Research Study: Energy Development and the Transportation System

FEBRUARY 2010

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EXECUTIVE SUMMARY

Purpose and Goals

Energy Production and Potential

Colorado has substantial resources of both conventional and renewable energy. In 2007, Colorado produced 2,335 trillion British thermal units (Btu) of energy, making it the tenth highest energy producing state, accounting for approximately 3.3 percent of the nation's total energy production. The potential for further energy development in Colorado is considerable; ten of the nation's 100 largest natural gas fields and three of its 100 largest oil fields are found in Colorado. Oil shale deposits in Colorado hold an estimated one trillion barrels of oil – almost as much oil as the world's proven oil reserves. The state's sunny climate offers solar power potential, and windy conditions along the Front Range and the eastern plains offer wind power potential. Agriculture is an important component of Colorado's economy, resulting in great potential for biofuel production. Recent initiatives to establish Colorado's "New Energy Economy" are expected to substantially increase Colorado's production and use of renewable energy. Current and future activity leads to energy being a large contributor to our state's economy.

Energy Production in Colorado

Colorado ranks 10th in the nation in total energy production, 11th in crude oil production, 6th in natural gas production, 9th in coal production, and 6th in wind power capacity.

Source: U.S. Energy Information Administration and American Wind Energy Association

Use of the Transportation System

Energy development and production necessitates use of the transportation system, and the level at which that activity uses Colorado's state highway system varies dramatically depending upon the energy source. During the oil and gas energy boom that occurred in Colorado during the first eight years of the 21st century, many state highways experienced substantial increases in traffic and specifically in truck traffic. The state highways that have been identified as key energy development corridors for the oil and gas industry experienced an approximate 35 percent increase in truck traffic over the ten year period between 1997 and 2007. These increases have led to congestion at some locations and degradation of pavement conditions on facilities that were not designed to weather the wear and tear associated with heavy vehicles. Anecdotes about the impacts of energy development on the state's roads became widespread; however, very little research has been done to correlate energy development with transportation activity.

Planning for the Future

During the recent energy boom, oil prices peaked at approximately $145 per barrel. Currently, oil prices are in the range of $70 per barrel (December 2009), and Colorado is no longer experiencing the oil and gas boom of a few years ago. Although oil and gas development has reached a relative plateau, renewable energy development in Colorado is becoming increasingly prevalent, making this an opportune time for the Colorado Department of Transportation (CDOT) to plan for future energy development. CDOT initiated this study to gain a better understanding of how development and production of various energy sources affect the state's transportation system.

Energy Sources Addressed in Research Study:

Non-Renewable Energy
- Crude oil
- Natural gas
- Coal bed methane
- Oil Shale
- Uranium
- Coal

Renewable Energy
- Wind
- Solar
- Biofuels

Primary Goals of Research Study

- Provide an industry overview for each energy source and a general understanding of the development trends and potential in Colorado.
- Correlate the phases of energy development, production, and reclamation to transportation activity, as appropriate for each energy source.
- Develop a planning level tool that can be used to assess the transportation activity associated with future energy development scenarios and that provides a means of comparing the relative impacts to various state highway corridors.
- Provide a relative comparison of transportation activity between various energy sources.
- Provide recommendations on areas in which CDOT should focus efforts related to planning for future energy development.

Research Study Process

Project Oversight

The study process was guided by a Project Management Team, comprised of key staff from the CDOT Division of Transportation Development (DTD) and the consulting team. A CDOT Working Group also played a critical role in the study process. The Working Group consisted of CDOT staff from a variety of departments and from the three engineering regions that are most heavily impacted by energy development.

Literature Review and Key Person Interviews

The study began with a literature review to ascertain what level of information is readily available linking energy development with transportation demands. The literature review focused primarily on Colorado impact studies and data, but also drew information from other neighboring states with similar energy sources and extraction techniques and where methodologies for quantifying energy–related transportation demands have been established.

The literature review and key person interviews provided data to enable the project team to estimate the numbers and types of vehicles generated by the various energy development phases for each energy source.

To supplement the literature review, a series of interviews with knowledgeable representatives from the various energy industries, associated energy professional organizations, state regulatory agencies and local communities were conducted to gather additional information on industry operations, current and projected production levels, and the degree to which each energy sector uses Colorado state highways.

Travel Estimation Model Development

One of the primary goals of the research study was to develop a planning level tool to help CDOT and others estimate transportation activity associated with future energy development scenarios. The project team developed three travel estimation models using Microsoft Excel through a peer review process with the Project Management Team and the CDOT Working Group. The purpose for developing three models was that the level of information available and the complexity of transportation demand for the different energy sources vary widely. Rather than tying the models to specific energy development projection levels, the models serve as a tool to evaluate the transportation demands associated with given input values (i.e., energy development scenarios). This approach ensures the long-term utility and flexibility of the model as the energy industry evolves in Colorado.

Overview of Energy Sources

The nine energy sources that are the subject of this research study have diverse development and production requirements and create demands on the transportation system that can vary by magnitudes from one energy source to another. The following sections provide a general overview of each energy source along with a description of the type and relative magnitude of the transportation activity associated with each.

Oil & Gas

In 2008 there were over 38,000 active oil and gas wells in Colorado, which are widely distributed around the state. There are active wells located in two-thirds of Colorado counties, with the highest levels of activity occurring in the Piceance and Denver/Julesburg basins. The Colorado Energy Research Institute defines economic study areas associated with the different oil and gas basins in Colorado, as shown on the map on the following page. The map also shows the 39 key energy development corridors associated with oil and gas on the state highway system.

85 percent of Colorado's active oil and gas wells are located in the following six counties:

- Weld
- Garfield
- Yuma
- La Plata
- Las Animas
- Rio Blanco

Source: Colorado Oil and Gas Conservation Commission

Crude oil and natural gas have similar development and extraction processes. Potential productive wells undergo a site evaluation which may include seismic tests, exploratory well drilling or core sample testing to confirm the quality of the oil or gas reserves. After an acceptable site has been selected, construction can begin. Transportation demands during construction are substantial due to a short timeframe (generally 30 to 60 days) and a high volume of heavyweight truckloads. The number of truckloads of equipment and supplies can vary substantially from one well to the next depending upon the depth of the well and the configuration of the oil or gas deposit. The construction phase represents the highest intensity of travel demand at an oil or gas well. Well drilling equipment and materials must be delivered, along with well structures, pumps, and well casings. Additionally, significant amounts of fresh water are brought to the site and waste materials are taken from the site during construction.

Oil and Gas Trip Generation Rates (average trips per well)

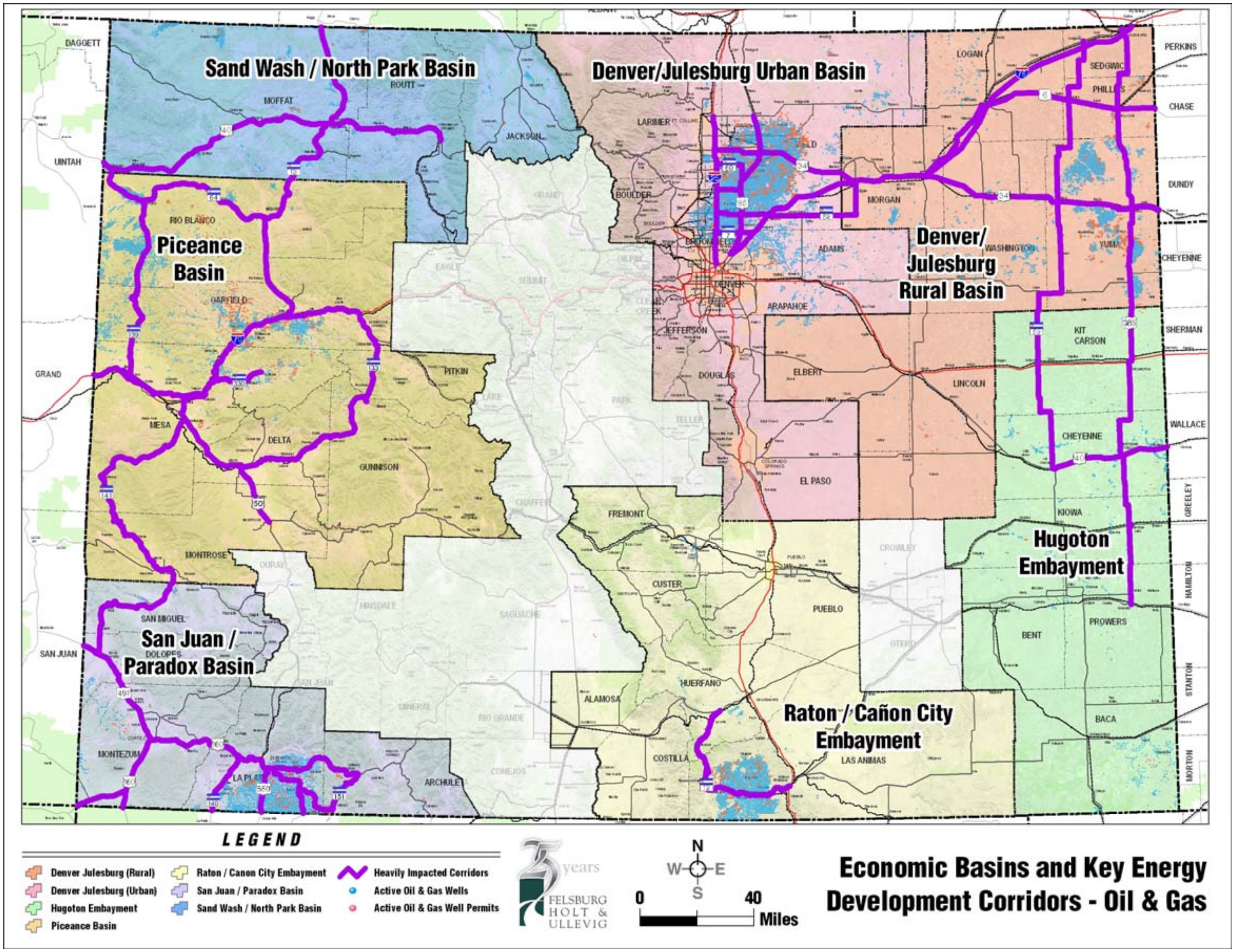
Phase	Crude Oil	Natural Gas	Coal Bed Methane
Development[1,2]	**1,710**	**1,721**	**684**
Production (Annual)	**974**	**111**	**742**
Reclamation[2]	**250**	**73**	**146**

[1] Development phase includes all activities prior to production (site preparation, drilling and completion)

[2] Development and reclamation trips represent single occurrences.

An operational well can produce oil or gas for about 10 to 30 years depending on the size of the resource deposit. During the production phase, trips to and from a well site are related to routine well maintenance, periodic well stimulation and removal of produced water. After extraction is complete, a well is retired and the site is reclaimed. Reclamation activities typically involve deconstruction, re-grading, removal of debris and contaminated soils, and plugging of the well.

Natural gas wells generally send product to market via surface and underground pipelines. Crude oil wells often require tanker trucks to deliver crude oil from the well to refineries.


Sand Wash / North Park Basin
Denver/Julesburg Urban Basin
Piceance Basin
Denver/ Julesburg Rural Basin
San Juan / Paradox Basin
Hugoton Embayment
Raton / Cañon City Embayment
LEGEND
Denver Julesburg (Rural)
Denver Julesburg (Urban)
Hugoton Embayment
Piceance Basin
Raton / Canon City Embayment
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Economic Basins and Key Energy Development Corridors - Oil & Gas

Coal bed methane (CBM) is a form of natural gas extracted from underground deposits of coal. It is extracted using similar techniques to a conventional oil or gas well, but the depths of CBM wells are much shallower, resulting in less travel demand during the construction phase. CBM wells create large quantities of produced water; at the initial production stage, CBM wells produce mostly water. Trip generation rates during the production phase are higher than conventional natural gas rates because of the extensive water removal requirements.

Colorado produces more than one-fourth of all coal bed methane in the country; coal bed methane accounts for about half of Colorado's natural gas production.

Source: U.S. Energy Information Administration

Oil shale refers to any rock that contains solid bituminous materials that release as petroleum when heated. Oil shale can be extracted and processed to generate oil similar to oil pumped from conventional oil wells; however, the extraction and processing is more complex than conventional oil recovery and currently is significantly more expensive. The extraction process involves mining the oil shale and then heating it to a high temperature; the resultant liquid must then be separated and collected. An alternative, experimental process involves heating the oil shale while it is still underground, and then pumping the liquid to the surface.

The largest deposits of oil shale in the world are found in the United States in the Green River Formation, which covers portions of Colorado, Utah, and Wyoming. Although the oil shale deposits in Colorado (primarily in the Piceance Basin) are tremendous, the potential for commercial scale oil shale production is highly uncertain at this time, as are the transportation demands.

Uranium

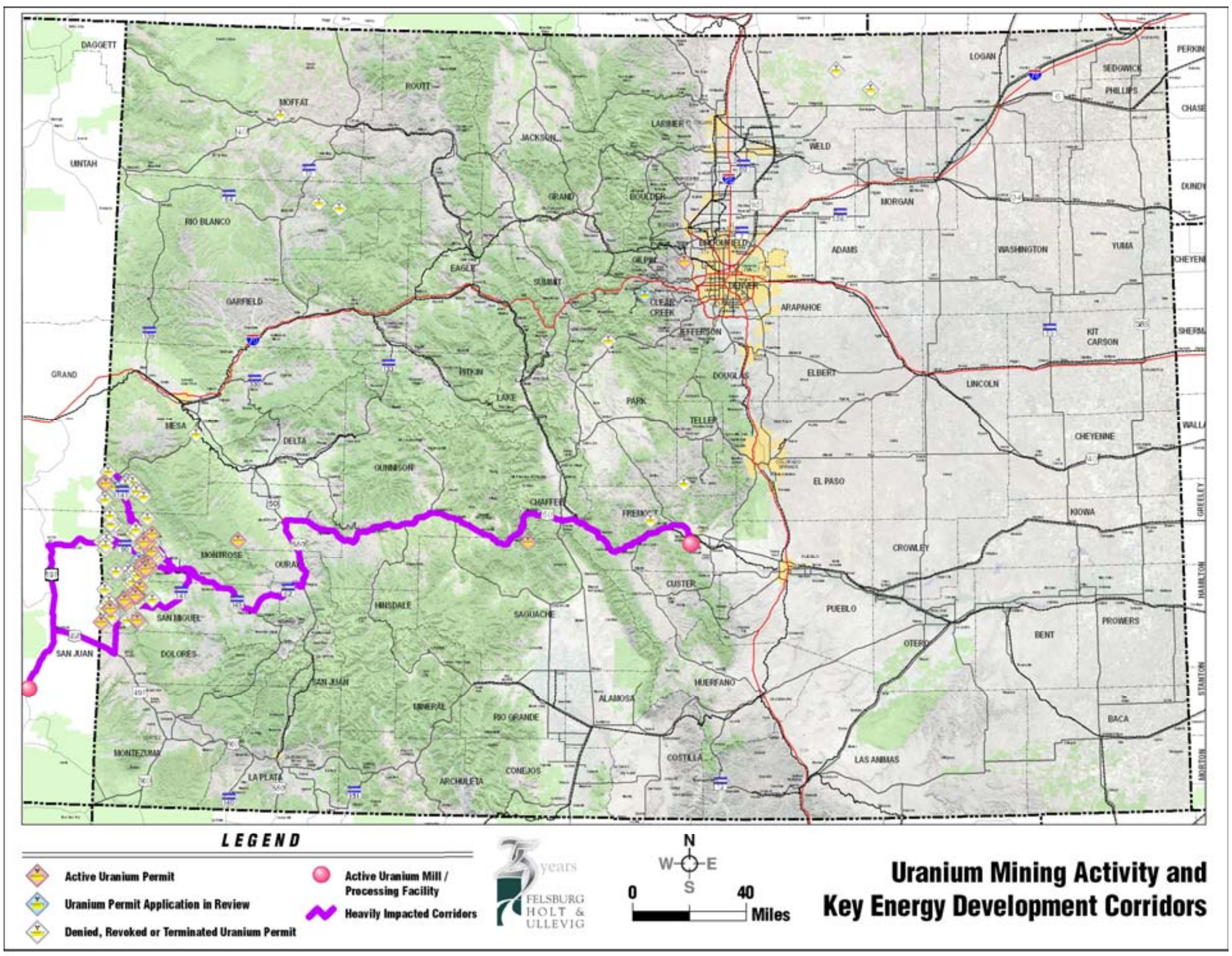
Uranium ore can be extracted using both open pit and underground mining methods. Given the proximity of uranium ore to the surface, open pit mining is the preferable extraction method in Colorado. Presently, all three operating uranium mines in Colorado are in the Uravan mineral belt which is located in the far western portion of the state in Montrose and San Miguel Counties.

Quarry material containing uranium ore must be transported to a processing facility; this transport represents the primary demand of uranium mining on the state highway system. The uranium is transported in trucks that carry 25 tons of ore. A typical uranium mining operation might mine 200 to 300 tons of uranium ore per day, which equates to 16 to 24 heavy vehicle trips per day to and from the mine.

Uranium Trip Generation Rate per Thousand Tons of Uranium Ore

Type	Trips
Haul Trips	**80**
Employee Trips (Annual)	**280**

There are only two uranium processing facilities in the region: the Canon City Mill near Canon City, Colorado and the White Mesa Uranium Mill near Blanding, Utah (as shown on the map below), although the Canon City Mill is not currently being used. Seven state highway corridors in Colorado have been identified as key energy development corridors for uranium. These corridors, as shown on the map below, are the routes which are used to travel between the Uravan mineral belt and the two processing facilities.



Source: Colorado Division of Reclamation, Mining, and Safety

Coal

Coal is one of the United States' most abundant and recoverable energy sources. The coal found in Colorado is generally low in sulfur and ash and is among the highest quality, cleanest coals found anywhere in the world, which makes it very desirable because it results in lower emissions when burned. Coal deposits are scattered throughout Colorado, primarily on the Western Slope and along the Front Range. The number of producing coal mines varies depending upon economic conditions; during the period between January and August of 2009, there were ten producing coal mines in Colorado.

Approximately three-quarters of rail freight originating in Colorado in 2005 was coal, and nearly 50 percent of the rail freight volume coming into Colorado was coal.

Source: 2035 Statewide Plan Freight Technical Report

In the United States, coal is predominantly transported by rail; the weight of coal and the length of travel make rail the most economical means of transporting coal. In Colorado, railroad spurs provide direct connections between producing coal mines and a mainline railroad. Therefore, the direct demands of coal mining on the state highway system are minimal, especially in comparison to the demands of the oil and gas industry. The primary impact of coal transport on the state highway system occurs at railroad/highway crossings. Where grade separated crossings are not provided, coal trains, which typically include 120 to 130 rail cars, create delays for the state highway system and also present safety concerns.

Wind

Wind power is the conversion of wind to a useable form of energy, typically electricity, using wind turbines. Wind energy production is attractive when a site has consistent winds with a mostly flat and open terrain. In eastern Colorado, all of these qualities are present. As of 2008, there were 820 wind turbines operating in Colorado throughout 11 operational wind farms, with a total wind power capacity of 1,068 megawatts (MW). The megawatt capacity of a wind turbine is the maximum potential energy produced with one hour of optimum wind speed.

In 2007, Colorado installed 776 MW of new wind power capacity, the second highest of any state that year.

Source: American Wind Energy Association

Transporting the massive structures needed for a wind turbine is challenging. A single turbine can require up to eight truck hauls. Although the turbine blades are relatively light (seven to eight tons each), they require permits for travel on the state highway system because they are so long (130 feet). Sometimes transporting wind turbines can necessitate the temporary removal of signal poles and mast arms at intersections. In addition to transporting the pieces of the wind turbines to the site, large cranes are required to erect the turbines, along with trips associated with building access roads, constructing concrete foundations, and delivering water for dust control. Once a wind farm is operational, it is typically staffed by on-site workers during normal business hours for routine maintenance. Infrequently, they need to bring in a crane to fix a problem. In some cases, the wind turbines are also monitored remotely.

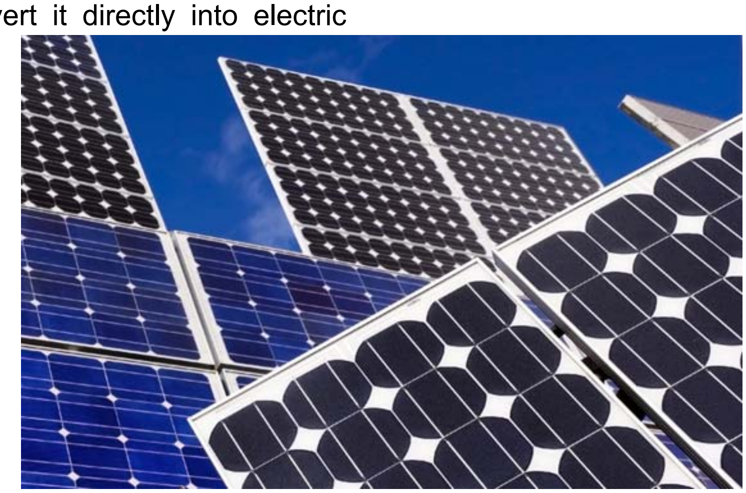
Wind Power Trip Generation Rates

Phase	Trips per Turbine	Trips per MW[1]
Construction	126	79
Operations (Annual)	8	5

[1] Trips per MW calculated based on average wind turbine capacity of 1.6 MW

Solar

There are two main types of solar energy, Photovoltaic (PV) and Concentrated Solar Power (CSP). CSP directs sunlight into a focused beam to create thermal energy for electric generation. PV cells capture solar radiation and convert it directly into electric current. This research study focuses on PV solar energy as development of this type has been more prevalent in Colorado. Solar energy production is attractive for areas with ample, direct sunlight. The entire state is suitable for utility-scale solar energy production, especially the southern third of the state. As of 2009, there were 16 megawatts (MW) of solar power capacity in Colorado across six utility-scale PV solar generation facilities, primarily located along the Front Range. PV solar panel capacity is



reported as the electric generation per hour of peak sun exposure. One MW of PV solar capacity typically requires ten acres of solar panels.

The primary equipment needed to build a PV solar facility, mounting materials and solar panels, can be delivered to a development site using semi-truck containers, flat bed trucks and light passenger trucks. Additionally, concrete is delivered to the site for pouring foundations that mount the panels. In addition to delivery of materials, construction equipment necessary for grading, dozing, excavating, trenching, and hoisting are delivered to the site. After a solar power array has been constructed, the operation requires periodic trips for general maintenance or for repairs caused by adverse weather conditions.

Solar Power Trip Generation Rates

Phase	Trips per MW[1]
Construction	202
Operations (Annual)	50

[1] One MW of capacity typically requires approximately ten acres of solar panels.

Biofuels

Biofuels, such as biodiesel and ethanol, are processed from organic matter and are designed to replace diesel and gasoline. Often, organic material is not grown for exclusive use at biofuel facilities; instead, the waste from organic production is used. Unlike other renewable energy sources, which are used for utility-scale electricity generation, the end use for biofuels is typically for personal or commercial auto transportation. American AgriDiesel

Colorado produces an estimated 125 million gallons of ethanol each year (about two percent of U.S. total production) and approximately 10 million gallons of biodiesel.

Sources: U.S. Energy Information Administration and American AgriDiesel

Biofuel plants exist throughout Colorado using corn, algae, soy, recycled vegetable oil, and woody biomass (small pellets of wood). Unlike most other energy sources, biofuels can be created wherever a developer chooses. The selected site is most likely near a developed transportation network to reduce transport costs. In Colorado, biofuel plants are generally very small scale at the present time and are located in areas on the Front Range and eastern plains.

Transporting materials to construct a biomass processing facility are similar to constructing other industrial manufacturing facilities. The largest transportation demands associated with biofuel are not during the construction phase as with other renewable power, but throughout the production phase as organic material is continually delivered to the processing plant for energy generation and processed fuels are exported for fossil fuel blending. These trips to and from the plants can be accomplished by semi-trucks.

Biofuel Trip Generation Rates

	Trips per Million Gallons of Ethanol or Biofuel
Input-Related	**793**
Output-Related	**442**
Total	**1,235**

Travel Estimation Models

The main impetus for this research study was the desire to better understand the level of travel demands placed on the state highway system by energy development in Colorado. The travel estimation models serve as a tool to relate future energy development scenarios to levels of travel demand on a statewide, economic basin, or corridor basis.

Using information gathered through the literature review and the key person interviews, the three travel estimation models were developed. The trip generation rates provided in the tables in the previous section serve as the foundation for estimating future travel demands for each energy source. These models are not intended to evaluate impacts associated with a particular energy development site. Rather, they are intended to be used to gain an understanding of the relative magnitude of the transportation demands associated with the various energy development sectors in Colorado and to compare the relative demands of energy development on key energy corridors.

The oil and gas model is the most complex of the three

Travel Estimation Models

Oil & Gas Model
- Crude Oil
- Natural Gas
- Coal Bed Methane

Uranium Model

Renewable Energy Model
- Wind
- Solar
- Biofuels

models. The outputs of the model include trip generation and vehicle classification estimates for crude oil, natural gas, and coal bed methane, as well as an allocation of travel demand to corridors throughout the state that have been identified as key energy development corridors. Oil shale is not included as part of the model because the industry has not matured to commercial scale production; therefore, insufficient data are currently available.

The uranium model is similar to the oil and gas model in that it includes both a trip generation/vehicle classification component and a corridor allocation component. However, it is less complex because the mining operations in Colorado are localized, the origins and destinations are known, and the activity on the transportation system is less dispersed than in the oil and gas industry. Coal, the other subject energy source that is mined, is not included as a part of the model because coal is predominantly transported by rail.

The third model is for renewable energy, including wind, solar, and biofuels. This model is considerably more simplistic than the oil and gas or uranium models; it provides trip generation and vehicle classification information, but does not go to the extent of allocating travel demands to specific corridors. These industries are in their formative stages and Colorado has not seen heavy renewable energy development to date. In addition, it is difficult to predict the exact location of future renewable energy development as several environmental and market factors need to align to ensure efficient and economically viable resource production.

Findings and Recommendations

Comparison of Annual Trip Generation

Trip generation rates contained in the previous section are difficult to compare from one energy source to another since energy source development and production are measured in different units (i.e., a well, a wind turbine, tons of uranium, etc.). The table shown to the right provides estimates of the total number of trips that were generated in 2007 and 2008 by each of the energy sources in Colorado. These estimates are based on information gathered from various sources on the level of production and development that occurred in 2007 and 2008, and on the trip generation rates that have been documented in the research study. These estimates provide a clear comparison of the relative demand between the various energy sources. The annual trips in Colorado generated by the oil and gas industry dwarf the travel demands of the other energy sources. Based on these estimates, the oil and gas trips account for 98.7 percent of total energy trips.

Estimated Annual Trip Generation

Energy Source	2007	2008	Average
Oil & Gas[1]	15,900,000	17,900,000	16,900,000
Uranium	26,000	26,000	26,000
Wind	63,000	5,400	34,200
Solar	200	2,700	1,450
Biofuels	167,000	167,000	167,000
Total	16,156,200	18,101,100	17,128,650

[1] Includes crude oil, natural gas and coalbed methane

Study Recommendations

The trip generation rates and the travel estimation models that have been developed as a part of this research study are intended to be used by CDOT, as well as Metropolitan Planning Organizations, Transportation Planning Regions, municipalities and counties in Colorado, to proactively plan for future energy development and establish ways to address the demands on the transportation system. The following list of recommendations is intended to provide CDOT direction on areas in which to focus to most efficiently plan for future energy development in Colorado.

Policy Recommendations

- Since the oil and gas travel demands account for the vast majority of the energy demands to the state highway system, CDOT should focus its planning efforts on oil and gas development.

- The project team experienced some hesitation from the energy sector (particularly from the oil and gas industry) in sharing information for this research study. CDOT should continue to build and improve relationships with the energy development industry and pursue opportunities for partnership with the energy sector.

- Build partnerships with resource and regulatory agencies to ensure that CDOT's interests (i.e., demands to the transportation system) are considered and adequately addressed in any environmental studies pertaining to the energy industry and that CDOT is alerted of any potential issues.

- With respect to future wind power development, CDOT should take a statewide perspective in identifying the best routes for transporting the oversized loads that comprise the wind turbines. For routing through specific municipalities or counties, CDOT should defer to the local governments' knowledge of the best routes order to minimize delays and the need for temporary removal of signal equipment.

- To continue improving safety at highway/rail crossings, maintain relationships with the Public Utilities Commission (PUC) and the railroads to improve the safety at existing at-grade railroad crossings and to provide grade separated crossings, particularly along railroad lines that are heavy used by the coal industry.

Model & Corridor Improvement Recommendations

- A baseline comparison of travel demands by corridor is provided in the research study document. This comparison can be used both as a measure for prioritizing corridors in the long range regional and statewide transportation plans and as a basis with which to compare future conditions.

- The travel estimation models should be used to estimate the level of energy-related activity on key corridors in the state. CDOT staff should update the models in advance of the regional and statewide transportation planning processes so that up to date corridor travel estimations can be incorporated into the planning process.

- Efforts to validate the travel estimation models in the future based on actual traffic and energy development data will help to ensure the long term utility of the models.

- The research study identifies potential corridor improvements for each of the key energy development corridors in the state. Potential improvements include improving infrastructure (such as surface treatment, bridge repair or replacement); enhancing safety (such as geometric modifications, guardrail, widened shoulders); or improving mobility (such as major widening, auxiliary lanes, passing or climbing lanes).This information should be used as a basis for conducting more detailed corridor studies, and should be incorporated into the next iteration of the long range regional and statewide transportation plans.

25 years

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