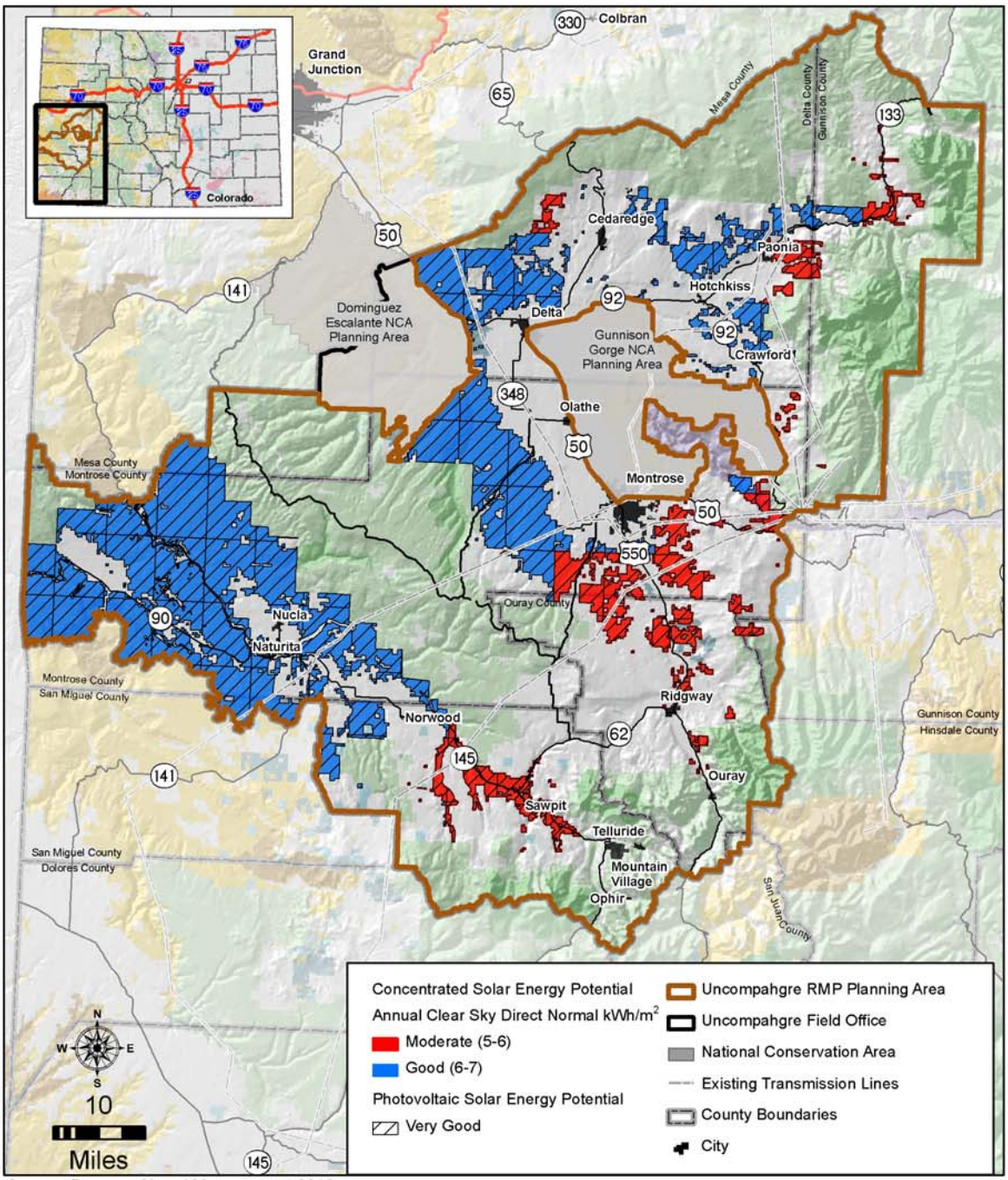
This report uses 10-kilometer resolution data, direct normal for concentrating solar power and Latitude Tilt for photovoltaic available in NREL's GIS database.

3.6 POTENTIAL AREAS WITHIN THE UNCOMPAHGRE RMP PLANNING AREA

As shown in **Figure 3-1**, on BLM-administered lands within the Uncompahgre RMP planning area, 557,000 acres have good concentrating solar power resource potential (6 to 7 kWh/m^2/day), and 118,400 acres have moderate (5 to 6 kWh/m^2/day) concentrating solar power resource potential. Photovoltaic solar potential is very good on all 675,700 acres of BLM-administered land within the Uncompahgre RMP planning area (Figure 3-1). The identified high-potential areas for both concentrating solar power and photovoltaic solar resources are predominantly found in the western and central regions of the Uncompahgre RMP planning area.

3.7 REASONABLE FORESEEABLE DEVELOPMENT SCENARIO

The likelihood of future solar project development in the Uncompahgre RMP planning area can be estimated by considering the quality of solar resources, the acreage of lands with slope less than five percent (which is required for Central Generation Technology), existing solar projects



Source: Bureau of Land Management 2010, National Renewable Energy Laboratory 2009a

Solar Energy Potential

Datum: NAD 83
Projection: UTM, Zone 13

The Bureau of Land Management (BLM) attempts to use the most current and complete geospatial data available. No warranty is made by the BLM as to the accuracy, reliability, or completeness of this data. Using this map for other than its intended purpose may yield inaccurate or misleading results.

Figure shows solar energy potential on BLM-administered lands in the Uncompahgre RMP planning area regardless of current management constraints.

Figure 3-1

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in the area, the number of pending ROW applications within the UFO, the quality of solar resources in the UFO compared with other areas in the region, and expressions of interest by solar companies.

As described in Section 3.6, all planning area lands have very good potential for photovoltaic applications and 557,000 acres have good potential for concentrating solar power applications. As shown in **Figure 3-2**, of the area with good (6 to 7 kWh/m^2/day) potential for concentrating solar power applications, there are 163,500 acres with slopes of less than five percent, and of the area with moderate (5 to 6 kWh/m^2/day) potential for concentration solar power applications, there are 18,400 acres with slopes of less than five percent. No commercial-scale solar projects currently exist within the UFO on BLM-administered lands or otherwise, and there are no solar installation projects on BLM-administered lands anywhere in Colorado. There are no pending ROW applications within Colorado.

Despite the lack of existing projects, ROW applications, low-slope lands, and interest by the solar industry at the time of this writing, changes in national policy, economic factors (such as incentives, regulation of carbon emissions), and technology could reasonably result in one commercial-scale solar project on lands within the Uncompahgre RMP planning area within the next 15 to 20 years. Additionally, as technology changes, there may be a shift toward smaller commercial or community scale solar facilities, potentially resulting in several such smaller projects by year 2030.

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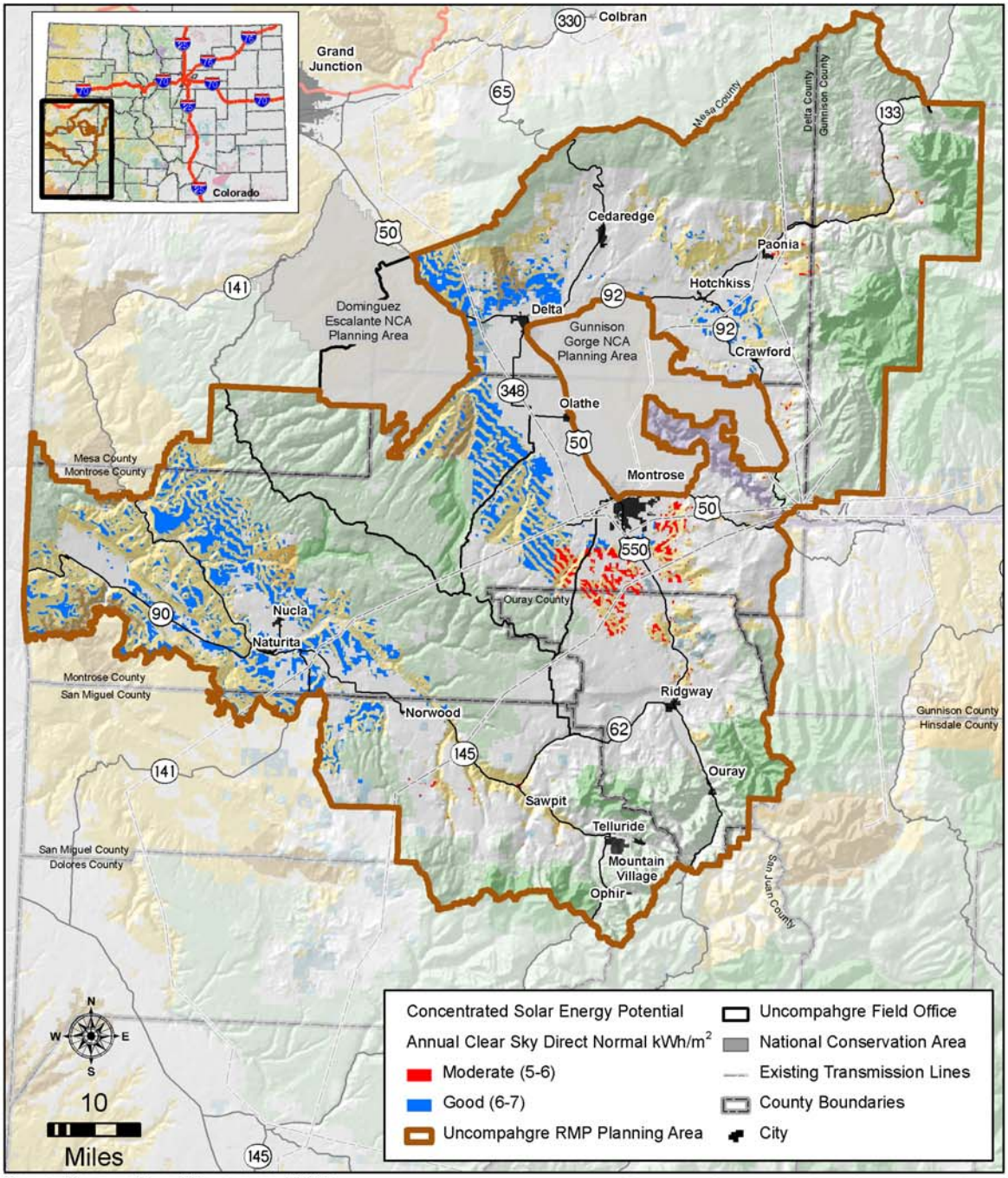

Source: Bureau of Land Management 2010, National Renewable Energy Laboratory 2009a

Datum: NAD 83
Projection: UTM, Zone 13

The Bureau of Land Management (BLM) attempts to use the most current and complete geospatial data available. No warranty is made by the BLM as to the accuracy, reliability, or completeness of this data. Using this map for other than its intended purpose may yield inaccurate or misleading results.

Developable Areas for Concentrating Solar Power

Figure shows all solar energy potential on BLM-administered lands in the Uncompahgre RMP planning area with slopes of five percent or less.

Figure 3-2

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CHAPTER 4
WIND ENERGY

4.1 WHAT IS WIND ENERGY?

Wind is a form of solar energy. Solar radiation causes uneven heating of the atmosphere, producing regions of high and low pressure. This pressure gradient results in movement of air from high-pressure to low-pressure regions, creating wind. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow when harvested by modern wind turbines can be used to generate electricity.

The terms wind energy or wind power describe the process by which the wind is used to generate mechanical power or electricity. Because air has mass, moving air carries with it kinetic energy. Wind turbines convert the wind's kinetic energy into mechanical power. This mechanical power can be used for specific tasks such as grinding grain, pumping water, or producing electricity.

4.2 HOW IS WIND ENERGY DEVELOPED?

A wind turbine is a mechanical assembly that converts the energy of wind into electricity. A wind turbine consists of a blade or rotor, a drive train (usually including a gearbox and a generator), a tower, and other equipment including controls, electrical cables, ground support equipment, and interconnection equipment. The blades turn in the moving air and power an electric generator that supplies an electric current. The blades act much like an airplane wing. When the wind blows, a pocket of low-pressure air forms on the downwind side of the blade, causing the blade to be pulled toward that pocket. This force causes the rotor to spin like a propeller and turn a shaft. The rotational energy of the shaft turns the generator and makes electricity. Wind turbines are mounted on a tower to enable them to capture the most energy. Tower height affects the amount of power that can be extracted by a given wind turbine. At 30 meters or more above ground, wind turbines can take advantage of the faster and less-turbulent wind.

Wind turbines fall into two basic groups, which include the horizontal-axis variety (propeller-style) like traditional farm windmills and the vertical-axis design like the eggbeater-style Darrieus model. The horizontal-axis type turbines are the most common, constituting nearly all the

utility-scale turbines. These typically have either two or three blades. The three-blade turbines are operated upwind with their blades facing into the wind.

Wind turbines are available in a variety of sizes, and therefore power ratings. Utility-scale wind turbines for land-based wind farms have rotor diameters ranging from 40 to about 120 meters, and towers of roughly 40 to 130 meters high. Wind turbines can also be installed offshore, where the wind speeds are generally higher and larger turbines can be incorporated. The size and design of offshore wind turbines are variable and depend on many factors, including the water depth and distance to shore of the installation site. Small wind turbines intended for residential or small business typically have rotors between 2 and 8 meters in diameter and are mounted on towers 30 to 40 meters above ground.

Utility-scale turbines range in power rating from 100 kilowatts to as large as several megawatts. Larger turbines are grouped together into wind farms, which provide bulk power to a utility power grid. Wind power plants are modular, which means they consist of small individual modules (turbines) and, depending on electricity demand, can easily be made larger or smaller.

Single small turbines, below 100 kilowatts, are used for homes, telecommunications, or water pumping. Small wind systems also have potential as distributed energy resources. These systems, called hybrid wind systems, operate in connection with diesel generators, batteries, and photovoltaic systems in remote, off-grid locations where a connection to the utility grid is not available.

4.3 WHAT BLM ACTIONS ARE INVOLVED IN WIND ENERGY DEVELOPMENT?

Wind energy development on BLM-administered lands is managed, at the time of this writing, through ROW authorization in accordance with the terms and conditions of BLM's Wind Energy Development Policy (Instruction Memorandum 2009-043 [BLM 2009b]). This guidance is expected to change over time.

BLM's Wind Energy Development Policy provides guidance on processing ROW applications for wind energy site testing and monitoring facilities, as well as applications for wind energy development projects on BLM-administered lands. Under this policy, all wind energy applications are processed in accordance with the requirements of Title V of the Federal Land Policy and Management Act of 1976 and 43 CFR 2800, "Right-of-Way under the Federal Land Policy Management Act." Under this policy, developers may apply for the following three types of wind energy ROW grants:

- A site-specific grant for testing and monitoring;
- A project-area grant for testing and monitoring; and
- A development grant.

A site-specific grant is used to authorize individual meteorological towers and instrumentation facilities. The area authorized for these facilities is the minimum area required for construction and maintenance of the temporary facility (including access roads). Under the current guidance, the term of this grant is limited to three years from the date of issuance and may not be renewed. The BLM may allocate numerous site-specific grants to various ROW holders in the

same area without any exclusive rights regarding future wind energy development. In addition, the BLM retains the right to authorize other compatible uses of public lands in the area.

A project-area grant with provisions for renewal beyond the three-year term authorizes wind energy site testing and monitoring facilities for a project area. The project area describes an area of land where wind resource information is being collected to determine the area's wind energy resource potential. The holder of the project area grant retains an interest in the site testing and monitoring project area, which precludes other wind energy ROW applications during the three-year term of the grant. However, it is required that for any future wind energy development proposals, the holder of the grant submit a separate ROW application and plan of development to the BLM for review.

A development grant authorizes all facilities related to a commercial wind energy development project on public lands. This authorization includes the wind turbine facilities, onsite access roads, electrical and distribution facilities, and other support facilities authorized by the wind energy development ROW grant. The lands involved in the development grant are defined by aliquot legal land descriptions and configured to minimize the amount of land involved, while still allowing an adequate distance between turbine positions and reasonable ROW boundaries. In the absence of any specific local zoning and management issues, no turbine will be positioned closer than five rotor-diameters from the center of the wind turbine to the ROW boundary in the dominant upwind or downwind direction to avoid potential wind turbulence interference issues with adjacent wind energy facilities, unless it can be demonstrated that site conditions, such as topography, natural features, or other conditions (e.g., offsets of turbine locations) warrant a lesser distance. Further, for safety reasons, no turbine on public land will be positioned closer than 1.5 times the total height of the wind turbine to the ROW boundary.

In addition, the wind energy development policy requires that all wind energy project ROW applications, whether for site testing and monitoring or for commercial development, be subjected to environmental review in accordance with the requirements of National Environmental Policy Act of 1969 and that such development be in compliance with the requirements of the Endangered Species Act, Migratory Bird Treaty Act, National Historic Preservation Act, and other appropriate laws.

4.4 How are Potential Levels Defined for Wind Energy?

Wind speed is a crucial element in projecting turbine performance, and a site's wind speed is measured through wind resource assessment prior to a wind system's construction. The power available in the wind is proportional to the cube of its speed, which means that a slightly higher wind speeds will produce a significantly higher power. Generally, an annual average wind speed greater than four meters per second (nine miles per hour) is required for small wind electric turbines. Less wind is required for water-pumping operations. Utility-scale wind power plants require minimum average wind speeds of 6 meters per second (13 miles per hour). Wind resources are characterized by wind power density classes, which range from Class 1 (the lowest) to Class 7 (the highest).

While the technical characteristics of the wind in a specific location are very important, many other factors also contribute to siting decisions. A location far removed from the power

transmission grid might be uneconomic, as new transmission lines would be required to connect the wind farm to the grid. Soil conditions and the terrain must be suitable for the construction of the towers' foundations. Surface roughness is another determining factor because it determines the amount of turbulence a turbine will experience. Turbulent winds put greater stresses on the rotor and tower, reducing the turbine's lifespan as a result.

4.5 WIND POTENTIAL

4.5.1 Data Sources

The main source of data on wind potential in the US is available through the DOE's NREL. The NREL's GIS offers a national wind resource assessment of the US as well as high-resolution wind data. The national wind resource assessment was developed in 1986 for the DOE by the Pacific Northwest Laboratory, which is documented in the Wind Energy Resource Atlas of the US (DOE 1986). The NREL website (NREL 2009b) provides a dynamic map based on the Wind Energy Resource Atlas of the US (NREL 2010c). In this assessment, the conterminous US was divided into grid cells one quarter of a degree of latitude by one third of a degree of longitude. Each grid cell was assigned a wind power class ranging from 1 (the lowest) to 7 (the highest), representative of the range of wind power densities. The wind power density limits for each wind power class are shown in **Table 4-1**, below.

In Table 4-1, the wind power classes represent different wind power densities at different heights above ground (10 and 50 meters). The data depicted in the NREL's wind resource potential map represents wind power densities at 50 meters above ground, which is typical for utility-scale wind turbine application. Estimates at the 30-meter level are useful for identifying small wind turbine opportunities; however, such data are yet to be developed. In the NREL's assessment, areas designated class 3 or greater are considered suitable for utility-scale applications, while class 2 areas are marginal, and class 1 areas are generally not suitable for utility-scale uses. According to the NREL's assessment, wind power class 2 may be suitable for rural applications, and wind power class 1 in a few locations such as exposed hilltops (not shown on the map) may be adequate for wind turbine applications.

High-resolution data are separated into two groups: NREL-produced and TrueWind-produced/NREL validated. The NREL-produced map data apply to areas of low surface roughness (e.g., grasslands) and areas with slopes less than 20 percent, while the TrueWind-produced estimates factor in surface roughness and include all slopes. The data produced by TrueWind were obtained in cooperation with the DOE's Wind Powering America program and have been validated by NREL and other wind energy meteorological consultants.

The Wind Powering America program provides a nationwide wind resource map, which is a combination of high-resolution and low-resolution databases for the US. The map shows the annual average wind power estimates at a height of 50 meters. The areas unlikely to be developed onshore due to land use or environmental issues have been excluded from this assessment. Only moderate- and high-potential areas (wind power class 3 and above) are represented in this assessment.

Table 4-1
Classes of Wind Power Density at 10 Meters and 50 Meters

Wind Power Class	Resource Potential (Utility Scale)	Wind Power Density (watts per square meter) at 10 Meters Above Ground	Speed (miles per hour) at 10 Meters Above Ground	Wind Power Density (watts per square meter) at 50 Meters Above Ground	Speed (miles per hour) at 50 Meters Above Ground
1	Poor	0–100	0–9.8	0–200	0–12.5
2	Marginal	100–150	9.8–11.5	200–300	12.5–14.3
3	Moderate	150–200	11.5–12.5	300–400	14.3–15.7
4	Good	200–250	12.5–13.4	400–500	15.7–16.8
5	Excellent	250–300	13.4–14.3	500–600	16.8–17.9
6	Outstanding	300–400	14.3–15.7	600–800	17.9–19.7
7	Superb	400–1000	15.7–21.1	800–2000	19.7–26.6

Source: NREL 2009b

The Wind Powering America program also provides high-resolution data at 50 meters for individual states (when such data are available). The data represent low-, moderate-, and high-potential areas for wind development. According to this assessment, wind power class 4 or higher is sufficient for generating wind power with utility-scale turbines. Particular locations in class 3 areas could have higher wind power class values at 80 meters than values at 50 meters.

There are two major existing BLM assessments addressing wind resource potential on public lands that utilize the NREL wind potential data. These include the BLM/DOE Renewable Potential Energy Assessment (BLM and DOE 2003) and the Wind Energy Development Programmatic Environmental Impact Statement (BLM 2005).

BLM/DOE Renewable Potential Energy Assessment

In 2003, the BLM, in collaboration with the NREL, conducted an assessment (BLM and DOE 2003) of renewable energy resources including solar, biomass, geothermal, water, and wind energy on BLM lands in the western US. The objective of this assessment was to identify BLM lands in the western US with highest potential for renewable energy development. The assessment used NREL's high-resolution data, when such data were available, and the 1987 low-resolution data, also available through the NREL. The following screening criteria (in order of importance) were developed for targeting high-potential wind resource potential areas:

- Wind power class 3 and above;

- Within 25 miles of transmission lines with capacity in the range of 69 to 345 kilovolts;
- Within 50 miles of a major road or railroad; and
- BLM-compatible land use.

Wind Energy Development Final Programmatic EIS

The Wind Energy Development Final Programmatic EIS (BLM 2005) evaluates the potential impacts associated with wind energy development on BLM-administered lands in the western US, excluding Alaska. For this Programmatic EIS, the NREL developed a maximum potential development scenario in order to define the potential for future wind energy development on BLM-administered lands. The NREL utilized the same methodology and screening criteria that was employed in the BLM's 2003 Renewable Potential Energy Assessment (BLM and DOE 2003) discussed above. In addition to the maximum potential development scenario, the NREL used a different model (the Wind Deployment System) to project the amount of wind power that might be generated over the next 20 years in the study area.

Maps depicting BLM-administered lands with low, medium, and high potential for wind energy development are available for 11 western states (BLM 2005). Wilderness Areas, Wilderness Study Areas, National Monuments, and National Conservation Areas were excluded from the maps. Lands categorized as having low potential fall in wind power classes 1 and 2. Lands with wind power class 3 are considered medium potential, while wind resources of class 4 and above are economically developable with current technology. Most of the BLM lands in the UFO have only low potential for wind energy development.

4.5.2 Wind Potential Data Used in this Report

For this analysis, the available high-resolution data created by TrueWind Solutions were used, as was done in the Wind Energy Development Final Programmatic EIS (BLM 2005). These data have been verified by the NREL and are also utilized in the assessment done by the Wind Powering America program.

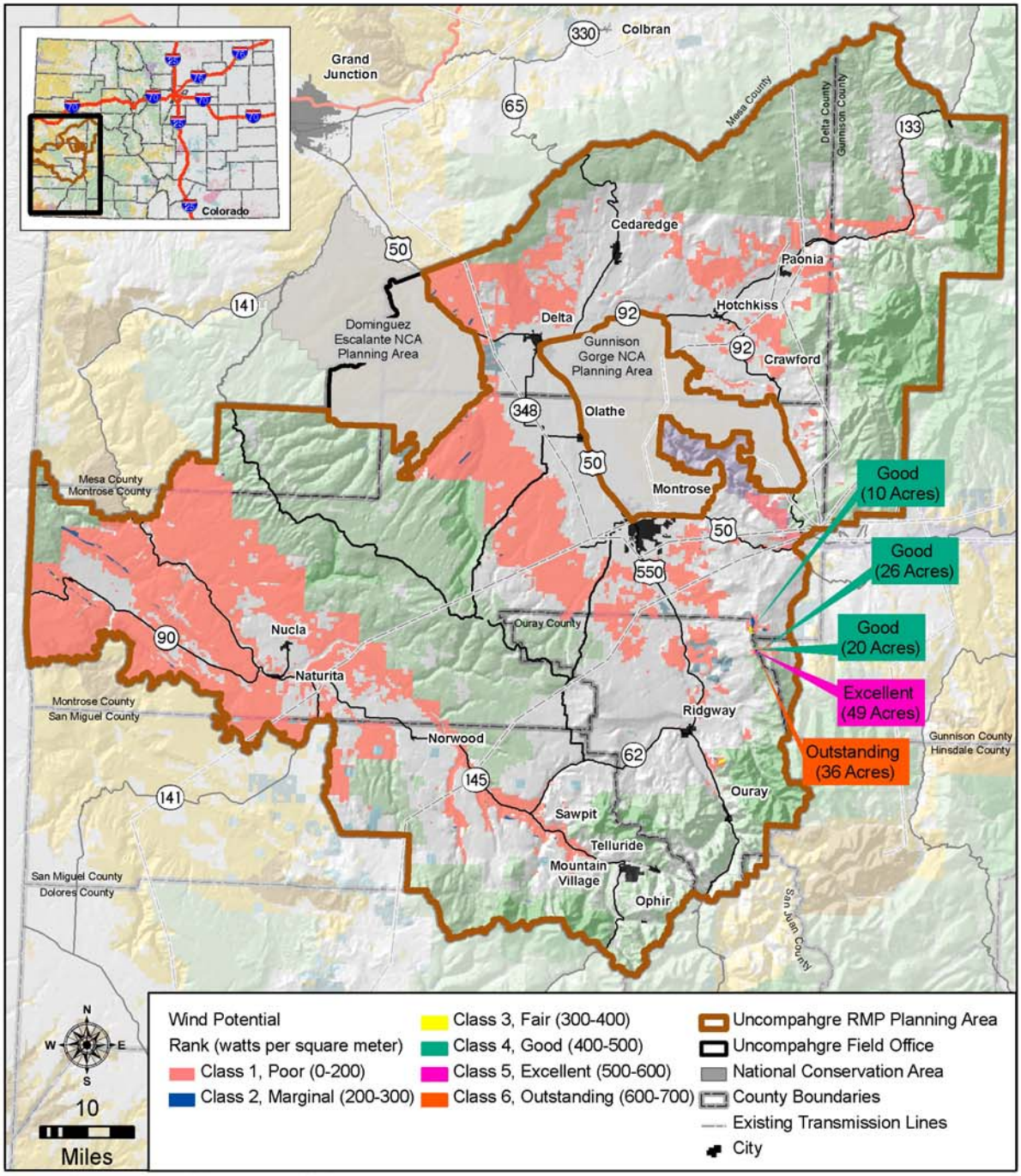
4.6 POTENTIAL AREAS WITHIN THE UNCOMPAHGRE RMP PLANNING AREA

Within the Uncompahgre RMP planning area, wind potential is generally marginal to poor. Outstanding wind potential areas (class 6) have been identified on 40 acres, while 50 acres have excellent (class 5) wind potential, and an additional 60 acres have good (class 4) wind potential. The identified high-potential areas are located on the eastern side of the planning area and are shown with these potential classes in **Figure 4-1**.

4.7 REASONABLE FORESEEABLE DEVELOPMENT SCENARIO

The likelihood of future development of wind projects in the Uncompahgre RMP planning area can be estimated by considering the quality of wind resources, existing wind projects in the area, the number of pending ROW applications within the UFO, the quality of wind resources in the UFO compared with other areas in the region, and expressions of interest by wind companies.

Wind energy potential is generally marginal to poor in the planning area, and only small areas (areas of 50 acres or smaller) have been identified as having high potential (class 4 or higher) for



Source: Bureau of Land Management 2010, National Renewable Energy Laboratory 2009a

Wind Energy Potential

Datum: NAD 83
Projection: UTM, Zone 13

The Bureau of Land Management (BLM) attempts to use the most current and complete geospatial data available. No warranty is made by the BLM as to the accuracy, reliability, or completeness of this data. Using this map for other than its intended purpose may yield inaccurate or misleading results.

Figure shows all wind energy potential areas on BLM-administered land in the Uncompahgre RMP planning area regardless of current management constraints.

Data show average wind resource potential at a height of 50 meters.

Figure 4-1

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wind energy development. As stated above, the planning area has one 40-acre area of outstanding wind resource, one 50-acre area of excellent wind resource, and three areas (30 acres, 20 acres, and 10 acres) of good wind resource. All of these areas are along the Cimarron Ridge near Slagel Pass along the border of Ouray and Gunnison Counties, except for the 10-acre good area, which is approximately 2 miles to the north, also along the Cimarron Ridge, along the border of Ouray and Montrose Counties near Storm King Mountain and Castle Rock. Potential transmission connections could be made to any power lines running along Highway 550 approximately 7 miles to the west-southwest, or along Highway 50 approximately 10 miles to the north-northeast.

No major wind projects exist within the UFO or anywhere in western Colorado. There are no existing wind ROWs or pending wind ROW applications within the UFO. A number of ROWs are authorized or pending for wind testing sites across Colorado, as follows: 1 authorized (Grand Junction), 3 pending (Royal Gorge), 1 pending (White River). Two additional ROWs are pending for wind test sites in the nearby Vernal Field Office in Utah.

The closest ROW authorization is located near Palisade, Colorado, in the Grand Junction Field Office and is for Wazee Energy, LLC, which is seeking to determine the feasibility of developing a wind farm. This application was approved in September 2009. Wazee Energy erected a single meteorological tower to test wind speed at the end of 2009 and expressed an intention to install up to three more towers if results were favorable.

Superb wind resources are located along the Front Range of Colorado, running north-south through central Colorado. Fair to good wind resources are located in Colorado's eastern plains.

The UFO has received no expressions of interest in developing wind resources within the planning area from wind developers. Attempts to contact the wind energy companies with pending or existing ROW authorizations in Colorado yielded no results.

Due to the limited size of plots of BLM-administered land with good-quality wind resources, the lack of wind projects in the UFO or western Colorado, the lack of pending ROW applications in the UFO, and the fact that much better wind resources occur in other parts of the state, it is not expected that many, if any, commercial-scale wind energy projects would be developed within the planning area by year 2025. If such development were to occur, it is expected it would be along Cimarron Ridge in the area described above.

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CHAPTER 5
BIOMASS

5.1 WHAT IS BIOMASS?

Biomass energy or bioenergy is the energy from plants and plant-derived materials. These include food crops, grassy and woody plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes. Even the fumes from landfills such as methane and natural gas can be used as a biomass energy source.

Biomass can be converted to liquid fuels (biofuels), such as ethanol and biodiesel, and used to meet transportation fuel needs. It can also be developed for power production to generate heat and electricity. In addition to biofuels and biopower, biomass can be converted into chemicals for making plastics and other products that would otherwise be made from fossil fuels. Using biomass for fuels, power productions, and products has the potential to greatly reduce greenhouse gas emissions and dependence on foreign oil, and to increase support of US agricultural and forest-product industries.

5.2 HOW IS ENERGY PRODUCED FROM BIOMASS?

Biopower, or biomass power technologies, convert biomass to heat and electricity using processes similar to that used with fossil fuels. Biopower system technologies include direct-firing, co-firing, gasification, pyrolysis, and anaerobic digestion. All of these technologies may be employed in small, modular systems that would be more applicable to villages, farms, and small industry.

5.2.1 Direct-firing

Most biopower plants use direct-firing, the burning of bioenergy feed stocks in a boiler to produce high-pressure steam. The steam rotates a turbine, which then turns a generator that produces electricity. The direct-fired power plants' efficiencies are limited (in the low 20-percent range). In some biomass industries, the spent steam from the power plant is used for manufacturing processes or heating buildings. Such combined heat and power systems greatly increase overall energy efficiency.

5.2.2 Co-firing

Co-firing involves mixing biomass with fossil fuels, typically coal, in an existing power plant furnace. Because much of the existing power plant equipment can be used without major modification, co-firing is the most economic near-term option for introducing new biomass power generation. Such plants can significantly reduce sulphur dioxide, nitrogen oxides, and other air emissions. Adding biomass results in little or no loss of efficiency. Such power plants allow biopower production with 30 to 37 percent efficiency.

5.2.3 Gasification

Gasification is a thermo-chemical process that converts biomass into a combustible, synthetic gas using high temperatures and an oxygen-starved environment. This synthetic gas, also called syngas, contains hydrogen, carbon monoxide, water vapor, carbon dioxide, tar vapor, and ash particles. The syngas retains 70 to 80 percent of the energy originally present in the biomass feedstock and can be chemically converted to other fuels or products, burned in a conventional boiler, or used instead of natural gas in a gas turbine.

Using syngas offers advantages over directly burning the biomass. Syngas can be cleaned and filtered to remove tar and particulate matter from the gas. It can also be used in more-efficient power-generation systems called combined cycles, which combine gas and steam turbines to produce electricity with efficiencies up to 60 percent.

5.2.4 Pyrolysis

Pyrolysis systems use a similar thermo-chemical process as in gasification but an oxygen-free environment to convert biomass into liquid. The pyrolysis oil can be burned to generate electricity or used for making plastics, adhesives, or other bioproducts.

5.2.5 Anaerobic Digestion

Anaerobic digestion refers to a biochemical process in which particular kinds of bacteria digest biomass in an oxygen-free environment and produce a gas composed primarily of methane and carbon dioxide. Methane, a combustible gas, is filtered and cleaned, then burned to produce electricity. Anaerobic digestion may be used to produce biogas from animal manure and organic biomass solids in municipal sewage. This process also occurs naturally in underground landfills. In such cases, wells can be drilled in order to release and capture the biogas that is produced.

5.3 WHAT BLM ACTIONS ARE INVOLVED IN BIOMASS PROJECTS?

Biomass resources are a byproduct of BLM actions on public lands and are not specifically cultivated for feedstock production. The BLM defines woody biomass as "the woody plants and portions of the trees, including limbs, tips, needles, leaves, and other woody parts, or rangeland environment, that are the byproducts of the management, restoration, and/or hazardous fuel reduction treatment." Biomass can be collected and harvested from BLM lands through any vegetation management activity related to wildlife, range resources, or forestry. Typically, biomass is primarily generated from timber sales, stewardship, and hazardous fuels reduction activities.

Although fire wood is biomass for energy, it is not considered in this report. The UFO will consider fire wood (personal use and commercial) along with other woodland products as it develops alternatives in the RMP.

5.4 How are Potential Levels Defined for Biomass-producing Areas?

Potential levels for biomass-producing areas are generally calculated based on biomass feedstock yield. Biomass feed stocks include crop residues, forest residues, primary and secondary mill residues, urban wood waste, and methane emissions from manure management, landfills, and domestic wastewater treatment.

Another biomass resource data that may be used in defining potential levels is the normalized difference vegetation index (NDVI), which computes surface vegetation using visible and near-infrared satellite data.

5.5 Biomass Productivity

5.5.1 Data Sources

There are two main sets of biomass resource data available for the US. These include NREL's biomass resource potential maps of the US available through US Atlas of Renewable Resources (NREL 2010b) and NDVI values computed from NASA's Advanced Very High Resolution Radiometer Land Pathfinder Satellite program (US Department of Agriculture 2009).

Biomass Resource Maps

The NREL offers GIS layers showing biomass resources of the US by county, through the interactive US Atlas of Renewable Resources (NREL 2010b). The data represented here include crop residues, forest residues, primary and secondary mill residues, urban wood waste, and methane emissions from manure management, landfills, and domestic wastewater management. The NREL also offers static US maps of biomass resources measured in thousands of tons per county per year. Additionally, the NREL offers separate static maps for each biomass resource. There are separate analyses for crop residues, forest residues, primary mill residues, secondary mill residues, urban wood waste, methane emissions from landfills, methane emissions from manure management, and methane emissions from domestic wastewater treatment.

In the NREL maps and analyses, biomass resource values less than 50,000 tons per county per year are considered low potential, while values of greater than 500,000 tons per county per year are considered high potential. According to the data presented here, Montrose County BLM lands in the planning area have biomass resources of 50,000 to 100,000 tons per county per year, while BLM lands in the remaining Uncompahgre RMP planning area all have biomass resources that are less than 50,000 tons per county per year.

Normalized Difference Vegetation Index

The NDVI computed from NASA's Advanced Very High Resolution Radiometer Land Pathfinder Satellite program (US Department of Agriculture 2009) measures vegetation vigor caused by chlorophyll activity. The NDVI has been shown to be highly correlated to surface vegetation and is derived from the visible and near-infrared channel reflectances. Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, and snow. Moderate values (0.2 to 0.3)

represent shrub and grassland, while high values (0.6 to 0.8) indicate temperate and tropical rainforests. NDVI values can theoretically range from -1 to +1.

The BLM/DOE's Renewable Potential Energy Assessment (BLM and DOE 2003) utilized NDVI values for the western US and developed screening criteria in order to identify high-productivity areas on public lands. The screening criteria used for this assessment were (in order of importance):

- NDVI of 0.4 or greater for at least 4 months between April and September 2000;
- Terrain slope of less than 12 percent;
- Site within 50 miles of a town with at least 100 people; and
- BLM-compatible land use.

These data include only areas that maintained the minimum NDVI of 0.4 for at least 4 months; such lands are present within the Uncompahgre RMP planning area.

5.5.2 Biomass Productivity Data Used in this Report

While NDVI data were considered the most appropriate for this assessment, NDVI data are not available in GIS format. As a proxy, BLM vegetation GIS data were used to indicate areas where biomass may be harvested.

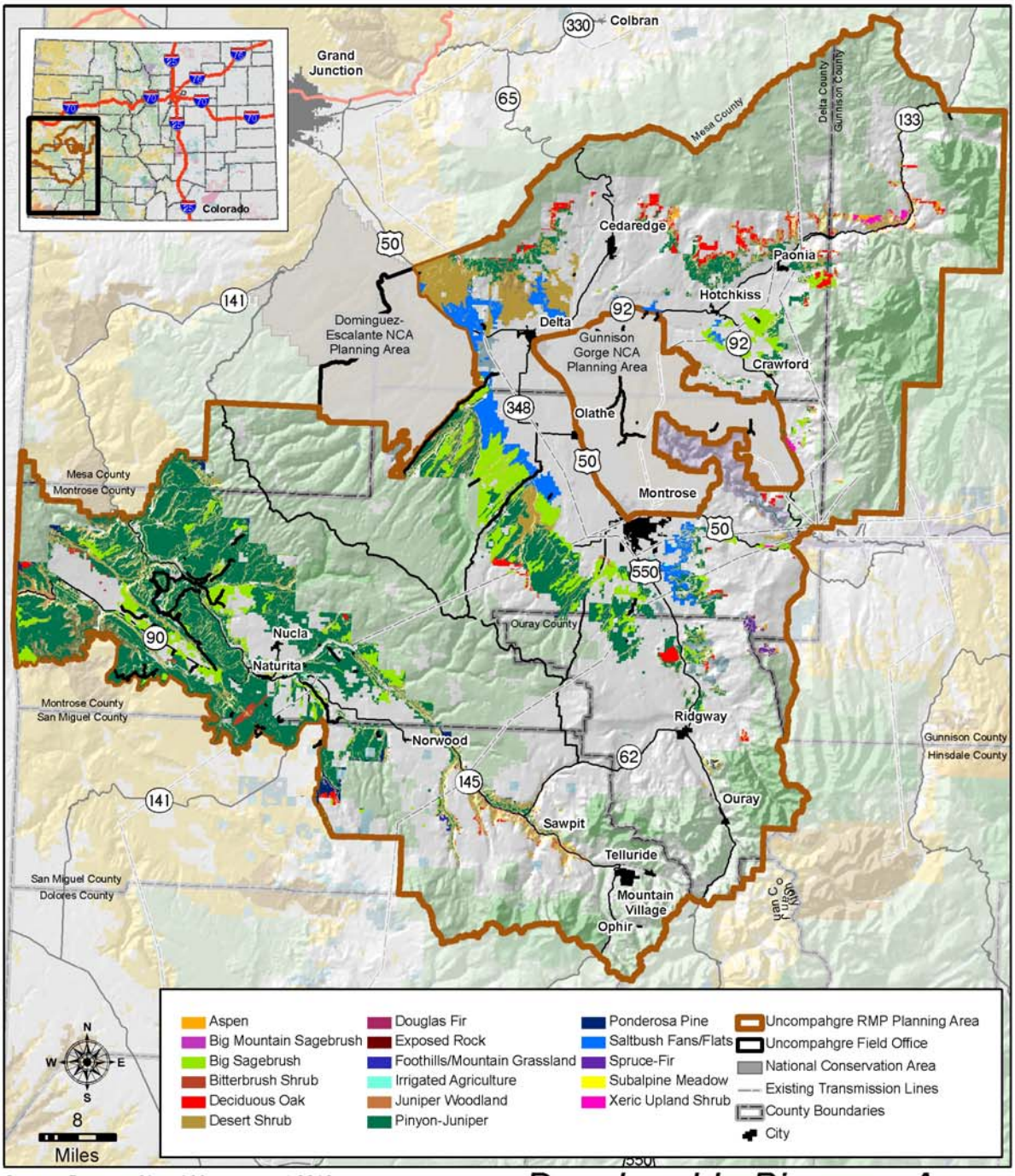
Because biomass is a byproduct of other land management activities, such as fire management and stewardship, biomass does not require lands to be designated as open or closed for biomass collection; however, the BLM may choose to include an alternative in the RMP Amendment/EIS that designates certain areas for biomass harvesting. **Figure 5-1** shows the vegetation types in areas considered to be feasible for biomass collection. Feasibility was considered to be areas within 50 miles of a road and with a slope of less than 30 percent. Aside from informing a biomass harvesting alternative in the RMP Amendment/EIS, the information in this assessment will serve as an informational tool so that BLM staff can keep biomass in mind as a potential useful byproduct when they are planning other actions and can arrange for its sale to biomass processors.

5.6 BIOMASS PRODUCTIVITY WITHIN THE UNCOMPAHGRE RMP PLANNING AREA

Figure 5-1 shows the vegetation types with slopes of 30 percent or less within the Uncompahgre RMP planning area. Biomass productivity attributes were not associated with the vegetation types. Biomass productivity from the lands supporting these vegetation types depends on how the BLM is managing the vegetation (i.e., how much of the vegetation is removed and how often).

5.7 REASONABLE FORESEEABLE DEVELOPMENT SCENARIO

Biomass energy production typically involves the collection of materials from BLM lands as the byproduct of other actions. In this case, a reasonable foreseeable development scenario is not applicable. However, because of some past interest in exploring the feasibility of harvesting local forests and woodlands solely for biomass, setting aside an area for biomass harvest (feedstock) could be considered as an alternative in the RMP.



Source: Bureau of Land Management 2010

Developable Biomass Areas

Datum: NAD 83
Projection: UTM, Zone 13

The Bureau of Land Management (BLM) attempts to use the most current and complete geospatial data available. No warranty is made by the BLM as to the accuracy, reliability, or completeness of this data. Using this map for other than its intended purpose may yield inaccurate or misleading results.

Figure depicts vegetation types on BLM-administered lands with slopes of 30 percent or less.

Figure 5-1

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The location of a biomass energy facility is not dependent upon the location of biomass resources (i.e., resources are typically hauled up to 50 miles to a biomass energy facility from various sources). Therefore, the presence of biomass resources on BLM-administered lands does not increase the likelihood that a private energy developer would seek to locate a biomass energy facility on BLM-administered lands. Biomass energy facilities are likely to be located on private land.

Given the flexibility in siting a power plant and the likelihood that a developer would prefer private lands over public lands, it is not expected that any biomass energy facilities would be developed in the planning area by year 2025. Biomass materials are likely to be produced from lands within the planning area during certain BLM activities such as stewardship and fire management actions.

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CHAPTER 6
REFERENCES

BLM (US Department of the Interior, Bureau of Land Management). 2004. Instruction Memorandum 2004-227, Biomass Utilization Strategy. August 16, 2004. Internet Web site: http://www.blm.gov/wo/st/en/info/regulations/Instruction_Memos_and_Bulletins/national_instruction.html. Accessed on February 20, 2010.

_____. 2005. Record of Decision for the Programmatic Environmental Impact Statement on Wind Energy Development. December 2005. Internet Web site: http://windeis.anl.gov/documents/docs/WindPEISROD.pdf. Accessed on February 20, 2010.

_____. 2006. Instruction Memorandum 2006-216, Wind Energy Development Policy. August 24, 2006. Internet Web site: http://www.blm.gov/wo/st/en/info/regulations/Instruction_Memos_and_Bulletins/national_instruction/2006/2006-216__.html. Accessed on February 20, 2010.

_____. 2007. Instruction Memorandum 2007-097, Solar Energy Development Policy. April 4, 2007. Internet Web site: http://www.blm.gov/wo/st/en/info/regulations/Instruction_Memos_and_Bulletins/national_instruction/2007/im_2007-097__.html. Accessed on February 20, 2010.

_____. 2009a. Instruction Memorandum 2009-022, Geothermal Leasing under the Energy Policy Act of 2005. October 9, 2008. Internet Web site: http://www.blm.gov/wo/st/en/info/regulations/Instruction_Memos_and_Bulletins/national_instruction/2009/IM_2009-022.html. Accessed on February 20, 2010.

_____. 2009b. Instruction Memorandum 2009-043, Wind Energy Development Policy. December 19, 2008. Internet Web site: http://www.blm.gov/wo/st/en/info/regulations/Instruction_Memos_and_Bulletins/national_instruction/2009/IM_2009-043.html. Accessed on February 22, 2010.

_____. 2010. Geographic Information System. Unpublished Data. BLM, Uncompahgre Field Office, Colorado.

BLM (US Department of the Interior, Bureau of Land Management) and DOE (US Department of Energy). 2003. Renewable Potential Energy Assessment. Available at Internet Web site: http://www.nrel.gov/docs/fy03osti/33530.pdf.

_____. 2010. Solar Energy Development Programmatic EIS Information Center. Internet Web site: http://solareis.anl.gov/. Accessed on February 22, 2010.

Blackwell, D. D., and Richards, M. 2004. Geothermal Map of North America. American Assoc. Petroleum Geologist (AAPG), 1 sheet, scale 1:6,500,000.

Colorado Gap Analysis Project. 1999. Vegetation data. Accessed through the UFO BLM GIS server.

Colorado Geological Survey. 2007. Geographic Information System (GIS) shape file boundary to define the area of geothermal potential for the Final Programmatic EIS for Geothermal Leasing in the Western US. Provided by Matt Sares of the Colorado Geological Survey to EMPSi. November 28, 2007.

_____. 2008. Interpretive Geothermal Heat Flow Map of Colorado. November 14, 2008.

DOE (US Department of Energy). 1986. Wind Energy Resource Atlas of United States. Internet Web site: http://rredc.nrel.gov/wind/pubs/atlas/atlas_index.html. Accessed on February 23, 2010.

_____. 2010. Solar Energy Technologies Program. Internet Web site: http://www1.eere.energy.gov/solar/technologies.html. Accessed on January 15, 2010.

First Solar Inc. 2009. Personal communication between Leilah Krohn of First Solar and Amanda Davila of EMPSi. December 9, 2009.

NREL (US Department of Energy, National Renewable Energy Laboratory). 2006. Geothermal – The Energy Under our Feet: Geothermal Resource Estimates for the United States. Technical Report NREL/TP-840-40665. By Bruce Green and Gerald Nix. November 2006.

_____. 2009a. Data Analysis and Tools: download data and tools. Internet Web site: http://www.nrel.gov/gis/data_analysis.html. Accessed on November 2, 2009.

_____. 2009b. Dynamic Maps, GIS Data, and Analysis Tools. Wind Maps. Internet Web site: http://www.nrel.gov/gis/wind.html. Accessed on December 9, 2009.

_____. 2010a. Concentrating Solar Power Resource Maps. Internet Web site: http://www.nrel.gov/csp/maps.html. Accessed on February 23, 2010.

_____. 2010b. United States Atlas of Renewable Resources. Internet Web site: http://mapserve2.nrel.gov/website/Resource_Atlas/viewer.htm. Accessed on February 23, 2010.

_____. 2010c. United States Annual Wind Resource Potential. Internet Web site: http://mapserve2.nrel.gov/website/wind_resource1/viewer.htm. Accessed on February 23, 2010.

University of Utah Energy and Geoscience Institute. 2007. Enhanced Geothermal Systems. Available at: http://egs.egi.utah.edu/home/main2.htm. Website accessed on December 18, 2007.

US Department of Agriculture. 2009. Vegetation Condition from AVHRR NDVI Data. National Agricultural Statistics Service. Research and Development Division. Internet Web site: http://www.nass.usda.gov/research/avhrr/avhrrmnu.htm. Accessed on December 16, 2009.

US Department of Energy. 2006. The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century. Prepared for the US DOE and Idaho National Laboratory by the Massachusetts Institute of Technology.

_____. 2007. Enhanced Geothermal Systems Technology. Available at: http://www1.eere.energy.gov/geothermal/egs_technology.html. Website accessed on December 18, 2007.

University of Oregon. 2002. Solar Radiation Monitoring Laboratory. Internet Web site: http://solardat.uoregon.edu/SolarRadiationBasics.html. Accessed on January 15, 2010.

Western Governors' Association. 2006. Geothermal Task Force Report. January 2006.

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