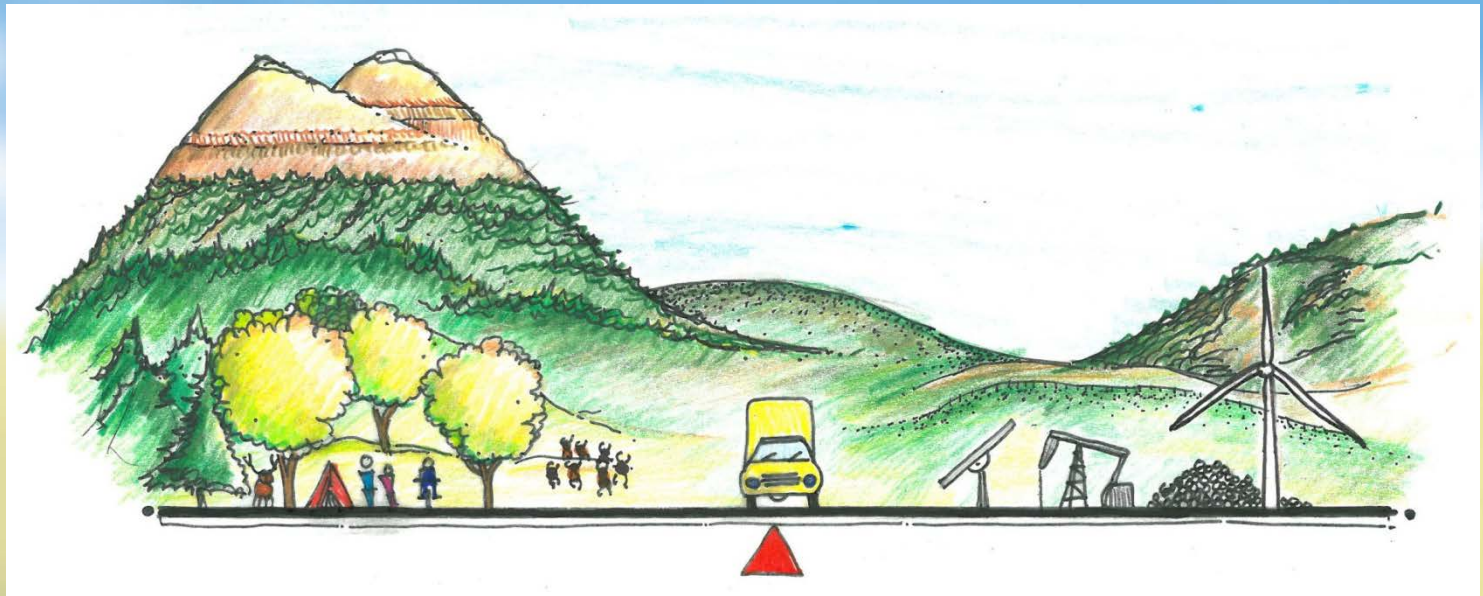
Energy Resource Inventory

Presentation For:

Garfield County

Striking a Balance …

- Economic advantage via energy resource development.
- Conservation of natural resources, wildlife, scenery, community values, public health, safety and welfare.
- Supports funding decisions associated with appropriate capital improvements for energy development projects.



Garfield County

TRC

The Project

- First of a two-phase project: the foundation.
- Project elements:
  - Collection of publicly-available information.
  - Development of resource and constraint maps.
- Supplemental information for the County:
  - County: aid with decision-making processes.
  - Federal: Summary Rules, Resource Management Plans.
  - Energy Policy Development for conventional and renewable resources.

TRC

The Process

The GIS Approach to the Energy Atlas

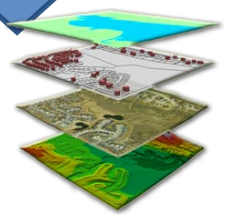
1. Energy Resource Locations

- Primary and secondary data collection; recognize limitations
- County staff, agencies, and resource experts

2. Constraints to Development

- Regulatory, resource impacts, ownership, access, etc.
- County Commissioners and TRC

3. Energy Development Opportunities



- Least constrained energy resources
- Spectrum of opportunities, range of constraints

TRC

Energy Resources

- Aggregate / Gravel
- Biomass
- Coal
- Coalbed Methane
- Geothermal
- Hydroelectric
- Natural Gas
- Oil
- Oil Shale
- Solar
- Uranium
- Wind

TRC

Data Aggregation

7 GB
> 1,000 datasets
32 programs

US Geological Survey Energy Resources Program

Energy Information Administration

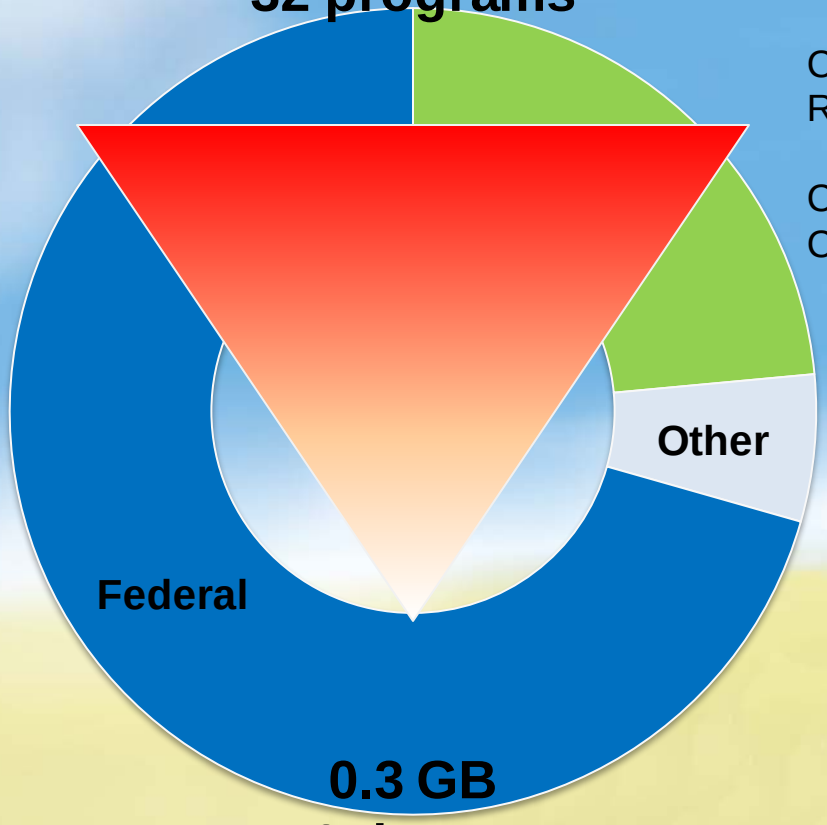
National Renewables Energy Laboratory

Idaho National Lab

US Forest Service

Bureau of Land Management

NOAA



Colorado Geological Survey

Colorado Division of Reclamation Mining & Safety

Colorado Oil and Gas Conservation Commission

Holy Cross Energy

Glenwood Springs Post Independent

0.3 GB
156 datasets
Garfield County Energy Resource Geodatabase

TRC

Geospatial Metadata

- Metadata record: a set of data that describes and gives information about geographic data.
- Metadata includes:
  - Surface ownership
  - Federal mineral ownership
  - Reliability categories
  - Section/township/range
  - Range of overburden (feet)

TRC

Sample Metadata

Annual Aerial Detection Overview Survey

File Geodatabase Feature Class

Tags

biomass, forest insect, forest disease

Summary

Aerial survey data sets are created annually to provide trend information on forest insects, diseases, and other biotic and abiotic causes of tree mortality and tree damage; referred to herein as "damage causal agents". Aerial surveys provide information on the current status for many causal agents, and are important when examining insect activity trends by comparing historical and current survey data over large areas.

Description

2012 USDA Forest Service, Rocky Mountain Region Aerial Detection Survey Data. This data depicts the occurrence and location of forest insect, disease, and other biotic and abiotic causes of tree mortality and tree damage. Aerial survey data is collected by observing areas of tree damage or tree mortality from an aircraft and manually recording the information onto a map.

Due to the nature of aerial surveys, this data will only provide rough estimates of location, intensity and the resulting trend information for agents detectable from the air. Many of the most destructive diseases are not represented in the data because these agents are not

Map Design

ENERGY RESOURCES

Natural Gas

GARFIELD COUNTY ENERGY RESOURCE ATLAS

1:500,000

0 2.5 5 10 miles

UNIVERSAL TRANSVERSE MERCATOR ZONE 13 NORTH
NORTH AMERICAN DATUM 1983

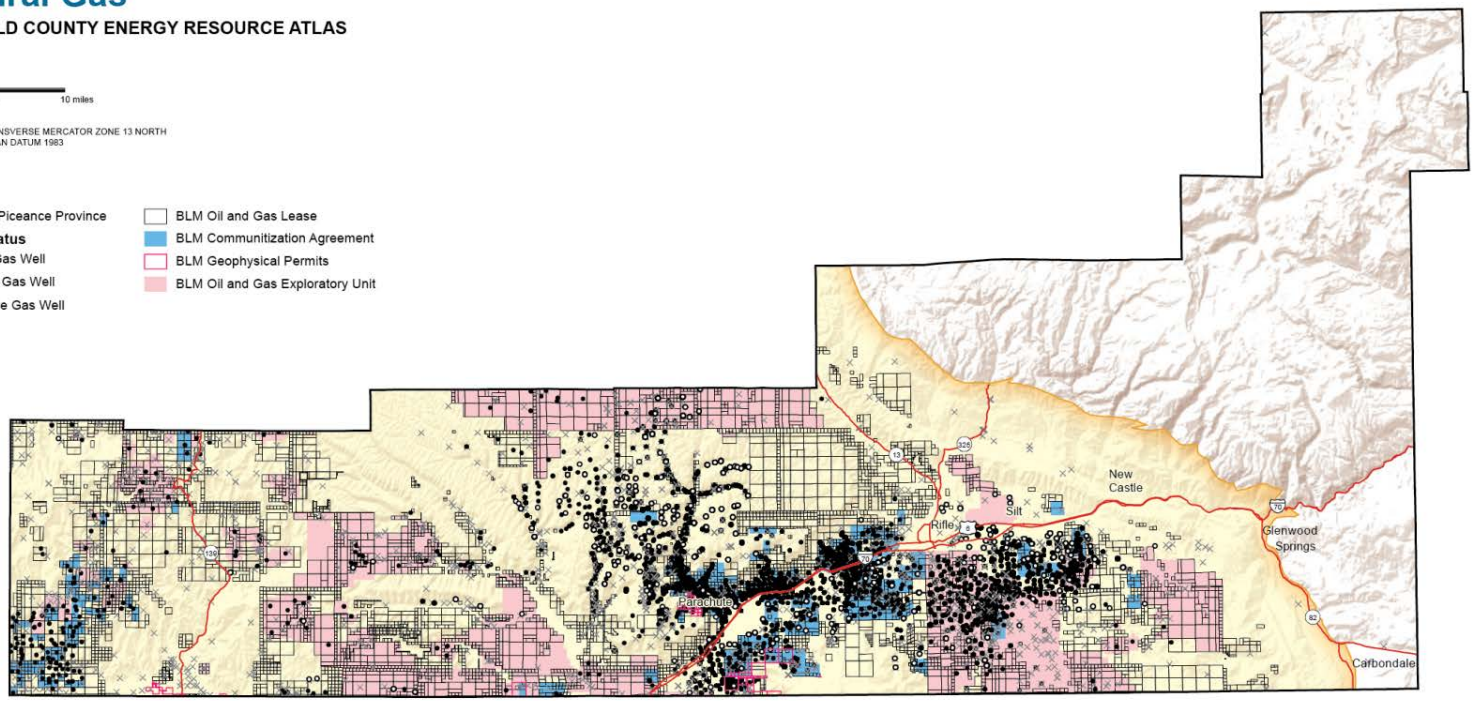
Legend

- Uinta-Piceance Province

Facility Status

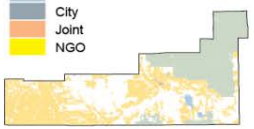
- New Gas Well
- Active Gas Well
- Inactive Gas Well

- BLM Oil and Gas Lease
- BLM Communitization Agreement
- BLM Geophysical Permits
- BLM Oil and Gas Exploratory Unit



Land Ownership

- BLM
- USFS
- Other Federal
- State
- City
- Joint
- NGO



Continuous Gas Resources

Continuous gas accumulations are widespread in the County. These reserves have been known to reside in the tight sands of the Mesaverde system in this area since the late 1950s, but the methods to extract them only became available in the early 1990s. The reserves are found in two petroleum systems: the Mesarverde and the Mancos Mowry.

	Billion ft^3 gas
Mancos Mowry	
Piceance Basin Continuous Gas	650
Uinta-Piceance Transitional and Migrated Gas	1,430
Mesaverde	
Piceance Basin Continuous Gas	1,900
Piceance Basin Transitional Gas	160

Conventional Gas Resources

Conventional gas accumulatations are pockets of gas that have been trapped by geological formations into discrete areas and are relatively easy to recover using conventional extraction methods. These reserves are found in two total petroleum systems: the Mesaverde and the Phosphoria.

	Billion ft^3 gas
Phosphoria	
Hanging Wall	11
Paleozoic/Mesozoic	16
Mesaverde	
Uinta-Piceance Basin Conventional Gas	18

Data Sources

Bureau of Land Management, 2012. Oil and Gas Leases.
_____. 2012. Oil and Gas Exploratory Units.
_____. 2012. Communitization Agreement Areas.
_____. 2012. Geophysical Permits.
Colorado Gas and Oil Conservation Commission, 2012. Wells.
_____. 2013. Colorado Oil and Gas Information System.
U.S. Energy Information Administration, 2005. Major Gas Fields.
U.S. Geological Survey, 2013. National Assessment of Oil and Gas Resource Update (March, 2013).
_____. 2002. Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado. U.S. Geological Survey Digital Data Series DDS-69-B.

Garfield County

December 2013

TRC

Solar Energy

GARFIELD COUNTY ENERGY RESOURCE ATLAS

1:500,000

0 2.5 5 10 miles

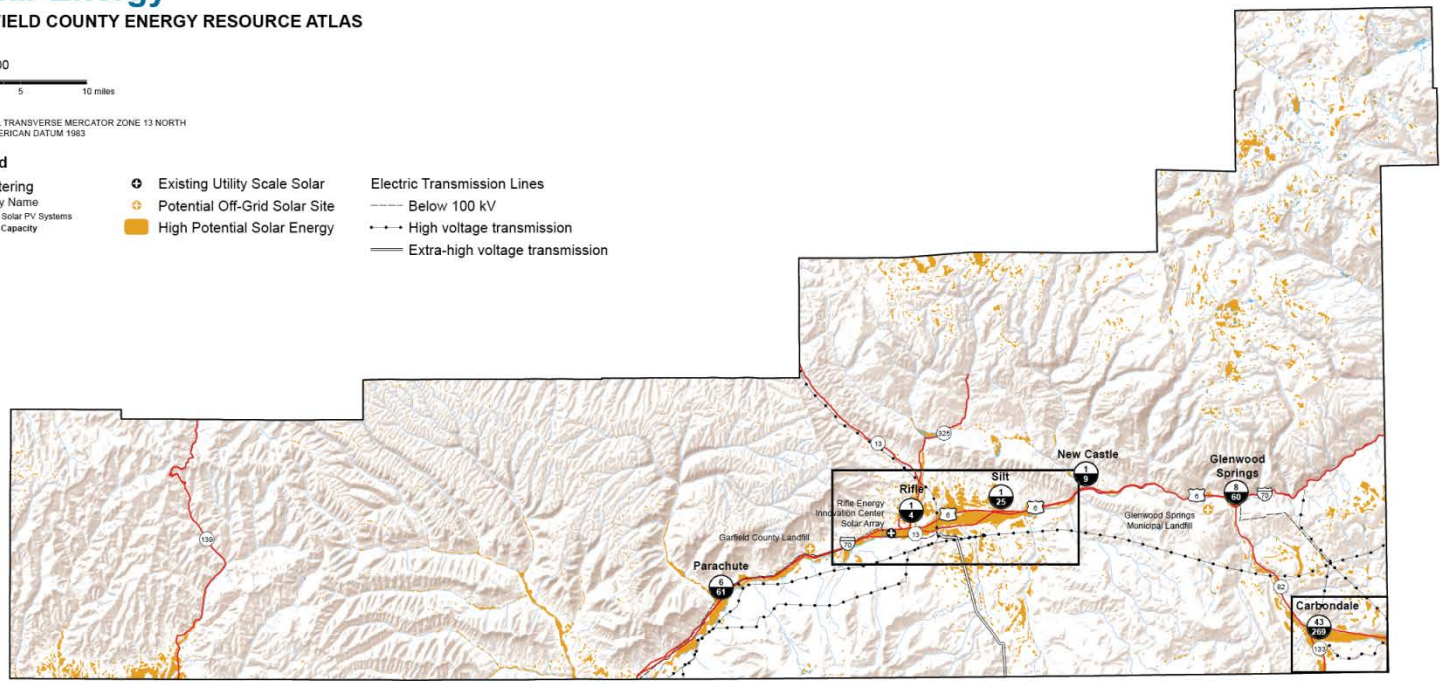
UNIVERSAL TRANSVERSE MERCATOR ZONE 13 NORTH
NORTH AMERICAN DATUM 1983

Legend

Net Metering
Rifle City Name
1 No. Solar PV Systems
4 kW Capacity

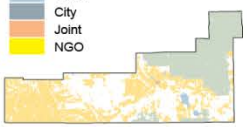
Existing Utility Scale Solar
Potential Off-Grid Solar Site
High Potential Solar Energy

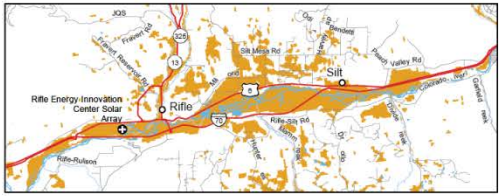
Electric Transmission Lines
Below 100 kV
High voltage transmission
Extra-high voltage transmission

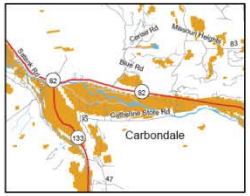


SOLAR POWER is derived from direct beam and diffuse radiation. Direct beam radiation comes in a direct line from the sun, while diffuse beam is scattered from the direct beam by small particles, such as water droplets or dust. On a clear day, most solar radiation is direct beam, but on cloudy days, it's diffuse.

Land Ownership
- BLM
- USFS
- Other Federal
- State
- City
- Joint
- NGO







Data Sources
Garfield Clean Energy. 2012. Garfield County Government Buildings Solar Rooftop Inventory.
Garfield Clean Energy. 2103. Grand Totals to Date, Installed PV Capacity.
Holy Cross Energy, 2013.
National Renewable Energy Laboratory [NREL]. 2012. Average Annual Direct Normal Irradiance Filtered by Slope Less than 3%.
U.S. Environmental Protection Agency [EPA]. 2013. RE-Powering America's Land

Garfield County

December 2013

TRC

Geothermal Energy

GARFIELD COUNTY ENERGY RESOURCE ATLAS

1:500,000

0 2.5 5 10 miles

UNIVERSAL TRANSVERSE MERCATOR ZONE 13 NORTH
NORTH AMERICAN DATUM 1983

Legend

- Geothermal spring or well

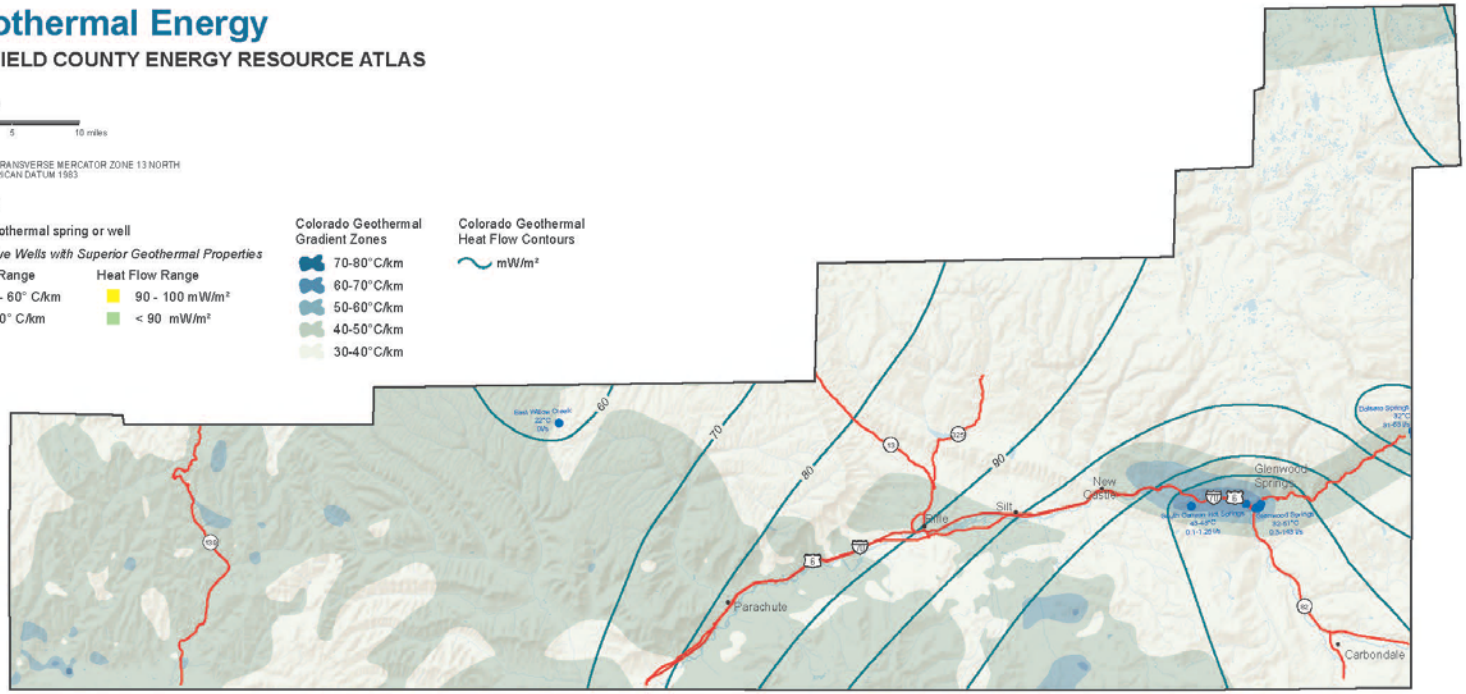
Prospective Wells with Superior Geothermal Properties

Gradient Range
- 50 - 60° C/km
- < 50° C/km

Heat Flow Range
- 90 - 100 mW/m²
- < 90 mW/m²

Colorado Geothermal Gradient Zones
- 70-80°C/km
- 60-70°C/km
- 50-60°C/km
- 40-50°C/km
- 30-40°C/km

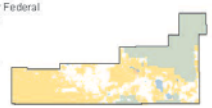
Colorado Geothermal Heat Flow Contours
- mW/m²



GEOTHERMAL ENERGY is heat derived from the earth. Heat is produced deep within the earth through a number of processes, most predominantly radioactive decay. This heat then flows from the earth's depths to its surface, where it can be captured and, depending on the temperature and available water, used in applications ranging from home, office, and aquaculture pond heating to electricity generation.

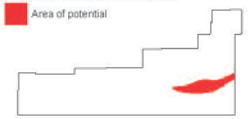
Geothermal energy is described using heat flow and gradient. Heat flow contours illustrate the movement of heat from the earth's interior to its surface in mW/m2, while geothermal gradients describe the change in temperature with depth. The average geothermal gradient worldwide is 25°C/km. Heat flow in the county increases in a northwest to southeasterly direction. The highest geothermal gradients are found around Glenwood Spring and in the far west of the county.

Land Ownership
- BLM
- USFS
- Other Federal
- State
- City
- Joint
- NGO



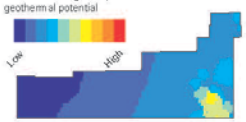
Low-temperature geothermal potential

Area of potential



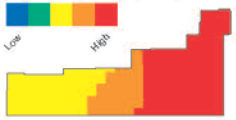
Low Temperature Geothermal Potential Areas around Glenwood Spring are most favorable for discovery and development of low-temperature (below 90°C) geothermal resources.

Moderate- to high-temperature geothermal potential



Moderate- to High- Temperature Geothermal Potential. The area between Carbondale and Glenwood Springs has moderate potential for conventional moderate- to high-temperature geothermal development

Deep enhanced geothermal systems potential



Deep Enhanced Geothermal Systems Potential. The east third of the county is among the most favorable areas nationwide for EGS development. EGS technologies are engineered hydrothermal reservoirs made by drilling and fracturing.

Data Sources

Colorado Geological Survey. 2011. Colorado Thermal Springs.
Colorado Geological Survey. 2010. Interpretive Geothermal Gradient Map of Colorado.
Colorado Geological Survey. 2010. Oil and Gas Wells in Areas of Colorado with Superior Geothermal Properties.
Colorado Geological Survey. 2009. Interpretive Geothermal Heat Flow Map of Colorado.
Idaho National Laboratory, modified from Sammel, EA. 1979. Occurrence of low-temperature geothermal waters in the United States. USGS Circular 790.
National Renewable Energy Laboratory. 2009. Favorability of Deep Enhanced Geothermal Systems.
NOAA National Geophysical Data Center. 1980. Thermal Springs List for the United States.
US Geological Survey. 2010. Geothermal Favorability Map Derived From Logistic Regression Models of the Western United States.

Garfield County

December 2013

TRC

Opportunities and Constraints

- Tasked with identifying and mapping all constraints to energy development.
- Constraints: limit or prevent development.
- *Land Use, Land Management, Infrastructure, Natural Resources, Regulatory Policy, Biology.*
- Lack of constraints: reveals development opportunities.
- Inform policy decisions on several platforms.

TRC

Constraints

1. Identify All Constraints
2. Collect Data
3. Produce Maps

TRC

1 Identify All Constraints

- What counts as a constraint?
  - Subjective and open to interpretation
  - Some constraints are not represented by existing data
    - *Air Quality: needs regional model to generate usable data*
- Are all constraints equal or are some constraints more weighted than others?
- Which resources are constrained by each constraint? *Varies by energy resource*
- How best to collaborate with County staff and the Board of County Commissioners.

TRC

1 Identify All Constraints

- TRC staff draft the initial list of constraints
- Commissioners rank constraints, add others
- Discrepancy in rankings: Major, Moderate, Minor
- Take the average of the ratings.
- Eliminate Minor constraints.
- Moderate + Major = Constraints

TRC

Constraints \ Energy Resources	Biomass	Coal	Coal Bed Methane	Geothermal	Gravel & Aggregate	Hydroelectric	Natural Gas	Oil
100-Year Floodplains	X	X	X	X	X		X	X
Air Space								
Areas of Critical Environmental Concern (ACEC)	X	X	X	X	X	X	X	X
Bighorn Sheep Range	X	X	X	X	X		X	X
Black Bear Range	X	X	X	X	X		X	X
Elk Range	X	X	X	X	X		X	X
Moose Range	X	X	X	X	X		X	X
Mule Deer Range	X	X	X	X	X		X	X
Pronghorn Range	X	X	X	X	X		X	X
Cities / Towns (proximity to)		X	X		X		X	X
Compressor Stations		X			X			
Geologic Hazards: Slope Hazard		X	X		X		X	X
Geologic Hazards: Soils Hazard		X	X		X		X	X
Geologic Hazards: Surficial Geology Hazard		X	X		X		X	X
Groundwater		X	X		X		X	X
Jurisdictional Wetlands	X	X	X	X	X	X	X	X
Land Ownership (public / private)	X	X	X	X	X	X	X	X
"No Lease" Stipulation Area	X	X	X	X	X	X	X	X
No Surface Occupancy areas (NSO)	X	X	X	X	X	X	X	X
Pipelines		X	X	X	X			
Private Conservation Easements	X	X	X	X	X	X	X	X
Public Lands Grazing Allotments	X				X			
Railroads		X	X		X		X	X
Rivers / Streams		X	X		X		X	X
Roadless Areas	X	X	X	X	X	X	X	X
Schools	X	X	X	X	X	X	X	X
State Parks	X	X	X	X	X	X	X	X
Threatened and Endangered Species	X	X	X	X	X	X	X	X
T&E Habitat - Boreal Toad	X	X	X	X	X	X	X	X
T&E Habitat - Colorado Pikeminnow	X	X	X	X	X	X	X	X
T&E Habitat - Razorback Sucker	X	X	X	X	X	X	X	X
T&E Habitat - Cutthroat Trout	X	X	X	X	X	X	X	X
T&E Habitat - Kit Fox	X	X	X	X	X	X	X	X
T&E Habitat - Lynx	X	X	X	X	X	X	X	X
T&E Habitat - River Otter	X	X	X	X	X	X	X	X
Greater Sage Grouse Habitat	X	X	X	X	X	X	X	X
Transmission Lines		X					X	X
Water Wells					X			
Wild and Scenic Rivers (Federal designation)					X			
Wilderness Areas	X	X			X			
Wilderness Study Areas	X	X	X	X	X	X	X	X
Wildfire Hazards	X	X	X				X	X
TOTAL	29	38	35	27	39	19	35	35

2 Collect Data

- Limited to publicly available data.
- Research & coordinate with multiple agencies.
- Incomplete/partial, time & space patchwork, mystery data
  - Land trusts, protected habitat, airspace
- Post-processing (projections, clipping, formatting)
- More processing (simplification, clarity)
  - Wildfire Hazard (1.8M polys, 16 classifications)

TRC

3 Produce Maps

- 40 constraints + resource + landmarks = *calamity*
- Points, lines, polygons
- All constraints have the same value = 1
- Constraint Density … layered like a cake

TRC

Constraints for Natural Gas

GARFIELD COUNTY ENERGY RESOURCE ATLAS

1:500,000

0 2.5 5 10 miles

UTM ZONE 13 NORTH
NORTH AMERICAN DATUM 1983

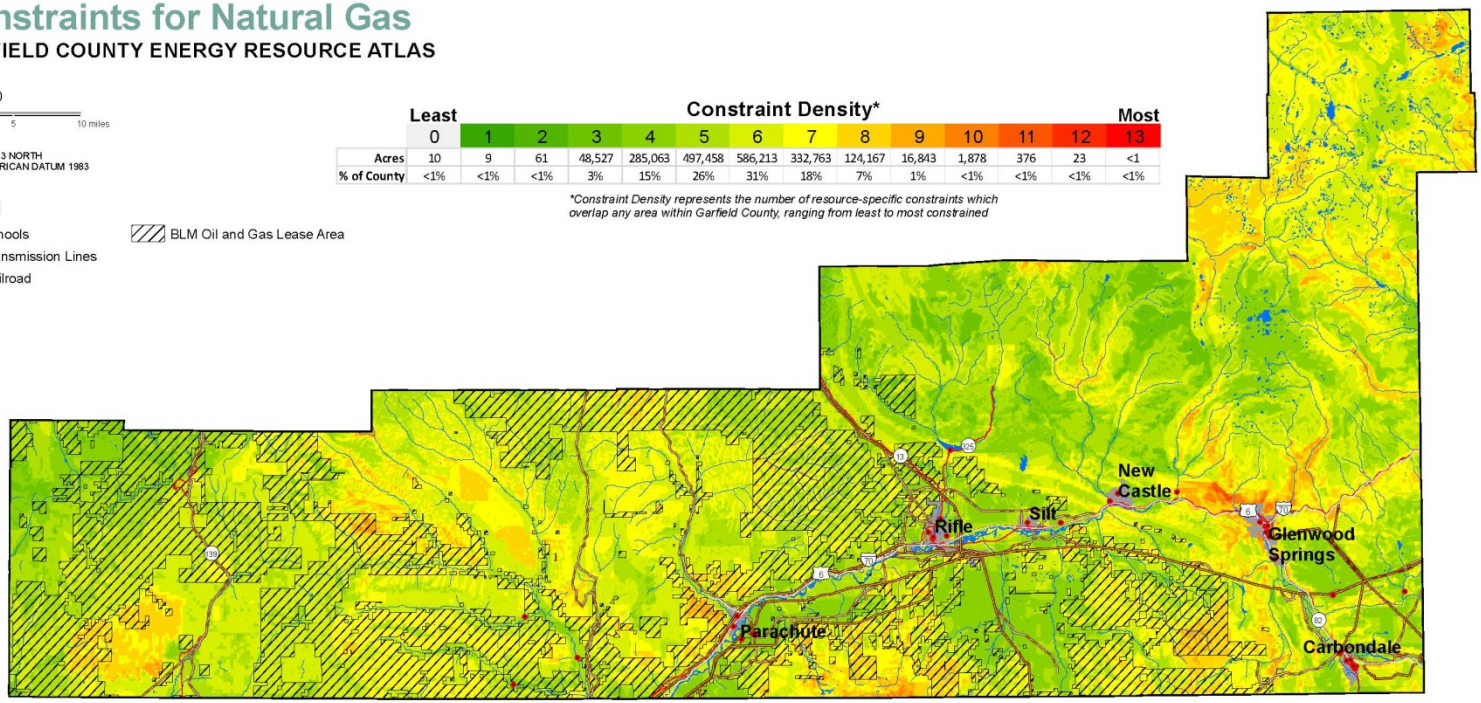
Legend

- Schools
- Transmission Lines
- Railroad
- BLM Oil and Gas Lease Area

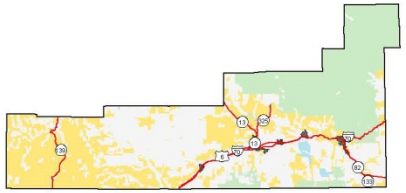
Constraint Density*

	Least 0	1	2	3	4	5	6	7	8	9	10	11	12	Most 13
Acres	10	9	61	48,527	285,063	497,458	586,213	332,763	124,167	16,843	1,878	376	23	<1
% of County	<1%	<1%	<1%	3%	15%	26%	31%	18%	7%	1%	<1%	<1%	<1%	<1%

*Constraint Density represents the number of resource-specific constraints which overlap any area within Garfield County, ranging from least to most constrained



Constraints Used in Natural Gas Analysis		
100-Year Floodplains	Soils Hazard	T&E Habitat - Boreal Toad
Areas of Critical Environmental Concern	Surficial Geology Hazard	T&E Habitat - Colorado Pikeminnow
Bighorn Sheep Range	Groundwater	T&E Habitat - Razorback Sucker
Black Bear Range	Jurisdictional Wetlands	T&E Habitat - Cutthroat Trout
Elk Range	"No Lease" Stipulation Areas	T&E Habitat - Kit Fox
Moose Range	No Surface Occupancy Areas	T&E Habitat - Lynx
Mule Deer Range	Private Conservation Easements	T&E Habitat - River Otter
Pronghorn Range	Roadless Areas	Greater Sage Grouse Habitat
Cities / Towns	State Parks	Wilderness Study Areas
Slope Hazard	Threatened and Endangered Species	Wildfire Hazards



Land Ownership

- BLM
- USFS
- Other Federal
- State
- City
- Joint
- NGO
- Private

Garfield County

TRC

Constraints for Coalbed Methane

GARFIELD COUNTY ENERGY RESOURCE ATLAS

1:500,000

0 2.5 5 10 miles

UTM ZONE 13 NORTH
NORTH AMERICAN DATUM 1983

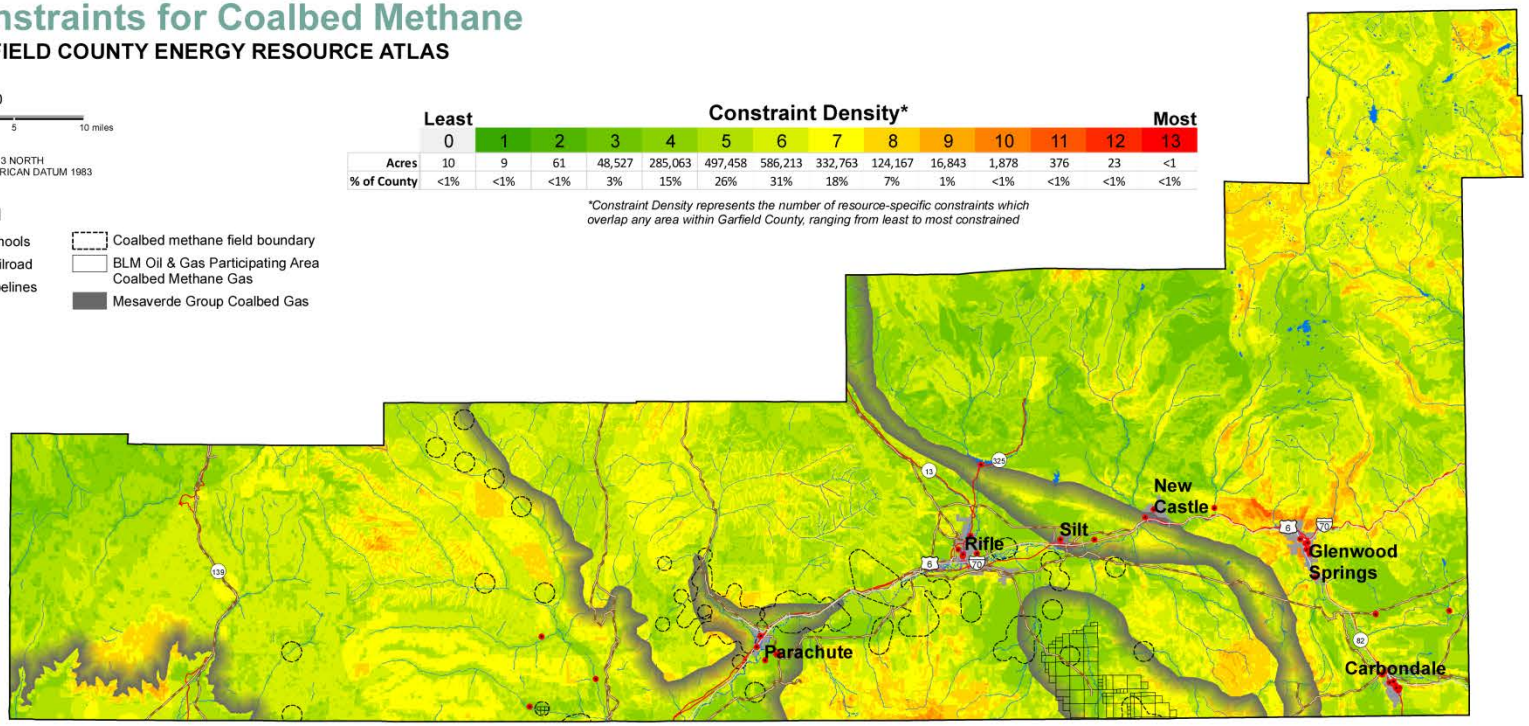
Legend

- Schools
- Railroad
- Pipelines
- Coalbed methane field boundary
- BLM Oil & Gas Participating Area Coalbed Methane Gas
- Mesaverde Group Coalbed Gas

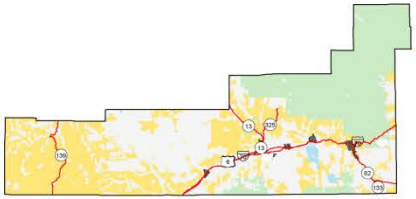
Constraint Density*

	Least													Most
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Acres	10	9	61	48,527	285,063	497,458	586,213	332,763	124,167	16,843	1,878	376	23	<1
% of County	<1%	<1%	<1%	3%	15%	26%	31%	18%	7%	1%	<1%	<1%	<1%	<1%

*Constraint Density represents the number of resource-specific constraints which overlap any area within Garfield County, ranging from least to most constrained



Constraints Used in Coalbed Methane Analysis		
100-Year Floodplains	Soils Hazard	T&E Habitat - Boreal Toad
Areas of Critical Environmental Concern	Surficial Geology Hazard	T&E Habitat - Colorado Pikeminnow
Bighorn Sheep Range	Groundwater	T&E Habitat - Razorback Sucker
Black Bear Range	Jurisdictional Wetlands	T&E Habitat - Cutthroat Trout
Elk Range	"No Lease" Stipulation Areas	T&E Habitat - Kit Fox
Moose Range	No Surface Occupancy Areas	T&E Habitat - Lynx
Mule Deer Range	Private Conservation Easements	T&E Habitat - River Otter
Pronghorn Range	Roadless Areas	Greater Sage Grouse Habitat
Cities / Towns	State Parks	Wilderness Study Areas
Slope Hazard	Threatened and Endangered Species	Wildfire Hazards



Land Ownership

- BLM
- USFS
- Other Federal
- State
- City
- Joint
- NGO
- Private

Garfield County

December 2013

TRC

Constraint Density*

	Least													Most
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Acres	10	9	61	48,527	285,063	497,458	586,213	332,763	124,167	16,843	1,878	376	23	<1
% of County	<1%	<1%	<1%	3%	15%	26%	31%	18%	7%	1%	<1%	<1%	<1%	<1%

**Constraint Density represents the number of resource-specific constraints which overlap any area within Garfield County, ranging from least to most constrained*

Constraints Used in Coalbed Methane Analysis		
100-Year Floodplains	Soils Hazard	T&E Habitat - Boreal Toad
Areas of Critical Environmental Concern	Surficial Geology Hazard	T&E Habitat - Colorado Pikeminnow
Bighorn Sheep Range	Groundwater	T&E Habitat - Razorback Sucker
Black Bear Range	Jurisdictional Wetlands	T&E Habitat - Cutthroat Trout
Elk Range	"No Lease" Stipulation Areas	T&E Habitat - Kit Fox
Moose Range	No Surface Occupancy Areas	T&E Habitat - Lynx
Mule Deer Range	Private Conservation Easements	T&E Habitat - River Otter
Pronghorn Range	Roadless Areas	Greater Sage Grouse Habitat
Cities / Towns	State Parks	Wilderness Study Areas
Slope Hazard	Threatened and Endangered Species	Wildfire Hazards

TRC

Constraints for Solar

GARFIELD COUNTY ENERGY RESOURCE ATLAS

1:500,000

0 2.5 5 10 miles

UTM ZONE 13 NORTH
NORTH AMERICAN DATUM 1983

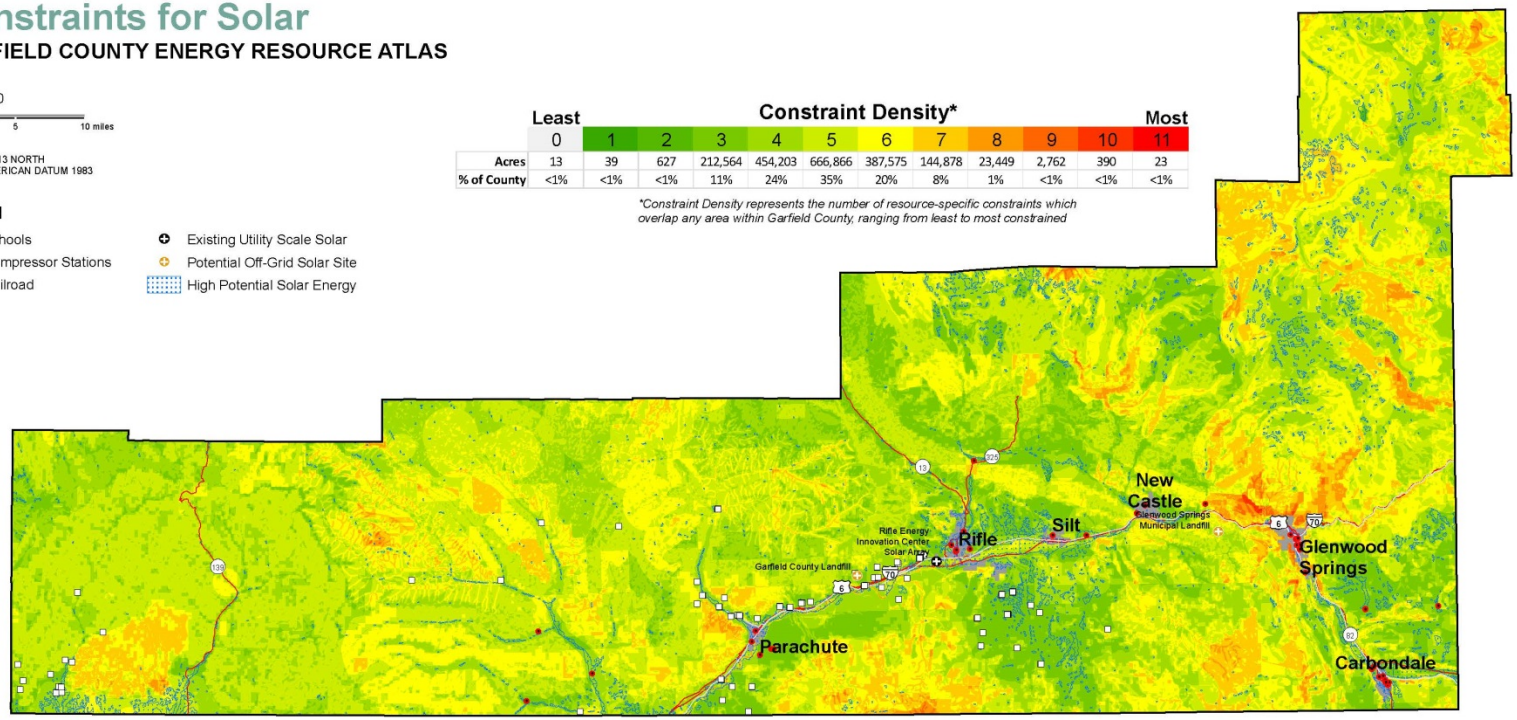
Constraint Density*

	Least 0	1	2	3	4	5	6	7	8	9	10	Most 11
Acres	13	39	627	212,564	454,203	666,866	387,575	144,878	23,449	2,762	390	23
% of County	<1%	<1%	<1%	11%	24%	35%	20%	8%	1%	<1%	<1%	<1%

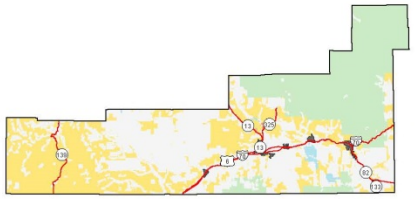
*Constraint Density represents the number of resource-specific constraints which overlap any area within Garfield County, ranging from least to most constrained

Legend

- Schools
- Compressor Stations
- Railroad
- Existing Utility Scale Solar
- Potential Off-Grid Solar Site
- High Potential Solar Energy



Constraints Used in Solar Analysis		
100-Year Floodplains	Soils Hazard	T&E Habitat - Colorado Pikeminnow
Air Space	Surficial Geology Hazard	T&E Habitat - Razorback Sucker
Areas of Critical Environmental Concern	Jurisdictional Wetlands	T&E Habitat - Cutthroat Trout
Bighorn Sheep Range	"No Lease" Stipulation Areas	T&E Habitat - Kit Fox
Black Bear Range	No Surface Occupancy Areas	T&E Habitat - Lynx
Elk Range	Private Conservation Easements	T&E Habitat - River Otter
Moose Range	Roadless Areas	Greater Sage Grouse Habitat
Mule Deer Range	State Parks	Wilderness Study Areas
Pronghorn Range	Threatened and Endangered Species	Wildfire Hazards
Slope Hazard	T&E Habitat - Boreal Toad	



Land Ownership

- BLM
- USFS
- Other Federal
- State
- City
- Joint
- NGO
- Private

Garfield County

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Constraints for Geothermal

GARFIELD COUNTY ENERGY RESOURCE ATLAS

1:500,000

0 2.5 5 10 miles

UTM ZONE 13 NORTH
NORTH AMERICAN DATUM 1983

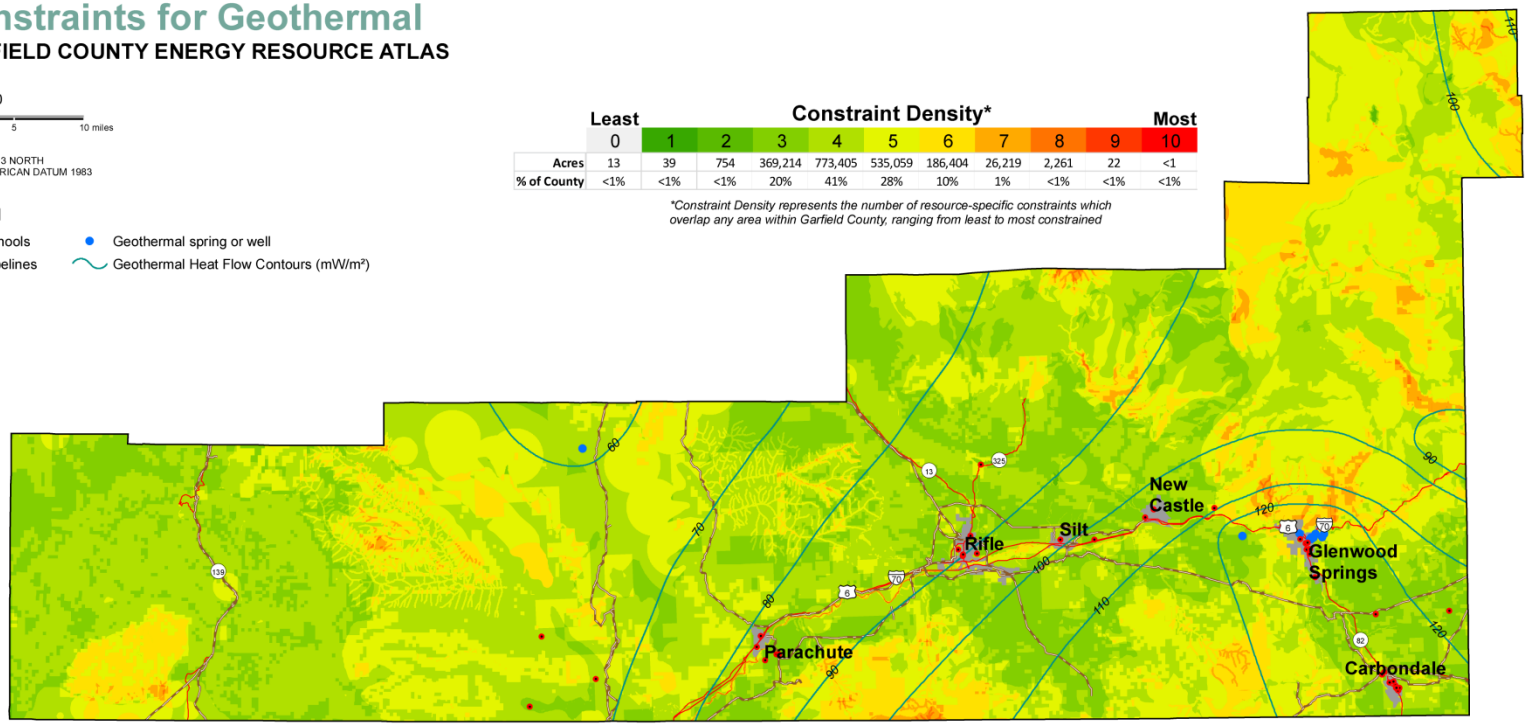
Legend

- Schools
- Pipelines
- Geothermal spring or well
- Geothermal Heat Flow Contours (mW/m²)

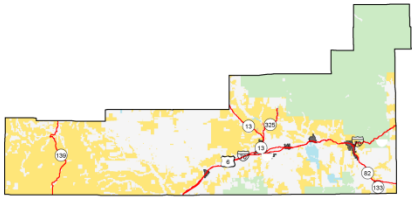
Constraint Density*

	Least 0	1	2	3	4	5	6	7	8	9	Most 10
Acres	13	39	754	369,214	773,405	535,059	186,404	26,219	2,261	22	<1
% of County	<1%	<1%	<1%	20%	41%	28%	10%	1%	<1%	<1%	<1%

*Constraint Density represents the number of resource-specific constraints which overlap any area within Garfield County, ranging from least to most constrained



Constraints Used in Geothermal Analysis		
100-Year Floodplains	Jurisdictional Wetlands	T&E Habitat - Colorado Pikeminnow
Areas of Critical Environmental Concern	"No Lease" Stipulation Areas	T&E Habitat - Razorback Sucker
Bighorn Sheep Range	No Surface Occupancy Areas	T&E Habitat - Cutthroat Trout
Black Bear Range	Private Conservation Easements	T&E Habitat - Kit Fox
Elk Range	Roadless Areas	T&E Habitat - Lynx
Moose Range	State Parks	T&E Habitat - River Otter
Mule Deer Range	Threatened and Endangered Species	Greater Sage Grouse Habitat
Pronghorn Range	T&E Habitat - Boreal Toad	Wilderness Study Areas



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Garfield County

December 2013

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Energy Resource Inventory: Summary Report

- Purpose of the Energy Resource Inventory
  - Methodology and process
- Inventory and Evaluation of Energy Resources
  - Constraints / regulatory exclusions: public and private
  - Energy resources: mineral, renewable, non-renewable
- Opportunities and Constraint Analysis
  - Each energy source: graphic and narrative
  - Quantification of area by constraint density
- Findings and Implications

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Next Steps

- Use the data and maps for planning decisions
  - Energy development
  - Resource protection
  - Supplement the Comprehensive Plan
- Creation of a user-friendly publicly available tool
  - Internet-base for accessibility
- Identification and development of data to address data gaps
- Energy resource policy development (Phase 2)

Questions and Answers