COLORADO Energy Office

Colorado Recycled Energy Market Overview

FINAL REPORT • FEBRUARY 2016

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Executive Summary

Recycled energy, also known as waste heat to power (WHP), is the process of capturing heat discarded by an existing process and using that heat to generate electricity. In Colorado, the term recycled energy is more commonly used and qualifies under the state's Renewable Electricity Standard (RES) as an eligible resource. Under the Colorado RES, recycled energy systems must have a nameplate capacity of 15 megawatts (MW) or less, convert the otherwise lost energy from the heat from exhaust stacks or pipes to electricity and not combust additional fossil fuel to be eligible. In addition, recycled energy does not include energy produced by systems that use waste heat from a process whose main purpose is the generation of electricity. In the industrial sector, most recycled energy streams are generated by kilns, furnaces, ovens, turbines, engines, and other equipment. Waste streams suitable for recycled energy can also be generated at field locations, including landfills, compressor stations, and mining sites.

Waste heat streams are also produced in the residential and commercial sectors, but compared to industrial sites these waste heat streams typically have lower temperatures and lower volumetric flow rates. The economic feasibility for recycled energy declines as the temperature and flow rate decline, and therefore, recycled energy technologies are applied in industrial markets where waste heat stream characteristics are more favorable.

This report provides an assessment of the potential market for recycled energy in Colorado, discusses market and policy trends, and includes recommendations on policies or programs that Colorado can adopt to support further recycled energy project development. The types of industrial waste heat streams that are considered in this study are shown in **Table 1** and are described in more detail below.

TABLE 1: TYPES OF WASTE HEAT STREAMS

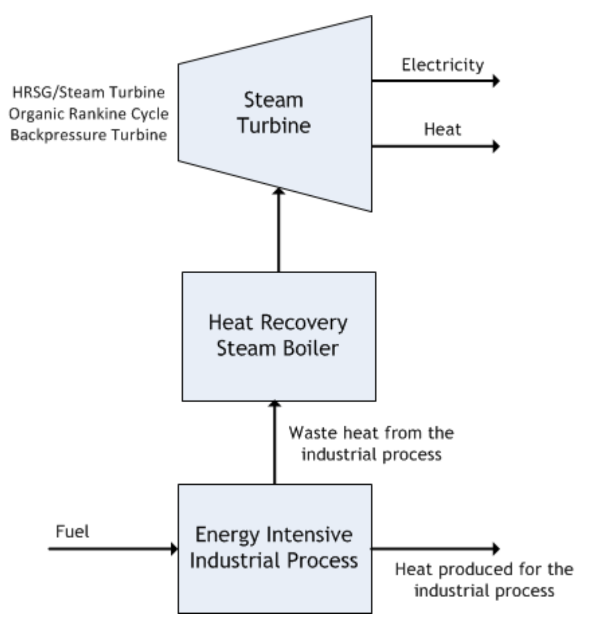
Source of Waste Heat Stream	Example (illustrations only, examples are not intended to be all inclusive).
Thermal Process	Energy recovered from a furnace, oven, or kiln, and subsequently used in a combined heat and power (CHP) bottoming cycle.
Mechanical Drive	Energy recovered from a natural gas pipeline compressor station.
Other	Waste heat recovered from industrial or other processes that generate heat as a byproduct, such as exothermic reactions, incineration, and pressure reduction.

1 | Introduction to Recycled Energy in Colorado

Recycled energy or waste heat to power (WHP) is the process of capturing heat discarded by an existing process and using that heat to generate electricity. In Colorado, the term recycled energy is more commonly used as compared to WHP, and as a result will be the term used throughout this report. Recycled energy systems are defined as eligible under Colorado's RES as "energy produced by a generation unit with a nameplate capacity of not more than 15 MW that converts the otherwise lost energy from the heat from exhaust stacks or pipes to electricity and that does not combust additional fossil fuels." This excludes energy produced by any system whose primary purpose is the generation of electricity. As a result, traditional CHP applications such as the Yuma and Sterling Ethanol systems discussed below do not qualify under Colorado's RES.[1] Most recycled energy applications are at larger industrial facilities. This analysis will primarily look at sites with recycled energy potential over 250 kilowatts (kW). This report builds on a previous analysis conducted by ICF International for Oak Ridge National Laboratory in February 2015, titled "Waste Heat to Power Market Assessment."

The waste heat sources that drive recycled energy technologies can be divided into three categories that have unique attributes, both in terms of viable technologies and legal definitions that may apply. All three categories of recycled energy discussed below can qualify under Colorado's RES.

FIGURE 1: DEFINING RECYCLED ENERGY



Waste heat from a thermal process – Energy can be recovered from a furnace, oven, kiln, or other industrial processes[2] and converted to electricity using a thermodynamic process such as a Rankine cycle steam turbine.[3] This configuration for a recycled energy system is also referred to as a combined heat and power (CHP) bottoming cycle system. In a CHP bottoming cycle, fuel is combusted to provide thermal input to industrial process equipment like a kiln or furnace, and the heat rejected from the process is captured and used for power production.

Waste heat from a mechanical drive – Engines and turbines can be used to drive mechanical shafts that in turn spin compressors, pumps, and electrical generators. An example is a pipeline compressor station that utilizes a gas turbine to drive a compressor that in turn moves natural gas through a pipeline. Waste heat can be recovered from the gas turbine exhaust and used to generate electricity. This configuration for a recycled energy system is not classified as CHP because there is no industrial process that utilizes the thermal energy (heat).

Waste heat from other systems – Unlike bottoming cycle CHP which combusts a fuel to generate heat for a thermal application and then uses the leftover waste heat to generate power, some industrial processes generate heat as a byproduct. Capture and use of that heat for a thermal purpose is classified as waste heat recovery, while capture and use of that heat to make power is often called waste heat to power, or in this case recycled energy. Based on these definitions, waste heat recovery is not considered eligible under Colorado's RES since no electricity is produced; however, waste heat to power is eligible. Operations that use byproduct heat to make power include exothermic reactions like those used in the manufacture of fertilizers, incineration of sewage sludge, heat released from pressure relief valves, and other processes that produce heat, not for a thermal purpose but as a result of their operation.

There is no single definition for recycled energy or WHP, and various definitions have been used by regulators, government agencies, manufacturers, and trade associations. In this report, the recycled energy market is defined to include all waste heat streams described in the preceding paragraphs.

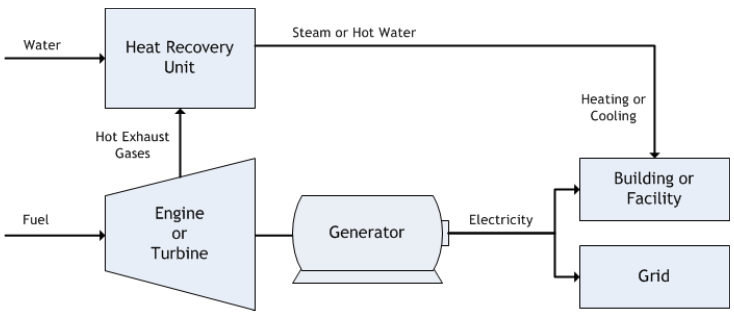
[1] EPA Combined Heat and Power Partnership, Portfolio Standards and the Promotion of Combined Heat and Power, March 2015, http://www.epa.gov/chp/documents/ps_paper.pdf.

[2] Processes include calciners, kilns, flares, incinerators, ovens, reciprocating engines, regenerative oxidizers, thermal oxidizers, and exhaust from petroleum refining.

[3] Other thermodynamic processes, such as organic Rankine cycle (ORC) and Kalina cycles, can be used, particularly for lower temperature waste heat streams.

Topping-cycle CHP, where electricity is the primary product, as shown in **Figure 2** below, is not eligible under Colorado's RES. In a typical topping cycle system, fuel is combusted in a prime mover such as a gas turbine or reciprocating engine to generate electricity. Energy normally lost in the prime mover's hot exhaust and cooling systems is instead recovered to provide heat for industrial processes (such as petroleum refining or food processing), hot water (e.g., for laundry or dishwashing), or for space heating, cooling, and dehumidification. In a bottoming cycle system, also referred to as "waste heat recovery," fuel is combusted to provide thermal input to a furnace or other industrial process and heat rejected from the process is used for electricity production.

FIGURE 2: DEFINING CHP



Report Overview

The purpose of this report is to provide a baseline assessment of the potential, both technical and economic, for recycled energy in Colorado, along with recommending policies and other initiatives that Colorado can implement to enhance recycled energy project development. This report is organized as follows:

Section 1 – Introduction

Section 2 – Evaluation of Existing Waste Heat Systems

Section 3 – Technical Potential for Recycled Energy (>450 F) in Colorado

Section 4 – Economic Potential for Recycled Energy Systems Over 250 kW in Colorado

Section 5 – Market Penetration of Recycled Energy ≥250 kWe in Colorado

Section 6 – Recycled Energy Market and Policy Trends

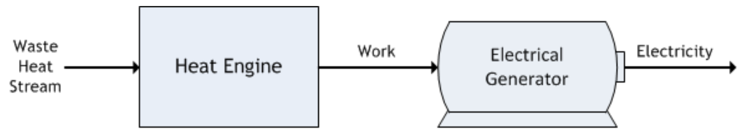
Section 7 – Opportunities for State Involvement in Recycled Energy Market

Section 8 – Summary and Conclusions

Common Technologies

From an energy conversion perspective, a recycled energy system consists of two major components: 1) a heat engine and 2) an electrical generator (see **Figure 3**). In thermodynamic terms, the heat engine converts energy (heat) in the waste heat stream to mechanical energy (work). The mechanical energy (e.g., a rotating shaft) is then used to generate power in an electrical generator.

FIGURE 3: MAJOR COMPONENTS IN A RECYCLED ENERGY SYSTEM



In a heat engine, heat flows from a hot reservoir to a cold reservoir, and the temperature difference between these reservoirs governs the efficiency of the heat engine. The maximum, or Carnot, efficiency (η) is defined to be (see **Figure 4** for illustration):

$\eta = W/ Q_H = 1 - (T_C / T_H)$

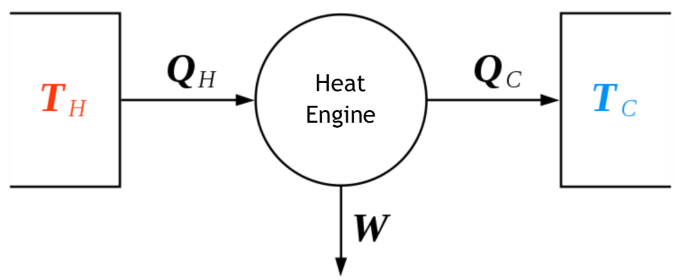
W – work done by the system (energy exiting the system as work)

Q_H – heat put into the system (heat energy entering the system)

T_C – absolute temperature of the cold reservoir

T_H – absolute temperature of the hot reservoir

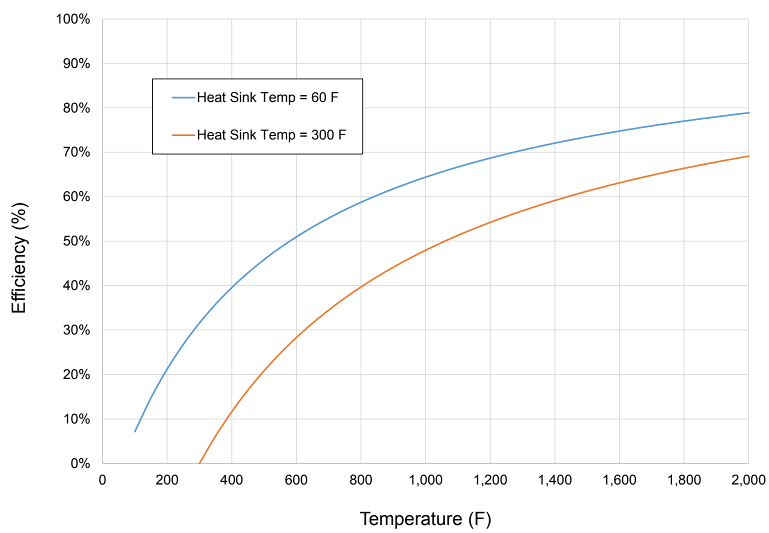
FIGURE 4: HEAT ENGINE DIAGRAM



For recycled energy technologies that are commercially available, the actual efficiencies are much lower than the theoretical Carnot efficiencies. In actual recycled energy systems, there are irreversible thermodynamic losses that push the efficiencies downward. In addition, energy is also lost in the electrical generation process.

The Rankine thermodynamic cycle is commonly used for recycled energy systems. Variations of this cycle include the steam Rankine cycle (SRC), organic Rankine cycle (ORC), Kalina cycle, and supercritical carbon dioxide (CO_2) cycle. These Rankine cycles are briefly described on the following pages. There is also a short discussion on emerging recycled energy technologies.

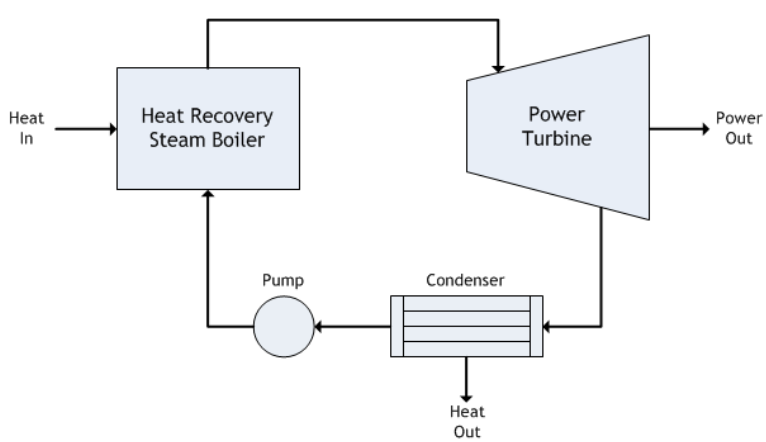
FIGURE 5: CARNOT (MAXIMUM) HEAT ENGINE EFFICIENCY



Rankine Cycle

In a Rankine cycle (either SRC or ORC); a liquid working fluid is pumped to elevated pressure before entering a heat recovery boiler as illustrated in **Figure 6**. The pressurized fluid is vaporized using energy captured from a waste heat stream, and then expanded to lower temperature and pressure in a turbine, generating mechanical power that can drive an electric generator. The low pressure working fluid is then exhausted to a condenser where heat is removed by condensing the vapor back into a liquid. The condensate from the condenser is returned to the pump and the cycle is repeated. For recycled energy applications, the Rankine cycle efficiency typically ranges from 30-50 percent of the Carnot theoretical efficiency. For example, if the Carnot efficiency is calculated to be 60 percent for a 900°F heat source, the actual efficiency achieved will likely be in the range of 18-30 percent.

FIGURE 6: RANKINE CYCLE HEAT ENGINE

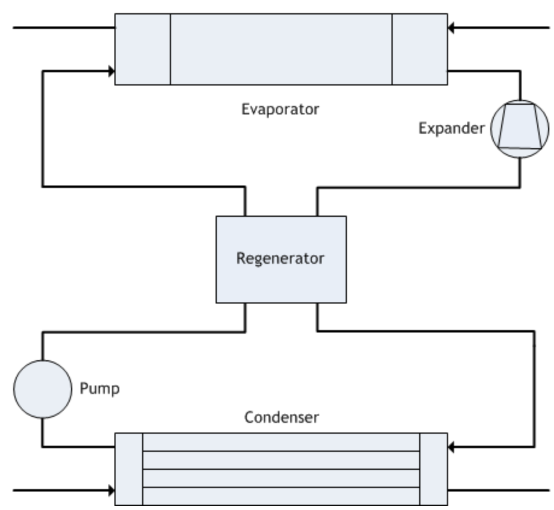


Most commercially available recycled energy technologies in the U.S. are based on either the steam Rankine cycle (SRC) or the organic Rankine cycle (ORC). The Kalina cycle and supercritical CO_2 cycle are variations of the Rankine cycle that have recently entered the market. For SRC systems, the working fluid is water, and for ORC systems the working fluid is a hydrocarbon, hydrofluorocarbon, or ammonia. The Kalina cycle uses a combination of water and ammonia, and the supercritical CO_2 cycle uses carbon dioxide.

Steam Rankine Cycle (SRC)

The most common example of the Rankine cycle is the steam turbine, or steam Rankine cycle (SRC). In an SRC system, the working fluid is water, and steam is created to drive a turbine. Most of the electricity produced in the U.S. is generated by conventional steam turbine power plants that use coal, natural gas, or nuclear energy as a fuel source. In recycled energy applications, the capacity of steam turbines can range from 50 kW to several hundred megawatts.

FIGURE 7: ORGANIC RANKINE CYCLE HEAT ENGINE WITH REGENERATOR



Organic Rankine Cycle (ORC)

Organic Rankine cycle (ORC) systems are similar to SRC systems, but instead of water the working fluid is a hydrocarbon, hydrofluorocarbon, or ammonia. One configuration of an ORC system is shown in **Figure 7**. This ORC design consists of an evaporator ("boiler"), expander ("turbine"), preheater, condenser, and regenerator. The regenerator improves efficiency by pre-heating the working fluid with energy that would otherwise be rejected. The working fluid in an ORC machine typically has a lower boiling point than water, which allows ORC systems to operate with relatively low temperature heat sources – sometimes as low as 200°F or below[4]. An example is working fluids that have been used in ORC systems include silicone oil, propane,

[4] ElectraTherm's Green Machine and the Ener-G-Rotors ORCATM systems are examples of modular ORCs that have the ability to operate with relatively low temperature heat sources.

isopentane, isobutane, xylene, and toluene. The working fluid is chosen based on the best thermodynamic match to the available heat source.

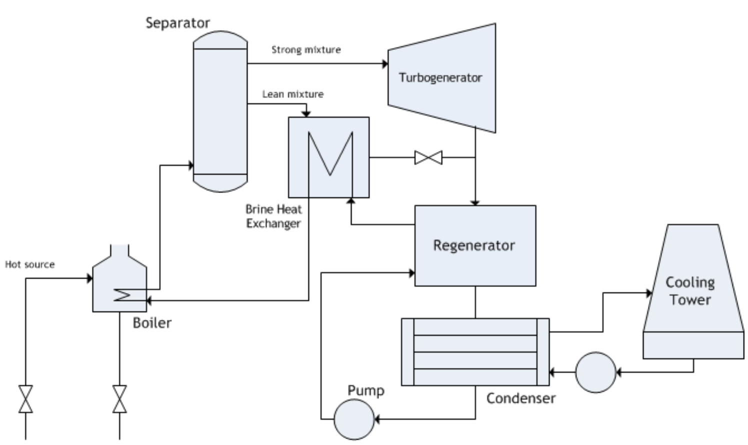
In comparison with water, the fluids used in ORCs have thermodynamic properties (e.g., boiling point characteristics) that enable operation with waste heat sources that have temperatures near 200°F, or even lower. Operation at such low temperatures, however, is typically only cost effective when using a liquid waste stream, which allows the use of a liquid-to-liquid heat exchanger.[5] For gaseous heat sources, such as hot exhaust from an industrial process, a temperature of at least 500°F is typically required for commercially available technologies.

While both cycles are classified as Rankine cycle heat engines, there are a few key distinctions between SRC and ORC systems:

- Heating and expansion for an ORC occurs with the application of heat to an evaporator, not a boiler.
- The ORC condenser is not operated at a vacuum or at sub-atmospheric pressure, which helps to avoid introducing air into the system.

ORC systems are commonly used to generate power in geothermal power plants, and more recently, in pipeline compressor heat recovery applications. A description of an ORC pipeline compressor application installed by Ormat on the Trailblazer pipeline in Colorado is described in the next section of this report. In these, and other ORC applications, electric generation efficiencies range from around 8 percent with waste heat sources at 300°F, to around 15 percent with waste heat sources near 800°F. As expected, these efficiencies are lower than the maximum Carnot efficiencies. For example, the Carnot efficiency for a heat source at 300°F and a heat sink at 77°F is about 30 percent.

FIGURE 8: KALINA CYCLE HEAT ENGINE



Source: Thekdi, 2007

[5] For equivalent levels of heat transfer, a liquid-to-liquid heat exchanger is much smaller, and less expensive, compared to a gas-to-liquid heat exchanger.

Kalina Cycle

The Kalina cycle is a variation of the Rankine cycle, using a binary fluid pair as the working fluid (typically water and ammonia). **Figure 8** shows a schematic view of a Kalina cycle power plant for waste heat. In addition to the classic four-stage Rankine cycle components (evaporator, turbine, condenser, compressor), there is a distillation-condensation subsystem consisting of a series of separators, heat exchangers, and pumps.

Like SRC/ORCs, the Kalina cycle is specifically designed for converting thermal energy to mechanical power, optimized for use with thermal sources that are at a relatively low temperature compared to the heat sink (or ambient) temperature. The primary difference between a single fluid Rankine cycle and the Kalina cycle is the temperature profile during boiling and condensation. In the SRC and ORC cycles, the temperature remains constant during boiling. As heat is transferred to the working fluid, its temperature slowly increases to the boiling temperature, at which point the temperature remains constant until all the fluid has evaporated. In contrast, a binary mixture of water and ammonia (each of which has a different boiling point) will increase in temperature during evaporation. This process allows better thermal matching with the waste heat source, and with the cooling medium in the condenser in counter flow heat exchangers. Consequently, these systems have relatively good energy efficiency performance compared to other WHP thermodynamic cycles. Operating efficiencies for a Kalina cycle WHP system are around 15 percent with a heat source temperature of 300°F. Because the phase change from liquid to steam is not at a constant temperature, the temperature profiles of the hot and cold fluids in a heat exchanger can be closer, thus increasing the overall efficiency. Because of these performance characteristics, the Kalina cycle is well suited for geothermal power plants, where the hot fluid is often below 212°F.

Supercritical CO_2 Cycle

Another variation of the Rankine Cycle is the supercritical CO_2 (sCO_2) cycle, which utilizes carbon dioxide in place of water/steam for a heat-driven power cycle. The sCO_2 cycle in its simplest form consists of the following main components: waste heat and recuperator heat exchangers, condenser, system pump, and turbine. Ancillary components (valves and sensors) provide system monitoring and control. Heat energy is introduced through a waste heat exchanger installed into a customer's exhaust stack, boiler or turbine exhaust duct, hot process gas or liquid line, or solar thermal concentrator. The fluid in either a liquid or dense supercritical state is compressed by a fluid pump/compressor. The high pressure fluid is preheated in the recuperator with residual heat from the expanded fluid discharged from the turbine. The preheated fluid is raised to its highest temperature by transferring heat from the process—either exhaust or other heat source(s). Next, the high temperature/pressure fluid is expanded through a turbine, which drives a motor/generator and the pump/compressor. As the sCO_2 cycle pressure ratio is relatively low, the fluid at the turbine exit retains sufficient heat to warrant recovery in the recuperator. Finally, the fluid is cooled back to the pump/compressor inlet temperature in the condenser/cooler heat exchanger. Both air-cooled and water-cooled systems are applicable.

Carbon dioxide is a low-cost working fluid that is non-toxic and non-flammable. The high fluid density of sCO_2 enables compact turbomachinery designs, and permits the use of compact heat exchanger technology to reduce system component size, cost, and system footprint. Due to its high thermal stability and non-flammability, the exhaust heat exchanger can be placed in direct contact with high temperature heat sources, typically from 400 to 1,000°F (or higher), eliminating an intermediate heat transfer loop.

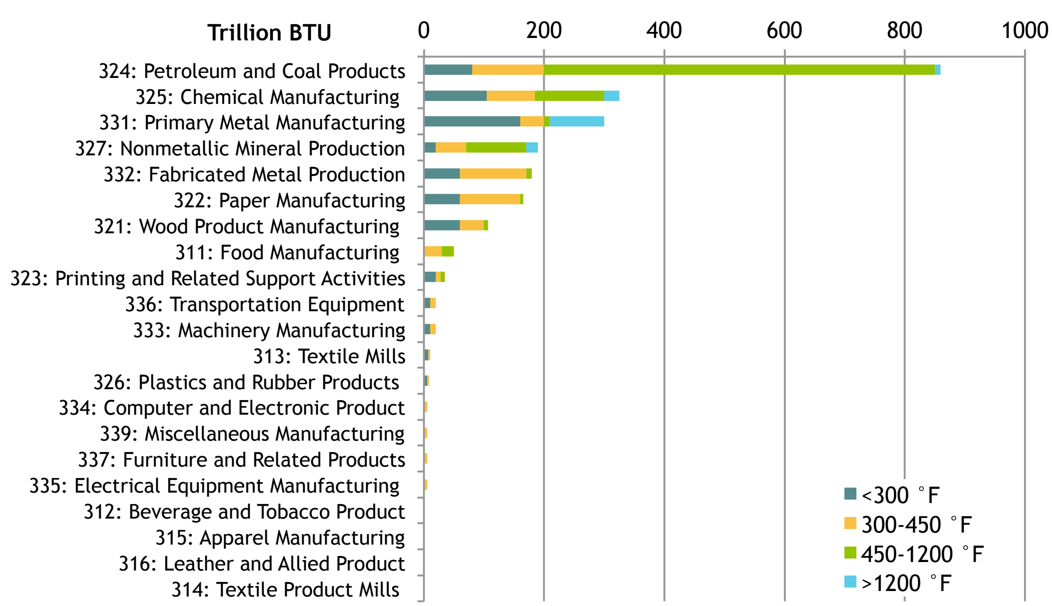
Emerging Technologies

There are a number of advanced technologies in the research and development stage that could, in the future, provide additional options for direct power generation from waste heat sources. These technologies include thermoelectric generators, piezoelectric generators, thermionic devices, thermo-photovoltaic generators, Stirling engines, and innovative concepts for steam engines. These systems range in terms of commercial readiness in the United States, although some – such as the Kalina Cycle – have achieved relative success internationally. A few have undergone prototype testing in applications such as heat recovery in automotive vehicles and from co-produced liquid in oil and gas wells.

Target Applications

The analysis of recycled energy potential begins with quantifying the amount of waste heat available for industrial applications in the U.S. There are two reports that have provided this information. A 2004 ORNL study presented an inventory of waste heat from manufacturing establishments (NAICS 31-33).[6] A 2008 U.S. DOE study presented an inventory of waste heat for selected manufacturing sources only.[7] A more detailed discussion of how the final estimates of waste heat were developed is presented in **Appendix C**, **Figure 9** and shows the waste heat potential by industry. Temperature ranges of waste heat differ substantially across the different industries. For example, the petroleum refining sector's waste heat is mainly within the 450 to 1,200°F, while for the chemical industry, it is mainly less than 300°F. The figure shows that the largest waste heat source for this temperature range (450 to 1,200°F) is the petroleum refining industry, followed by chemical, primary metals, nonmetallic minerals, fabricated metals, and paper manufacturing. **Figures 10** and **11** show manufacturing sector waste heat inventories, broken into lower temperature and higher temperature waste heat levels.

FIGURE 9: U.S. MANUFACTURING SECTOR WASTE HEAT INVENTORY BY INDUSTRY AND TEMPERATURE RANGE
(reference temperature at 120°F)



[6] ORNL 2004, An Inventory of Industrial Waste Heat and Opportunities for Thermally Activated Technologies, Prepared by United Technologies Research Center for Oak Ridge National Laboratory.

[7] DOE 2008, Waste Heat Recovery: Technology and Opportunities in U.S. Industry, Prepared by BCS for the U.S. Department of Energy.

FIGURE 10: U.S. MANUFACTURING SECTOR WASTE HEAT INVENTORY BY INDUSTRY AND TEMPERATURE RANGE < 300 UP TO 450°F
(reference temperature at 120°F)

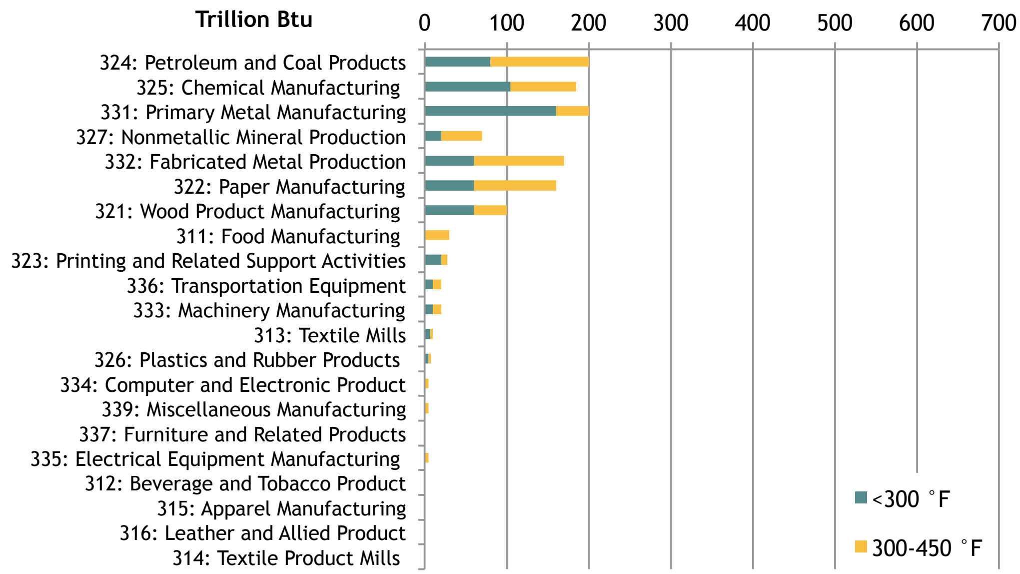
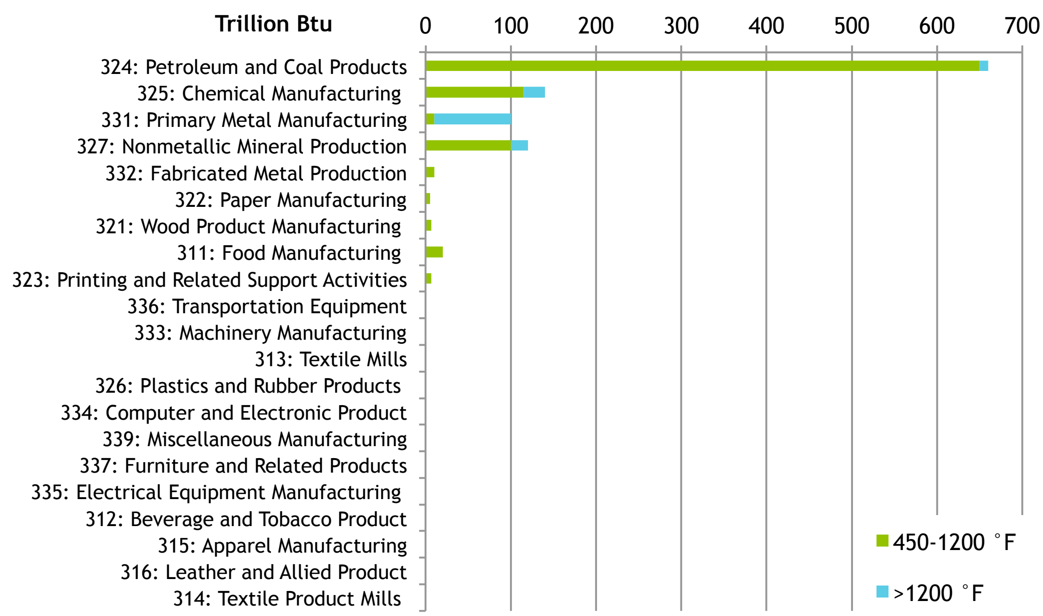


FIGURE 11: U.S MANUFACTURING SECTOR WASTE HEAT INVENTORY BY INDUSTRY AND TEMPERATURE RANGE 450 TO > 1200°F



NAICS 324: Petroleum and Coal Products

Petroleum and coal product manufacturing, particularly petroleum refining, represent the largest energy consuming industrial group in the U.S. and include the production of refined end-use products, such as gasoline, kerosene, and liquefied petroleum gas (LPG), as well as the production of feedstocks used in other industries, such as chemicals, rubber, and plastics manufacturing. Basic processes used in petroleum refineries include distillation processes (fractionation), thermal cracking processes, catalytic processes, and treatment processes. Although these processes use large amounts of energy, modern refineries capture and use waste heat for heating other processes, resulting in integrated heat recovery systems for process use.

Some exhaust streams at refineries contain high-quality waste heat that could be recovered for power production. An example is the exhaust from petroleum coke calciners. In this process, petroleum coke is heated to 2,400°F, and

energy from the hot exhaust is recovered. One example is the heat recovery boiler/steam turbine WHP project at a petroleum coke plant in Texas. Port Arthur Steam Energy (PASE) recovers energy from the 2,000 °F exhaust from three petroleum-coke calcining kilns and produces 450,000 lb/hr of steam for process use at an adjacent refinery plus 5 MW of power.[8]

NAICS 325: Chemical Manufacturing

The chemical industry is the second largest consumer of energy in the industrial sector, producing 70,000 different products (DOE, 2000). Many of the processes used to produce these products result in significant amounts of waste heat that has the potential to be converted to power. Major sectors in the chemical industry that have the potential for WHP applications include petrochemicals, industrial gases, alkalies and chlorine, cyclic crudes and intermediates (e.g., ethylene, propylene, and benzene/toluene/xylene), plastic materials, synthetic rubber, synthetic organic fibers, and agricultural chemicals (fertilizers and pesticides).

The Mosaic Fertilizer plant in Bartow, Florida, for example, produces sulfuric acid as an intermediate product, which is then used with other feedstock chemicals to manufacture a variety of dry fertilizer products. The sulfuric acid plant generates superheated steam at pressures in the range of 150 to 600 psig (the sulfuric acid process is exothermic). The site has 70 MW of WHP capacity and exports about 40 percent of the electricity through the local utility grid to five nearby Mosaic plants.

NAICS 327: Non-Metallic Mineral Products

The non-metallic mineral products industries, which include cement manufacturing, glass and glass products manufacturing, clay tile and brick material manufacturing, are large consumers of energy with a strong potential for use of WHP for power production.

Similar to chemical manufacturing, there are numerous processes for which WHP could provide benefit. The glass industry uses raw material melting furnaces, annealing ovens, and tempering furnaces, all operated at high temperatures so exhaust heat may be available for power generation. Clay building products are fired in high-temperature kilns. Clay firing employs tunnel kilns and periodic kilns, depending on the product being produced. Periodic kilns do not represent a good opportunity for heat recovery for power due to their intermittent operation, but tunnel kilns are steadier in output and could provide an economic application.

[8]EPA, 2012. Waste Heat to Power Systems, U.S. Environmental Protection Agency, http://www.epa.gov/chp/documents/waste_heat_power.pdf.

Other Market Sectors for Waste Heat

Natural Gas Compressor Stations

Compressor stations are suitable for waste heat to electricity conversion. Waste heat is available in the form of exhaust from the internal combustion engines or gas turbines that drive the compressors. In most cases there is no thermal requirement at compressor stations; therefore there is a strong case for converting the waste heat to electricity[9]. Currently, there are 12 ORC power generation systems installed at natural gas compressor stations in the U.S., including the Trailblazer Pipeline compressor station in Colorado. The 12 U.S. systems have a total electric capacity of 64 MW using the exhaust heat from 247,000 hp of gas turbine driven compressors.[10] A recycled energy system at a natural gas compressor station qualifies under Colorado's RES since the primary purpose of the facility is to compress gas, not for the production of electricity.

Landfill Gas

There are two types of opportunities for WHP at landfills. At those facilities that use engines or turbines to produce power, there is an opportunity for additional power generation using ORC systems to generate power from the exhaust gases. Those facilities that do not have energy recovery could install an ORC WHP system to recover the heat associated with gas flaring or use the byproduct fuel in a reciprocating engine to generate electricity. A biogas-fired electric generating unit is eligible under Colorado's RES. However, exhaust gases from a natural gas-fired engine or turbine that is used for additional power generation using ORC would not be eligible.

Flare Gas in Oil and Gas Production

In oil and gas production, methane-containing gases are vented and flared throughout the production cycle. Flares are used for both background and upset (emergency) use. This methane can be recovered and used for local power production.

Adding an ORC system to a flare to produce electricity is an alternative to the option of removing the flare and using the previously flared fuel in an internal combustion engine or microturbine. The internal combustion engine or microturbine option would produce more power per unit of heat input and would generally be less costly. However, where fuel quality is variable and contains contaminants, the ORC WHP option may be technically and economically preferable. An ORC WHP system added to a flare would be eligible under Colorado's RES since the primary purpose is the flaring of gas, not the production of electricity.

Steam Pressure Reduction

A market niche is developing for small back pressure steam turbine power systems to be installed in parallel with steam pressure reducing valves (PRV) for applications where steam is produced or delivered at a higher pressure than needed. This situation typically exists for commercial or industrial facilities that are connected to a steam district heating system or for industrial sites that have a centralized high pressure steam production and distribution system with multiple steam using applications, many of them at low pressure.

A customer of a district heating system may receive steam at 200 psig and require only 15 psig for an absorption chiller. A PRV typically is used to reduce pressure in this case. The PRV does not recover energy or work from the pressure reduction. A back pressure steam turbine, on the other hand, can be used in place of a PRV to reduce pressure and generate power. This power generation is not "free" energy, because the work performed by the turbine removes energy from the steam flow. The efficiency of this power generation, however, is very high – approaching the original boiler efficiency. With an 80 percent efficient boiler, power can be generated with a back pressure steam turbine (BPST) at a heat rate of under 4,500 Btu/kWh (HHV). This type of application is not eligible under Colorado's RES.

[9]Using exhaust gases or byproduct fuels to generate power does qualify under the RES as long as the system does not combust additional fossil fuel and as long as the system's primary purpose is not the generation of electricity, see, 40-2-124 C.R.S., accessed at: http://www.lexisnexis.com/hottopics/colorado/.

[10]ICF Internal Estimates, based on data from pipeline compressor companies.

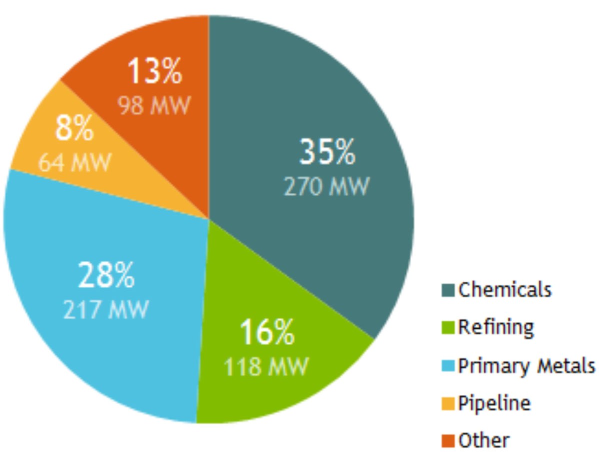
2 | Evaluation of Existing Waste Heat Systems

Nationwide Trends

The installed base of recycled energy in the U.S. was developed by first examining the CHP Installation Database.[11] This database contains both CHP topping cycle and CHP bottoming cycle projects. All installations in this database labeled as bottoming cycle were pulled out and identified as WHP installations. Next, ICF researched non-CHP applications for WHP. This research identified several mechanical drive applications, mostly natural gas pipeline compressor stations, with WHP equipment, as well as several WHP systems using waste heat from exothermic reactions.

In total, ICF identified 96 existing WHP systems (CHP and non-CHP), totaling 766 MW of power generation capacity. **Figure 12** shows a breakdown of existing industrial WHP capacity by sector. Existing systems are concentrated in the chemical, primary metals, petroleum refining, and pipeline transportation sectors. The chemical industry has the largest number of WHP facilities and the largest WHP capacity, with 19 installations totaling almost 270 MW. The primary metals industry has the second largest WHP capacity, with 3 large installations totaling 217 MW. The petroleum refining industry has 5 WHP installations with a total of 118 MW.

FIGURE 12: EXISTING WASTE HEAT TO POWER PROJECTS IN U.S. BY SECTOR



The 12 WHP projects in the pipeline transportation sector are all in compressor stations, and have a total capacity of 64 MW. These four sectors account for 672 MW, or 87 percent of total WHP capacity.

Recycled energy sites are located in 40 states, with Indiana having the largest total capacity at 185 MW, which comes from two steel plants. In terms of the number of installations, Pennsylvania has the largest number (9), followed by Minnesota (7), Massachusetts (6), and Florida (4).

Recycled Energy Systems in Colorado

Colorado has one 3.5 MW recycled energy facility that is eligible under Colorado's renewable energy standard–The Highline Electric Co-op system, which is owned by Ormat and discussed below.

Trailblazer Pipeline Compressor Station Recycled Energy Project

One of the recycled energy systems in Colorado is owned by Ormat, a leading provider for organic rankine cycle (ORC), geothermal energy and recovered energy generation (REG). In 2009, this 4 MW Ormat ORC system was constructed along a natural gas compression station (owned by Trailblazer Pipeline Company) in Peetz, Colorado.[12] The facility converts waste heat from the exhaust of existing gas turbines into clean energy. Ormat owns and operates this facility and then Highline Electric Association buys the output through a 20-year power purchase agreement. Ormat has secured the rights to use the waste heat under a Waste Heat Host Agreement with Trailblazer Pipeline Company (owned by Kinder Morgan). The Ormat ORC system is in the service territory of Highline Electric Association and is one of the only recycled energy projects in Colorado counting towards the Colorado Renewable Energy Standard.

Some similar Ormat REG plants have been in operation in other states besides this ORC system in Colorado. In total, Ormat has 21 recycled energy systems installed

[11] ICF/DOE CHP Installation Database. Maintained by ICF for Oak Ridge National Laboratory. 2015. https://doe.icfwebservices.com/chpdb/

[12] Ormat. "Ormat Technologies Signs New Contract Recovered Energy Generation Facility in Colorado." (2007, July 23). http://www.Ormat.com/news/Ormat-technologies-signs-new-contract-recovered-energy-generation-facility-colorado.

TABLE 2: OTHER WASTE HEAT SYSTEMS IN COLORADO

Organization Name	Facility Name	City	State	NAICS	Op Year	Capacity (MW)	Prime mover
Sterling Ethanol, LLC	Sterling Ethanol	Sterling	CO	325193	2006	1	BPST/WH
Yuma Ethanol	Yuma Ethanol	Yuma	CO	325193	2007	2	BPST/WH

and operating in North America.[13] The other systems are in Canada – one on a TransCanada pipeline compressor station has been in operation for more than seven years and a second plant has been operating inside an Enterprise Products gas processing plant for more than three years.

Other Waste Heat Systems in Colorado

Colorado has two additional waste heat systems that are not eligible under the state's renewable energy standard. The Sterling and Yuma ethanol facilities are both configured as bottoming cycle CHP systems, meaning that there is an industrial process that utilizes the thermal energy (heat).

Sterling Ethanol Plant Recycled Energy Project

Sterling Ethanol LLC, has a 42 million gallon per year plant in Sterling, Colorado, in the northeastern corner of the state. The ethanol plant uses a natural gas fired CHP system to meet its electricity and steam needs. Some of the steam enters the boilers at 130 psi. The rest of the steam goes through a back pressure steam (or steam let-down) turbine system which lowers the steam to ambient pressure for use in the evaporators. As part of the process of reducing the pressure of the steam to meet plant requirements, the back pressure steam turbine generates additional electricity. The BPST generates about a megawatt of electricity. This represents between a quarter and a third of the plant's electric demand, which runs to three or four megawatts.[14] This project and the similar Yuma facility discussed below are not eligible under Colorado's RES—the generation of power and then capture of any waste heat to produce additional power is not considered an eligible activity since the primary purpose is the production of electricity. This system is functioning like a natural gas CHP system which is comprised of three components—a gas turbine that burns fuel to generate electricity, a heat recovery system that captures exhaust and distributes it for use as steam, and a steam turbine that delivers additional electricity from the unused steam. Such system configurations are not eligible under the RES since their primary focus is electricity production.

Yuma Ethanol Plant Recycled Energy Project

The Yuma Ethanol Plant, located in Yuma County, Colorado is designed to produce 40 million gallons of ethanol annually. The CHP system that provides heat and power to the plant consists of a 2 MW boiler/steam turbine that began operation in 2007. The CHP system operates in a similar fashion to the Sterling Ethanol plant; the leftover steam is used to power a turbine. Very few details are available regarding the specific operational details of the Sterling or Yuma CHP systems.[15]

Yuma Ethanol, Sterling Ethanol, and Front Range Energy are Colorado's three major ethanol plants. Front Range Energy is the only major ethanol plant that does not have a recycled energy project[16], but would be a good candidate for such a project.

Technologies Installed

In the U.S., most of the existing recycled energy systems, 80 facilities out of 96 total facilities (83 percent), are steam Rankine cycle configurations. There are some heat recovery steam generator (HRSG) and steam turbine combinations – four systems (two in TX, and in IN and PA), ORC – 15 systems, and one ORC + combustion turbine combination (this is the Trailblazer Pipeline compressor station project in Colorado).

[13] Public Utilities Commission of Colorado. "Answer Testimony of Christine Brinker on Behalf of Western Resource Advocates." (2013, December 2). https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCE-QFjAA&url=https percent3A percent2F percent2Fwww.dora.state.co.us percent2Fpls percent2Fefi percent2Fefi.show_document percent3Fp_dms_document_id percent3D274233 percent26p_session_id percent3D&ei=S9-aVcn3KsP7sAWyg7-gBA&usg=AFQjCNF4PXPs0KVSwnlToCRG8HzDUUv12g&sig2=q0lNcjNAxLoIr91lSheBKg&bvm=bv.96952980,d.b2w.

[14] Eisenthal, Jonathan. "Self-Powering Ethanol Production." Ethanol Today. http://www.ethanoltoday.com/index.php?option=com_content&task=view&id=5&Itemid=6&fid=106.

[15] Yuma Ethanol LLC. (2010, July 23). http://www.yumaethanol.com/index.cfm?-show=10&mid=21.

[16] Wingerd, Bowe. "Advancing Colorado's Renewable Energy (ACRE) Program." (2010, February). https://www.colorado.gov/pacific/sites/default/files/Feedlot percent20Biofuel_Feasibility percent20Study_0.pdf.

3 | Technical Potential for Recycled Energy (>450°F) in Colorado

This section provides an estimate of the technical market potential for recycled energy in all applicable applications throughout the state of Colorado. The technical potential is an estimation of market size constrained only by technological limits – the ability of recycled energy technologies to fit customer energy needs. Recycled energy technical potential is calculated in terms of recycled energy electrical capacity that could be installed at existing and new industrial and commercial facilities, based on the estimated electric and available onsite waste heat streams. The technical market potential does not consider screening for economic rate of return, or other factors such as ability to retrofit, owner interest in applying recycled energy, capital availability, or variation of energy consumption within customer application/size class.

The technical potential is useful in understanding the potential size and distribution of the target recycled energy market in the state. Identifying the technical market potential is a preliminary step in the assessment of actual economic market size.

Technical Potential Methodology

To determine the economic potential, ICF has developed a recycled energy technical potential site database[17] based on analyzing five source databases:

- EPA Greenhouse Gas Reporting Program (EPA GHGRP) database
- Oil and Gas Journal's Gas Processing Plants database
- Oil and Gas Journal's Refinery Survey
- Portland Cement Association's Cement Kilns database
- Association of Iron and Steel Engineer's Directory of Iron and Steel Plants

The EPA GHGRP provided an essential database for information on many different manufacturing processes, enabling the creation of a methodology upon which many of the applications were modeled. The GHGRP provided information on:

- Facility name and zip code
- Process name and process type
- Fuel input capacity (MMBtu/hour) and annual fuel consumption (MMBtu/year)
- Annual CO_2 emissions
- Fuel type and GHG emissions factor (kg/MMBtu)

All of the databases, except for the EPA GHGRP database, cover a specific industry or application. Databases for a specific industry or application were used to identify facilities for that specific application. For all other applications, the EPA GHGRP database was used. The data was cross-checked between the sources and if a site was present in an industry-specific source as well as the EPA GHGRP database it was only entered into the overall recycled energy potential site database once.

The technical potential analysis for recycled energy sites was constrained to waste heat sources with a temperature of 450°F or higher. Power generation from waste heat has predominantly occurred with medium- to high-temperature waste heat sources (i.e., > 450°F) for commercially available technologies. There are several emerging technologies that utilize low-temperature waste heat streams that are in the demonstration stage in the U.S. and may become commercially available in the future. However, this analysis focuses on commercially available technologies and sites with waste heat streams >450°F.

Since recycled energy is powered by waste heat streams, sizing a recycled energy unit to a facility depends upon the quantity and quality of the waste heat available onsite. The waste heat temperature is a factor in selecting the prime mover technology. The recycled energy system and capacity are a function of the temperature of the waste heat and the expected efficiency of the technology.[18] ICF used information from the aforementioned databases to estimate the energy content available in Btus from the waste heat at each site[19]. The waste heat temperature for the site is converted into an energy content figure (btu/yr). This number is multiplied by the expected recycled energy efficiency, which is proportional to the temperature of the available waste heat. The result is an output of technical potential in Btu/year, which is then converted into a recycled energy system capacity in megawatts.

The methodology to estimate the recycled energy system size utilized the temperature of the stack gas emissions minus an assumed minimum temperature of 250°F. This difference was multiplied by the average specific heat for combustion of 0.26 Btu/lb. The result was the energy content of the stack gas emissions.

[17] ICF estimated the technical potential from the national database created from the resources described in this section.

[18] The type of prime mover selected for the site will depend on the application.

[19] For example, for the GHGRP, ICF established stack temperatures for each relevant type of manufacturing equipment (kilns, incinerators, ovens, etc.).

Table 3 displays the exhaust heat stack temperatures assumed for the various processes and equipment types. The theoretical electrical efficiency of the system is estimated based on the relationship of these temperatures with the selected technology. Each waste heat temperature has a Carnot theoretical electrical efficiency associated with converting the waste heat steam into electricity. In practice, however, the actual electrical efficiencies achieved by these systems are less than the Carnot efficiency.[20]

The energy content of the stack emissions, the expected efficiency of the recycled energy system selected, and the operating hours for the plant[21] were then used to produce a recycled energy technical potential for the specific site. The recycled energy prime mover technology chosen for the site was tailored to the application.

TABLE 3: STACK EMISSIONS TEMPERATURE BY EQUIPMENT

Equipment	Temperature (^{0}F)
GHGRP Equipment	
Calciner, Kilns	700
Flare	1200
Incinerator	1400
Oven	700
Reciprocating Engine	800
Regenerative Oxidizer	1,200
Thermal Oxidizer	1,200
Gas Refining	
Coking	800
Thermal Cracking	800
Visbreaking	800
Catalytic Cracking	1,148
Catalytic Reforming	900
Hydrocracking	800
Desulfurization	968
Alkylation	800
Coke Production	1,000
Steam Methane Reforming	1,500
Cement Manufacturing (type of kiln)	
Dry	840
Dry/Precalciner	640
Dry/Preheater	640
Wet	640

TABLE 4: RECYCLED ENERGY PRIME MOVER TECHNOLOGY BY APPLICATION

NAICS	NAICS Description	Recycled Energy Technology
324	Petroleum Refining	SRC
327	Non-Metallic Minerals	SRC
331	Primary Metals	SRC
486	Pipeline Transportation	ORC
562	Waste Management	ORC

Table 4 displays the assumed prime mover selected by application.[22] The project team selected an Organic Rankine Cycle (ORC) or a Steam Rankine Cycle (SRC), depending on the application in which the recycled energy system is installed. Rankine cycle technologies were chosen because of their widespread commercial availability and economic feasibility compared to other types of recycled energy prime mover technologies. The selection by application will often depend on the quality of the waste heat (in terms of temperature). Commercially available ORC technologies using gaseous heat sources usually require a temperature of at least 450°F.[23]

The gas processing sizing methodology is the only application that used a noticeably different methodology than that of the GHGRP data. This data originated from the Oil and Gas Journal's gas processing database. In order to estimate the recycled energy technical potential, ICF used the daily gas processing rate (in MMcfd) and matched it to an existing site's characteristics that has recycled energy as a model to size a system.

[20]For WHP systems using the Rankine cycle, the electrical efficiencies are generally 30-50 percent of the "theoretical" or Carnot efficiency for the technology-temperature pairing. For this study, Rankine cycle efficiencies were estimated to be 40 percent of the Carnot efficiency.

[21]Some of the source databases used to build up the site list included information on plant operating hours. When specific data was not available an estimate of 7,500 hours per year was assumed.

[22]More WHP applications exist. However, the applications listed in this table are those relevant for Colorado technical potential.

[23]Hot exhaust gas from industrial processes will typically satisfy this criterion.

Technical Potential Results

Using the methodology described above, ICF identified 108 MW of recycled energy technical potential at 70 sites throughout the state of Colorado. **Table 5** displays a more detailed breakdown of the technical potential. Roughly 53 percent (58 MW) of the total technical potential are found in systems with capacities greater than 5 megawatts. However, 65 of the 70 sites have a technical potential smaller than 5 megawatts. This indicates that there are fewer candidate sites for large systems than there are for low capacity systems.

Table 6 shows the technical potential breakdown by utility. The Xcel Energy and Black Hills Energy service territories contain roughly 60 percent (26 MW and 38 MW respectively) of the entire technical potential capacity. However, Xcel Energy service territory contains almost 40 percent (27) of the candidate sites within the entire state, making this territory of particular importance for recycled energy potential within the state. Sites that were in an unknown utility service territory (mainly rural pipeline compressor stations) are included in the tables under "CO State Average."

TABLE 5: ONSITE RECYCLED ENERGY TECHNICAL POTENTIAL BY APPLICATION

		50-500 kW		500-1,000 kW		1-5 MW		5-20 MW		>20 MW			
SIC	**Application**	**No. of Sites**	**Onsite Potntial (MW)**	**No. of Sites**	**Onsite Potntial (MW)**	**No. of Sites**	**Onsite Potntial (MW)**	**No. of Sites**	**Onsite Potntial (MW)**	**No. of Sites**	**Onsite Potntial (MW)**	**Total Sites**	**Total Onsite Potntial (MW)**
29	Petroleum Refining	14	3.7	2	1.3	6	10.5	3	23.9	0	0.0	25	39.4
32	Non-Metallic Minerals	1	0.4	0	0.0	4	10.8	1	7.4	0	0.0	6	18.5
33	Primary Metals	0	0.0	0	0.0	0	0.0	0	0.0	1	26.5	1	26.5
49	Pipeline Transportation	20	4.5	9	6.4	8	12.8	0	0.0	0	0.0	37	23.7
49	Waste Management	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3
	Total	**36**	**8.9**	**11**	**7.7**	**18**	**34.1**	**4**	**31.4**	**1**	**26.5**	**70**	**108.4**

TABLE 6: ONSITE TECHNICAL POTENTIAL BY UTILITY

	50-500 kW		500-1,000 kW		1-5 MW		5-20 MW		>20 MW			
Utility	**No. of Sites**	**Onsite Potntial (MW)**	**No. of Sites**	**Onsite Potntial (MW)**	**No. of Sites**	**Onsite Potntial (MW)**	**No. of Sites**	**Onsite Potntial (MW)**	**No. of Sites**	**Onsite Potntial (MW)**	**Total Sites**	**Total Onsite Potntial (MW)**
Black Hills Energy	1	0.2	0	0.0	1	3.9	1	7.4	1	26.5	4	38.0
CO State Average	12	2.4	2	1.4	2	2.2	0	0.0	0	0.0	16	6.0
Empire Electric Association	0	0.0	1	0.9	0	0.0	0	0.0	0	0.0	1	0.9
Fort Morgan Electric Light Dept.	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0	1	0.4
Highline Electric Association	0	0.0	0	0.0	1	2.6	0	0.0	0	0.0	1	2.6
KC Electric Association	4	1.3	1	0.7	2	4.3	0	0.0	0	0.0	7	6.3
La Plata Electric Association	0	0.0	0	0.0	2	4.2	0	0.0	0	0.0	2	4.2
Longmont Electric Utility	0	0.0	0	0.0	1	2.2	0	0.0	0	0.0	1	2.2
Moon Lake Electric Association	0	0.0	1	0.5	0	0.0	0	0.0	0	0.0	1	0.5
San Isabel Electric Association	1	0.5	1	0.6	0	0.0	0	0.0	0	0.0	2	1.0
Southeast Colorado Electric Association	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0	1	0.4
White River Electric Association	0	0.0	0	0.0	2	2.6	2	17.0	0	0.0	4	19.6
Xcel Energy	14	3.8	5	3.6	7	12.0	1	7.0	0	0.0	27	26.4
Y-W Electric Association	2	0.2	0	0.0	0	0.0	0	0.0	0	0.0	2	0.2
Total	**36**	**9.2**	**11**	**7.7**	**18**	**34.0**	**4**	**31.4**	**1**	**26.5**	**70**	**108.7**

4 | Economic Potential for Recycled Energy Systems over 250 kWe in Colorado

The economic potential analysis visualizes the distribution of the technical potential in terms of simple payback. Payback is defined as the amount of time (e.g., number of years) required to recover the total installed capital cost of a recycled energy system. For each site included in the technical potential analysis, an economic payback is calculated based on the appropriate recycled energy system cost and performance characteristics and energy rates for that system size and application.

Recycled energy project economics are site-specific. Utility-specific electricity rates and tariff structures, and site-specific conditions (i.e. space availability and integration into existing thermal and electric systems, permitting, siting, and grid interconnection requirements) all contribute to the unique economics of each recycled energy system.[24] For this analysis, an estimate of economic potential by system size range was developed for this analysis using:

- Recycled energy Cost and Performance Characteristics
- Electricity Rates
    - Performed bottom rate analyses for relevant Xcel Energy and used utility averages for other utilities.[25]
- Relevant Incentives
    - Xcel Energy production incentive
    - Federal ITC

Simple yearly paybacks were then calculated for each unique customer. Different types of customers will have varying thresholds for economic feasibility. Commercial and industrial customers will typically require paybacks

[24]Components such as space availability, interconnection, siting, and permitting are difficult to quantify and were not included in the payback calculations for this study.

[25]The rate analyses used utility-specific commercial and industrial average electricity prices from the EIA *Electric Power Monthly*, Table 8 and Table 7 (April 2015). For more information please see: http://www.eia.gov/electricity/data.cfm#sales.

TABLE 7: UTILITY-SPECIFIC RETAIL ELECTRICITY RATES

	Utility Retail Electric Rates ($/kWh)1				
Utility	**50-500 kW**	**500-1 MW**	**1-5 MW**	**5-20 MW**	**>20 MW**
KC Electric Association	$0.112	$0.101	$0.098	$0.088	$0.078
Black Hills Energy (West Plains Energy)	$0.123	$0.110	$0.102	$0.092	$0.081
Colorado Spgs Electric Dept.	$0.076	$0.069	$0.069	$0.062	$0.055
Black Hills Energy (Southern Colorado Power Co)	$0.134	$0.121	$0.108	$0.098	$0.087
Fort Collins Light & Power Dept.	$0.077	$0.070	$0.060	$0.054	$0.048
Fort Morgan Electric Light Dept.	$0.089	$0.080	$0.082	$0.074	$0.066
La Junta City Utilities Co.	$0.109	$0.098	$0.104	$0.094	$0.083
Lamar Utilities Board	$0.109	$0.098	$0.104	$0.094	$0.083
Longmont Electric Utility	$0.074	$0.067	$0.062	$0.056	$0.050
Delta Montrose Elec Assn.	$0.113	$0.102	$0.081	$0.073	$0.065
Rural Electric Co.	$0.109	$0.098	$0.104	$0.094	$0.083
Meeker Co-op Light & Power	$0.109	$0.098	$0.079	$0.071	$0.063
Southeast Colorado Power Association	$0.134	$0.121	$0.108	$0.098	$0.087
Y-W Electric Association	$0.109	$0.098	$0.104	$0.094	$0.083
Highline Electric Association	$0.117	$0.105	$0.113	$0.102	$0.091
San Isabel Electric Association	$0.150	$0.135	$0.084	$0.075	$0.067
Moon Lake Electric Association	$0.073	$0.066	$0.063	$0.056	$0.050
Xcel Energy	$0.089	$0.089	$0.084	$0.084	$0.075
CO State Average	$0.107	$0.097	$0.103	$0.092	$0.082
La Plata Electric Association	$0.112	$0.101	$0.078	$0.070	$0.062

under two years. Institutional customers, such as schools or government buildings have longer payback thresholds. The payback calculation was conducted and the technical potential in terms of megawatts was categorized into three payback categories representing the degree of economic potential:

- High potential – simple payback < 5 years
- Moderate potential – simple payback ≥ 5 and ≤ 10 years
- Low potential – simple payback > 10 years

For this analysis, ICF analyzed sites with a potential of 250 kW or larger. This focus reduced the technical potential analyzed from 108 MW to roughly 106 MW and removed 18 sites from the study. This accounts for the difference between the technical potential analysis and the total figures presented in the economic potential results.

Economic Potential Methodology

The economic potential, or payback, of a project is driven by the relationship between the costs and savings of the recycled energy project. In order to estimate the economic potential, the project team used assumptions for three primary categories: electricity rates, recycled energy cost and performance metrics, and any available incentives. This section will provide a brief discussion on the methodology for creating these assumptions.

Electricity Rates

For this analysis, the project team utilized utility-specific EIA industrial and commercial retail electricity prices to apply to each site. In addition, a bottom-up rate analysis was performed for Xcel Energy, given its prominent status as an electric power provider in the state. **Table 7** displays the electricity rates used for the economic analysis by utility. **Table 8** shows the breakdown of the Xcel Energy bottom-up rate analysis. The project team used the Commercial and Industrial rate classification and selected the Secondary General (SG), Primary General (PG), and Transmission General (TG) tariffs to analyze for each customer class.[26] The rates shown below reflect the retail electric rates. However, the economics of a recycled energy system can be highly impacted by the amount of the retail rate the system can avoid through onsite power generation versus purchasing grid electricity, otherwise known as the "avoided rate."

A retail customer generating onsite power with a recycled energy system cannot avoid all the charges within the retail rate. Therefore, it is important in evaluating the economic competitiveness of recycled energy to use only that portion of the electric bill that is saved by the operation of recycled energy, defined in this analysis as the *Average Avoidable Rate*. The avoided cost is an important concept for evaluating the treatment of onsite generation by partial requirement tariff structures. One of the key economic

[26]For more information, see the Xcel Energy Colorado Tariff Index: http://Xcel Energyenergy.com/staticfiles/xe/Regulatory/Regulatory percent20PDFs/rates/CO/psco_elec_entire_tariff.pdf.

values of onsite generation is the displacement of purchased electricity and the avoidance of those costs. Ideally, the reduction in electricity price should be commensurate with the reduction in purchased electricity—if the onsite system reduces consumption by 80 percent, the cost of electricity purchases would also be reduced by 80 percent. However, only a portion of the full retail rate is avoided by onsite generation due to fixed customer charges, demand charges and standby rate structures. The economics of WHP are severely impacted if partial requirements rates are structured so that only a small portion of the electricity price can be avoided.

Retail electric customers installing recycled energy are subject to standby charges and customer charges. In addition, demand charges in a customer's rate are more difficult to avoid for recycled energy. A momentary outage can trigger the demand charge for the entire month. For this particular analysis, the project team assumed standard avoided rate percentages for each recycled energy size range, with the exception of Xcel Energy.[27] As is evident in **Table 9**, a prospective recycled energy customer in Xcel Energy's territory will not avoid as much of the retail rate as customers in other areas of the State. This is largely due to the amount of fixed and demand charges that a customer must pay in each billing cycle for Xcel Energy. As discussed later in the section, these charges can have a negative impact on the economics of a recycled energy system.

[27] These percentages are based off of numerous rate analyses ICF has conducted for other utility territories throughout the U.S.

Recycled Energy Cost and Performance

Recycled energy systems use waste heat streams to generate electricity for the customer. The waste heat will generally originate from heat intensive onsite operations. There are many different technologies and products that are capable of capturing waste heat to generate power. While these technologies differ significantly in how they are configured and how they operate, the economic value of recycled energy depends on key factors common to all WHP technologies:

- Installed capital cost of the system, on a unit basis expressed in $/kWh
- Operating and maintenance costs, expressed on unit basis in $/kWh including annual costs and amortization of overhaul costs that can be required after a number of years of operation.
- Economic life of the equipment.

For this study ICF used the cost and performance metrics detailed in **Table 10** and **Table 11**. As discussed earlier, an ORC or SRC prime mover technology was chosen based on the application of the system.

TABLE 8: XCEL ENERGY RATE ANALYSIS

Standard Customer Retail Rate Analysis					
Rate Classification	SG	SG	PG	PG	TG
Standard Customer Size (kW)	275	750	3,000	12,500	40,000
Voltage Level	S	S	P	P	T
Avg Retail Rate ($/kWh)	$0.0887	$0.0886	$0.0837	$0.0835	$0.0746

TABLE 9: AVOIDED RATE PERCENTAGES

Avoided Rate Percentages					
Utility	50-500 kW	500-1,000 MW	1-5 MW	5-20 MW	>20 MW
Xcel Energy	63%	63%	64%	65%	71%
Typical Average	80%	85%	87%	88%	90%

TABLE 10: STEAM RANKINE CYCLE COST AND PERFORMANCE

Steam Rankine Cycle					
Recycled Energy Cost and Performance	50-500 kW	500-1,000 MW	1-5 MW	5-20 MW	>20 MW
U.S. Average Installed Cost, $/kW	$3,000	$2,500	$1,800	$1,500	$1,200
Cost Summary	$4,500	$2,500	$1,800	$1,500	$1,200
O&M Costs, $/kWh	$0.013	$0.009	$0.008	$0.006	$0.005
Capacity Factor	80%	80%	80%	85%	92%

TABLE 11: ORGANIC RANKINE CYCLE COST AND PERFORMANCE

Organic Rankine Cycle					
Utility	50-500 kW	500-1,000 MW	1-5 MW	5-20 MW	>20 MW
U.S. Average Inst	$4,500	$4,000	$3,000	$2,500	$2,100
Cost Summary	$4,500	$4,000	$3,000	$2,500	$2,100
O&M Costs, $/kWh	$0.020	$0.015	$0.013	$0.012	$0.010
Capacity Factor	80%	80%	80%	85%	92%

TABLE 12: ECONOMIC POTENTIAL BY APPLICATION

SIC	Application	< 5 years		5-10 years		>10 years		Total Sites	Total Potential (MW)
		No. of Sites	Economic Potntial (MW)	No. of Sites	Economic Potntial (MW)	No. of Sites	Economic Potntial (MW)		
29	Petroleum Refining	3	10.4	9	23.8	6	4.0	18	38.3
32	Non-Metallic Minerals	4	16.8	1	0.4	1	1.3	6	18.5
33	Primary Metals	1	26.5	0	0.0	0	0.0	1	26.5
49	Pipeline Transport	2	3.7	21	17.7	3	1.1	26	22.5
52	Waste Management	0	0.0	0	0.0	1	0.3	1	0.3
	Total[3]	**10**	**57.4**	**31**	**41.9**	**11**	**6.7**	**52**	**106.1**

Available Incentives

The last piece of the economic potential methodology is to incorporate any available incentives for recycled energy. Recycled energy does not currently qualify for the Federal Investment Tax Credit (ITC) that CHP systems are eligible to receive. However, there are many state, utility, and local incentive programs that can impact the economics of a recycled energy project. As is discussed in the following chapter, Colorado has various programs in place that could help encourage recycled energy installation. One incentive which has been incorporated into the modeling for the economic analysis is the capacity incentive offered by Xcel Energy.[28] The utility will offer $500/kW for each project within its territory that will be paid out over 10 years (annuitized over a 10-year period). Using the same assumptions employed by Xcel Energy in its original incentive calculation–a 70 percent capacity factor and a 7.4 percent weighted average cost of capital – Southwest Energy Efficiency Project (SWEEP), calculates the incentive would be $11.83/MWh over a 10-year period.[29] Projects up to 10 MW in size qualify under the Xcel Energy Program; projects above 10 MW have a different route they can use to potentially receive incentives. Annually 20 MW worth of projects can receive funding. The Xcel Energy incentive will only apply to recycled energy projects that do not export, which may limit compressor stations from receiving funding due to their lack of an onsite electric load.

Economic Potential Results

The economic potential results reflect the amount of capacity that is economically feasible. The results take into account many of the costs and potential savings associated with installing a CHP system. As mentioned at the beginning of this section, the economic potential is quantified as the simple payback of the particular system for that site. Paybacks will vary on a site-by-site basis.

Table 12 shows the economic potential by application. In total, 10 sites containing 54 percent of the technical potential exhibit paybacks less than five years. Seven of the 10 sites that fall below the five-year payback period are sites within petroleum refining or non-metallic minerals application. This is likely due to the very high quality and quantity of the heat available from these applications.

[28] See Chapter 6 for more details on the incentive program.

[29] Public Utilities Commission of Colorado. "Answer Testimony of Christine Brinker on Behalf of Western Resource Advocates." (2013, December 2). https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB4QFjAA&url=https percent3A percent2F percent2Fwww.dora.state.co.us percent2Fpls percent2Fefi percent2Fefi.show_document percent3Fp_dms_document_id percent3D274233 percent26p_session_id percent3D&ei=ceGaVbywAdinyAT6r43YAg&usg=AFQjCNF4PXPs0KVSwn-lToCRG8HzDUUv12g&sig2=oBvKLfYRb9tpc3KOngJbPw.

Table 13 displays the economic potential by utility. There are four known utilities that contain eight of the 10 projects with paybacks below five years. These utilities are Highline Electric Association, Black Hills Energy, Xcel Energy, and Longmont Electric Utility. As indicated when discussing the avoided rates, Xcel Energy's territory does not contain many sites with strong economic potential. Seventeen of the 20 sites in its territory have paybacks greater than five years. However, three sites still manage to achieve less than five years payback within the territory. Overall, 54 percent (57 MW) of the recycled energy technical potential sites exhibit paybacks less than 10 years. It is important to note that studies have indicated that 50 percent of the market of potential investors will opt out of installing a recycled energy unit if the payback is greater than two years. For Colorado, this means that the market adoption of recycled energy could remain fairly low absent any changes in electricity rates and/or incentives, depending on the distribution of paybacks within this category.

Table 14 shows the economic potential by system size. The sites that have a payback under five years are large sites over 5 MW. However, these sites represent over half of the entire economic potential. The economic potential trends are not unexpected. Small systems are generally unable to achieve the same economies of scale as large systems, making their payback timelines longer on average. The results shown below illustrate this conclusion, as no sites under 500 kW exhibit paybacks below five years.

TABLE 13: ECONOMIC POTENTIAL BY UTILITY

Utility	< 5 years		5-10 years		>10 years		Total Sites	Total Potential (MW)
	No. of Sites	Economic Potntial (MW)	No. of Sites	Economic Potntial (MW)	No. of Sites	Economic Potntial (MW)		
Black Hills Energy	3	37.8	0	0.0	0	0.0	3	37.8
CO State Average	2	2.2	7	3.2	0	0.0	9	5.4
Empire Electric Association	0	0.0	1	0.9	0	0.0	1	0.9
Fort Morgan Electric Light Dept.	0	0.0	0	0.0	1	0.4	1	0.4
Highline Electric Association	1	2.6	0	0.0	0	0.0	1	2.6
KC Electric Association	0	0.0	6	6.1	0	0.0	6	6.1
La Plata Electric Association	0	0.0	2	4.2	0	0.0	2	4.2
Longmont Electric Utility	1	2.2	0	0.0	0	0.0	1	2.2
Moon Lake Electric Association	0	0.0	0	0.0	1	0.5	1	0.5
San Isabel Electric Association	0	0.0	2	1.0	0	0.0	2	1.0
Southeast Colorado Power Association	0	0.0	1	0.4	0	0.0	1	0.4
White River Electric Association	0	0.0	3	18.2	1	1.3	4	19.6
Xcel Energy	3	12.6	9	7.9	8	4.5	20	25.1
Total	**10**	**57.4**	**31**	**41.9**	**11**	**6.7**	**52**	**106.1**

TABLE 14: ECONOMIC POTENTIAL BY SYSTEM SIZE

System Size	< 5 years		5-10 years		>10 years		Total Sites	Total Potential (MW)
	No. of Sites	Economic Potntial (MW)	No. of Sites	Economic Potntial (MW)	No. of Sites	Economic Potntial (MW)		
250-500 kW	0	0.0	11	4.2	7	2.4	18	6.6
500-1,000 kW	0	0.0	10	7.2	1	0.5	11	7.7
1-5 MW	7	16.6	8	13.6	3	3.8	18	34.0
5-20 MW	2	14.4	2	17.0	0	0.0	4	31.4
>20 MW	1	26.5	0	0.0	0	0.0	1	26.5
Total	**10**	**57.4**	**31**	**41.9**	**11**	**6.7**	**52**	**106.1**

5 | 2015 Market Penetration of Recycled Energy ≥250 kWe in Colorado

Market Penetration Methodology

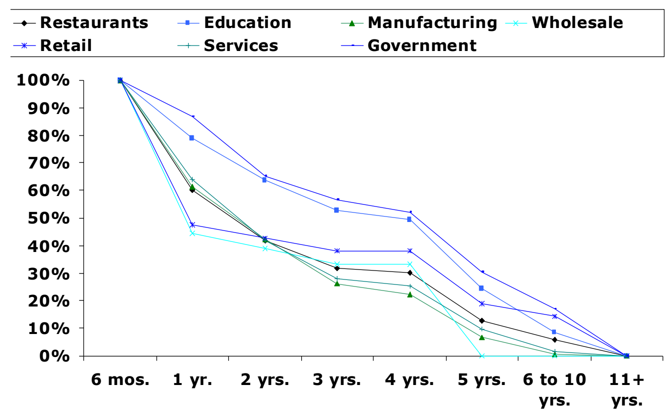
Based on the calculated economic potential, a market diffusion model is used to determine the cumulative recycled energy market penetration over the analysis timeframe. The market penetration represents an estimate of recycled energy capacity that will actually enter the market. This value discounts the economic potential to reflect non-economic screening factors[30] and the rate that recycled energy is likely to actually enter the market.

Rather than use a single yearly payback value as the sole determinant of economic potential, a market acceptance rate has also been included. These acceptance rates are based on a survey of commercial and industrial facility operators, identifying the level of payback required to consider installing recycled energy.

Figure 13 shows the percentage of survey respondents that would accept recycled investments at different payback levels[31]. As can be seen from the figure, more than 30 percent of industrial customers surveyed would reject a project that promised to return their initial investment in just one year. A little more than half would reject a project with a payback of two years. This type of payback translates into a project with an ROI of around 50 percent. Potential explanations for rejecting a project with such high returns include the following:

- The average customer does not believe that the results are valid and is attempting to mitigate this perceived risk by requiring very high projected returns before a project would be accepted.
- The facility has limited capital and is rationing its ability to raise capital for higher priority projects (i.e. market expansion, product improvement, etc.). As shown in the figure, customers in different application classes exhibit different trends in market acceptance. ICF used the acceptance curve for manufacturing customers to represent the industrial applications, and the acceptance curve for education was used to model the commercial and institutional applications.

FIGURE 13: MARKET ACCEPTANCE CURVES



Source: Primen's 2003 Distributed Energy Market Survey

Market Penetration Results

Using the methodology described above, ICF estimated how much of the technical potential can be expected to be developed in Colorado. Of the 106 MW of technical potential at systems above 250 kW, ICF estimates that roughly 30 MW will be developed under current market conditions. **Table 15** shows the distribution of recycled energy deployment. Roughly 85 percent (44) of the sites are concentrated in the refining and pipeline transportation applications. However, these two applications combined only comprise 36 percent (11.1 MW) of overall penetration. Conversely, 63 percent (19.4 MW) of the deployed capacity is distributed among just 7 (or 13 percent) of the 52 identified sites.

Table 16 illustrates the market penetration by utility region. Xcel Energy shows a penetration of 5.2 MW among the 20 sites identified within its territory. Nineteen of the 20 sites identified are those with technical potentials under 5 MW. Black Hills Energy has the highest absolute penetration of 17.8 MW. These are distributed among three sites contained within the territory. Roughly 23 MW of the 30 MW expected to deploy within Colorado are located within these two electric territories. However, this capacity is constrained to 23 sites, or just over 50 percent of the identified candidate sites.

It is important to remember that the figures presented in this analysis represent market adoption based on current market and policy conditions. Recycled energy faces a number of barriers to entry that, if relieved, could improve project economics and boost development. The following section will discuss the current recycled energy market and policy trends in Colorado that drive the economic potential and market acceptance.

[30] Examples of non-economic screening factors are space availability, interconnection, siting, and permitting are difficult to quantify and were not included in the payback calculations for this study.

[31] "Assessment of California CHP Market and Policy Options for Increased Penetration", California Energy Commission, July, 2005.

TABLE 15: MARKET PENETRATION BY APPLICATION

SIC	Application	250-500 kW (MW)	500-1,000 kW (MW)	1-5 MW (MW)	5-20 MW (MW)	>20 MW (MW)	Total Penetration (MW)
29	Petroleum Refining	0.1	0.1	1.6	5.6	0.0	7.5
32	Non-Metallic Minerals	0.1	0.0	3.2	3.4	0.0	6.7
33	Primary Metals	0.0	0.0	0.0	0.0	12.7	12.7
49	Pipeline Transportation	0.3	0.6	2.7	0.0	0.0	3.6
49	Waste Management	0.0	0.0	0.0	0.0	0.0	0.0
	Total	**0.5**	**0.7**	**7.5**	**9.0**	**12.7**	**30.4**

TABLE 16: MARKET PENETRATION BY UTILITY

Utility	250-500 kW (MW)	500-1,000 kW (MW)	1-5 MW (MW)	5-20 MW (MW)	>20 MW (MW)	Total Penetration (MW)
Black Hills Energy	0.0	0.0	1.6	3.4	12.74	17.8
CO State Average	0.1	0.2	0.5	0.0	0.00	0.9
Empire Electric Association	0.0	0.1	0.0	0.0	0.00	0.1
Fort Morgan Electric Light Dept.	0.0	0.0	0.0	0.0	0.00	0.0
Highline Electric Association	0.0	0.0	0.7	0.0	0.00	0.7
KC Electric Association	0.1	0.1	1.0	0.0	0.00	1.2
La Plata Electric Association	0.0	0.0	0.6	0.0	0.00	0.6
Longmont Electric Utility	0.0	0.0	0.5	0.0	0.00	0.5
Moon Lake Electric Association	0.0	0.0	0.0	0.0	0.00	0.0
San Isabel Electric Association	0.1	0.1	0.0	0.0	0.00	0.2
Southeast Colorado Power Association	0.1	0.0	0.0	0.0	0.00	0.1
White River Electric Association	0.0	0.0	0.2	3.0	0.00	3.2
Xcel Energy	0.1	0.2	2.3	2.6	0.00	5.2
Total	**0.5**	**0.7**	**7.5**	**9.0**	**12.74**	**30.4**

6 | Recycled Energy Market and Policy Trends

Identification of Key Barriers and the Current Policy Environment in Colorado

There are a number of barriers that prove limiting to recycled energy projects. These barriers can be categorized as financial, regulatory, or informational in nature. Some of the key barriers to the increased deployment of recycled energy are discussed below. This section also goes on to discuss the policy environment for recycled energy in Colorado. The following chapter will cover opportunities to help address these barriers.

Key Regulatory Barriers

- *Standby rates*. The structure of standby rates that are not designed to closely preserve the nexus between charges and cost of service can determine whether a recycled energy project moves forward. Utility rates and fees can have an impact on recycled energy project economics. Most industrial customers are motivated to install recycled energy systems to meet electricity and thermal energy needs at a lower cost. Standby rates, or partial requirements tariffs, are a potential impediment to recycled energy projects if the rates are not properly designed. Utility rates, including standby charges, should allow a utility to recover costs from customer classes based on energy usage patterns for each class. This principle of "cost causation" is implemented through rate designs that fairly allocate costs based on measureable customer characteristics. Some utilities in Colorado have standby rates that are considered high and can deter recycled energy projects.

- *Environmental permitting and regulatory issues*. Complicated state and federal permitting requirements can impede the adoption of recycled energy projects. The installation of recycled energy systems may require industrial users to modify their process equipment, potentially triggering permitting issues. Ensuring that state permitting processes are straightforward and predictable, clarifying when recycled energy systems would trigger additional permitting requirements, helps to avoid costly delays and uncertainty in the planning process.

- *Lack of recognition of environmental benefits*. Lack of financial value for the potential emissions benefits of recycled energy projects can deter development of recycled energy projects. Treating environmental benefits as an externality that cannot be monetized reduces the value of recycled energy projects. For example, recycled energy projects help reduce CO_2 emissions as compared to separate heat and power projects. These emissions savings typically do not receive economic value from companies because they typically cannot be monetized under existing regulation. However, there may be significant value (monetary and shareholder) from such emissions savings in certain markets, such as recycled energy systems receiving CO_2 emissions credits under the Regional Greenhouse Gas Initiative (RGGI) or future Clean Power Plan regulations, as well as in corporate sustainability reporting.

Other Barriers

- *Internal competition for capital*. Payback expectations and capital budget constraints influence recycled energy investment decisions. Facility capital budgets are limited and there is often strong competition for new capital investment. Even a recycled energy system that has an attractive financial return may not be funded over other alternatives that are closer to a company's core business, such as investments in productivity or product quality or investments to respond to regulatory requirements.

- *Financial risk*. Facilities may have a hard time finding low-cost financing for recycled energy projects due to financial risks. Gaining access to capital at affordable rates can be especially difficult for long-term investments in facility upgrades, such as recycled energy projects. For example, there are complicating factors like lender uncertainty about the recycled energy technology and the viability of process-related changes (e.g., how the system works, how it will be incorporated into the process, and whether it will perform as expected).

- *Access to favorable tax structures*. Lack of inclusion of recycled energy in federal tax incentives such as the federal Investment Tax Credit (ITC) can prevent further deployment of this technology type. Qualifying CHP projects are eligible for a 10 percent ITC through the end of 2016. Recycled energy projects do not qualify for the ITC. A recent study by the Heat is Power (HiP) Association found that given equal tax treatment, industrial waste heat could provide enough emission-free electricity to power 10 million American homes, provide thousands of new American jobs, and support critical U.S. manufacturing industries.[32]
- *Sales of excess power*. The inability to sell excess power or access to reasonable sales agreements for excess power if all of the generation cannot be used onsite can be a barrier. Excess power sales may provide a revenue stream for a recycled energy project, possibly enabling the project to go forward. The inability to sell excess power or to sell excess power at a competitive price can serve as a deterrent to recycled energy projects.
- *Awareness of available incentives*. Insufficient knowledge of federal, state and utility incentives and eligibility requirements for recycled energy projects can prevent good candidate sites for recycled energy from moving forward with such projects.

Existing Colorado Incentives and Policies for Recycled Energy

There are a number of policies that impact recycled energy opportunities in Colorado. The Colorado Renewable Energy Standard (RES) is the key policy driver for recycled energy project development. The RES requires each qualifying retail utility to generate or acquire sufficient renewable energy credits (RECs) to meet a specified portion of its retail electricity sales by 2020. IOUs must acquire 30 percent of their generation from eligible resources, electric co-ops that serve 100,000 meters or more must meet a 20 percent requirement, and electric co-ops serving less than 100,000 meters and each municipal utility serving more than 40,000 meters must meet a 10 percent requirement. Investor-owned utilities must meet a requirement that 3 percent of their retail sales by 2020 must come from distributed generation; half of this requirement (1.5 percent) must come from "retail distributed generation"[33] (DG) serving onsite load. Co-ops that provide service to 10,000 or more meters must also meet a DG requirement of 1 percent of retail sales by 2020 (0.5 percent must come from "retail distributed generation").

The RES currently defines eligible recycled energy as "energy produced by a generation unit with a nameplate capacity of not more than 15 megawatts (MW) that converts

[32]Heat is Power (HIP). "Comments: Energy Tax Reform" Submitted to the House Ways and Means Tax Reform Working Group on Energy." (2013, April). http://www.heatispower.org/wp-content/uploads/2013/04/Heat-is-Power-Association-letter-to-W-and-M-Energy-Tax-Reform-Working-Group-4-15-2013.pdf.

[33]"Retail Distributed Generation" is defined as a "resource that is located on the site of a customer's facilities and is interconnected to the customer's side of the meter." Presumably, this would include all renewable energy systems that participate in net metering. "Wholesale distributed generation" is defined as a "resource with a nameplate capacity rating of 30 MW or less and that does not qualify as retail distributed generation." DG systems with a nameplate capacity of 1 MW or greater must be registered with a REC tracking system which will be selected by the PUC.

the otherwise lost energy from the heat from exhaust stacks or pipes to electricity and that does not combust additional fossil fuel. Recycled energy does not include energy produced by any system that uses energy, lost or otherwise, from a process whose primary purpose is the generation of electricity, including, without limitation, any process involving engine-driven generation or pumped hydroelectricity generation."[34] There are certain REC credit multipliers for projects that began on or after January 1, 2015, and for projects that are interconnected to electrical transmission or distribution lines owned by a co-op or municipal utility that were installed prior to December 31, 2014. The Trailblazer Pipeline compressor station is the only recycled energy project that has been able to receive Renewable Energy Credit (RECs) under the RES. The Trailblazer project annually generates around 27,600 MWh/yr[35], which amounts to $600,000 in annual revenues through RECs.[36]

Xcel Energy and Black Hills Energy are required to regularly submit Renewable Energy Compliance Plans to the state Public Utilities Commission (PUC). In Black Hills Energy's latest Compliance Plan for 2014, the utility did not use any recycled energy projects to help meet its compliance targets.[37] Regarding Xcel Energy's RES Compliance Plan, due to comments by the HiP association, and the SWEEP on ways to provide further opportunities to recycled energy projects under the Plan, the PUC Administrative Law Judge ruled in December 2014[38] that Xcel Energy must now offer some incentives. Recycled energy projects up to 10 MW in size qualify under the Xcel Energy Program; projects above 10 MW have a different route they can use to potentially receive incentives. Annually 20 MW worth of projects can receive funding. The funding amount is set at $500/kW over 10 years. [39] Lastly, the ruling addressed standby rates–the PUC directed Xcel Energy to "file a new tariff to support the Recycled Energy programs within 60 days of the effective date of this decision. The tariff filing shall address why recycled energy projects should be required to take Standby

[34]Colorado Department of Regulatory Agencies, Public Utilities Commission. "4 Code of Colorado Regulations (CCR) 723-3, Part 3 Rule Regulating Electric Utilities." (2014, June). http://cdn.colorado.gov/cs/Satellite?blobcol=urldata&blobheadername1=Content-Disposition&blobheadername2=Content-Type&blobheadervalue1=inline percent3B+filename percent3D percent22Rules+Regulating+Electric+Utilities.pdf percent22&blobheadervalue2=application percent2Fpdf&blobkey=id&blobtable=MungoBlobs&blobwhere=1252044766643&ssbinary=true.

[35]U.S. Department of Energy Clean Energy Application Centers. "Recycled Energy Basics and Benefits, Arizona Recycled Energy in Action." (2012, January 26). http://www.southwestchptap.org/data/sites/1/events/2012-01-26/Broderick-Recycled_Energy_Basics_and_Benefits.pdf.

[36]Hales, Roy, L. "The New Renewables Are Recycled Energy Technologies." (2015, January 17). http://cleantechnica.com/2015/01/17/new-renewables-recycled-energy-technologies/.

[37]Black Hills Energy/Colorado Electric Utility Company, LP, d/b/a Black Hills Energy Energy. "2014 Renewable Energy Compliance." http://www.blackhillsenergy.com/sites/default/files/bhe-coe-res-compliance-rpt.pdf.

[38]Colorado Public Utilities Commission. "Decision Approving Renewable Energy Standard Compliance Plan and Addressing Exceptions to Decision No. R14-0902." (2014, December 26). https://www.dora.state.co.us/pls/efi/EFI.Run_Document?p_session_id=&p_document_id=3711105.

[39]Heat is Power (HIP). "2014 Waste Heat to Power Mid-Year Report." (2014, August 12). http://www.heatispower.org/2014-waste-heat-to-power-mid-year-report/ .

Service."[40] In March 2015, Xcel Energy filed new tariff pages. However, Western Resource Advocates protested the new Xcel Energy tariff pages and requested that the PUC set the matter for hearing. The Commission decided to set the tariff pages for hearing which suspends the effective date of the tariffs for 120 days after the proposed effective date (so suspended until July 24, 2015).[41] Xcel Energy issued amended tariffs in May 2015; however, a final decision regarding tariffs for recycled energy has not been made.[42] Under Interim Decision No. R15-0470-I issued May 15, 2015, a procedural schedule was adopted which among other things, scheduled an evidentiary hearing for July 31, 2015. Ormat Technologies, Inc., the developer of the Trailblazer Pipeline project, is now an intervener in this Proceeding.

One of the policies in Colorado that is considered a barrier to recycled energy projects is applicable standby rates. Xcel Energy is proposing that recycled energy projects with capacities of 0-10 MW pay their regular standby rate; the same standby rate that is already applied to natural gas-fired topping cycle CHP systems. SWEEP is proposing that recycled energy systems under 500 kW be exempted and be on the general rate. Currently standby rates in Xcel Energy's territory are unfavorable and a decision regarding its standby rates for recycled energy projects is expected to be made later this summer (see the discussion directly above).

Concerning other policies in Colorado, DOE's Southwest CHP Technical Assistance Partnership (TAP) has an overview of policies in Colorado impacting CHP, along with a rating. Interconnection standards in the state for CHP are considered decent – CHP and recycled energy projects are called out as eligible for a standardized interconnection process, and systems up to 10 MW in size can interconnect. However, the interconnection standards are criticized due to the additional insurance requirements, whereby owners of grid-tied DG systems must carry their own liability insurance when the rules already have provisions for indemnification. Standby rates in Colorado are also not considered favorable to CHP. Standby rates are relatively high in Xcel Energy's territory and in some co-op territories. There are instances of projects not going forward or shutting down due to these high standby rates. However, Xcel Energy is working on assessing its standby rates based on the December 2014 PUC ruling related to recycled energy (see the discussion above). There are a couple of other financing incentives for which CHP and recycled energy projects may be eligible. Tri-State provides power to 44 rural cooperatives, including some in Colorado. Tri-State has some incentives for its member co-ops to develop distributed and/or renewable energy projects, and recycled energy projects qualify.[43]

[40]Colorado Public Utilities Commission. "Decision Approving Renewable Energy Standard Compliance Plan and Addressing Exceptions to Decision No. R14-0902." (2014, December 26). https://www.dora.state.co.us/pls/efi/efi_p2_v2_demo.show_document?p_dms_document_id=444676

[41]Colorado Public Utilities Commission. "Decision Approving Renewable Energy Standard Compliance Plan and Addressing Exceptions to Decision No. R14-0902." (2014, December 26). https://www.dora.state.co.us/pls/efi/efi_p2_v2_demo.show_document?p_dms_document_id=444676.

[42]See Colorado PUC proceeding No. 15AL-0118E.

[43]DOE, CHP Technical Assistance Partnerships, Southwest. "Colorado." (Accessed June 2015). http://www.southwestchptap.org/states-co.

7 | Opportunities for State Involvement in Recycled Energy Market

Evaluation of Potential Options for State Involvement

In Colorado the key policy in place to encourage recycled energy projects is its inclusion in the state's Renewable Energy Standard (RES), and only one project so far has received RES credits. Other states can serve as an example for Colorado on best policy practices for encouraging further recycled energy deployment in the state. Model state incentives and policies will be described in this section, along with the pros and cons of each approach. Federal drivers for increased development of recycled energy projects are also discussed.

Portfolio Standards

A handful of states include recycled energy in their Energy Efficiency Resource Standards (EERS) or in their Renewable Portfolio Standards (RPS), including Colorado. However, Colorado may want to consider increasing the size limit applicable to recycled energy projects or including a specific recycled energy target that utilities must meet. According to HiP, 17 states consider waste heat to power or recycled energy projects to be a renewable resource in their state renewable portfolio standards and three states include recycled energy as an efficiency measure in their energy efficiency resource standards.[44] Although there are 13 different terms for recycled energy in the 19 states, all 19 state policies and programs specify the generation of electricity from waste heat in their definition of recycled energy. Examples of states that have favorable provisions involving recycled energy or have made recent policy changes are as follows:

[44]Heat is Power (HiP). "Comments of the Heat is Power Association on Docket ID No. EPA-HQ-OAR-2013-0602, Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units." (2014, December 1). http://www.heatispower.org/wp-content/uploads/2014/12/Heat-is-Power-Association-comments-on-Clean-Power-Plan-December-1-2014.pdf.

- HiP highlights Ohio SB 315 as a good model for including recycled energy in RPS legislation.[45] Senate Bill 315 and 289 enacted in 2012 added certain CHP and recycled energy system (termed waste energy recovery system[46]) technologies that meet specific requirements (Docket 12-2156-EL-ORD). A recycled energy or CHP system may qualify for either the Renewable Energy Resource Standard or the Energy Efficiency Portfolio Standard. However, legislation enacted in 2014, SB 310, froze the current state standards for two years and weakened a number of the other RPS + EERS provisions.[47] As a result, the RPS + EERS are not being implemented until the two-year freeze is over. During this freeze, some of the utilities in the state have granted rebates to CHP projects, and Dayton Light and Power recently issued a CHP incentive program.

Colorado may want to consider establishing a carve-out or target solely for recycled energy projects. This would require affected utilities to incentivize a certain amount of recycled energy projects to meet their compliance obligations. Renewable energy advocates also often support the tier/carve-out structure under portfolio standards or the establishment of a separate EERS. Both approaches serve as a way to not detract from the amount of energy procured from traditional renewable energy resources such as wind and solar.

Public Benefits Funds (PBF)

A Public Benefit Fund (PBF) or System Benefits Charge (SBC) is a small monthly surcharge on customers' electricity bills that is collected and used for state-wide investments in clean energy supply.[48] Oregon passed restructuring legislation in 1999 that established a PBF in the state. The funds are directed towards renewable and energy efficiency projects and are administered by the Energy Trust of Oregon. CHP and heat recovery technologies are eligible for funding. For example, at Oregon Tech's Klamath Falls campus, a recycled energy/geothermal CHP system was installed and received PBF funds – $1.55 million cash incentive came from the Oregon Energy Trust. "The geothermal power plant works by pumping 196°F water from a well 5,308 feet below campus. That hot water heats a refrigerant to create steam, which is used to spin two turbines. These turbines create electricity and spin in series–one after the other–to extract an optimal amount of energy from the system, increasing efficiency by 20 percent. The innovative approach was proposed by Johnson Controls, which designed and constructed the turbine and generator. After generating electricity, the warm water is also used to heat campus buildings."[49] Oregon Tech has now installed two geothermal power plants that, together with a solar electric

[45]Heat is Power (HiP). "Heat is Power Statement to House Committee on Energy and Commerce." (2013, February 26). http://www.heatispower.org/hip-statement-to-house-committee-on-energy-and-commerce/.

[46]"Waste energy recovery system" means either of the following:
(a) A facility that generates electricity through the conversion of energy from either of the following:
(i) Exhaust heat from engines or manufacturing, industrial, commercial, or institutional sites, except for exhaust heat from a facility whose primary purpose is the generation of electricity;
(ii) Reduction of pressure in gas pipelines before gas is distributed through the pipeline, provided that the conversion of energy to electricity is achieved without using additional fossil fuels.

[47]NC Clean Energy Technology Center, DSIRE. "Ohio, Alternative Energy Portfolio Standard." (2014, July 24). http://programs.dsireusa.org/system/program/detail/2934.

[48]EPA. "Public Benefit Funds." (2008, October). http://www.epa.gov/chp/policies/funds.html.

[49]Energy Trust of Oregon. "Oregon Tech Makes History with Renewable Power." (Accessed June 2015). https://energytrust.org/library/case-studies/OIT_CS_1404.pdf.

system, make the university the first in North America to generate all of its electricity onsite. The combined-heat-power plant is comprised of one modular organic Rankine cycle (ORC), a water cooling tower, and individual heat exchangers in various campus buildings.[50]

A key emerging opportunity to help finance clean energy projects such as recycled energy is the establishment of "green banks" in several northeastern states (CT, MA, and NY) and Hawaii. For example, in Connecticut and New York, systems benefit charges were repurposed and Regional Greenhouse Gas Initiative (RGGI) funds also provided initial capital for the green bank.[51] A "green bank" is typically defined as a public or quasi-public financing institution that provides low-cost, long-term financing to support a wide range of clean energy projects. Green banks often leverage public funds to attract private investment.[52] In Connecticut, the green bank has a CHP pilot program. The program is run by the Clean Energy Finance and Investment Authority (CEFIA) and provides grants, loans, loan enhancements, and power purchase incentives to CHP projects in the development phase. Systems must be 5 MW or less in size and must be located within certain utility service territories within the state. Financial incentives are capped at $450/kW of nameplate rated capacity.[53]

In October 2014, the New York Green Bank announced its first planned transactions. The Bank of America/Merrill Lynch transaction focuses on increasing the bank's loans to commercial entities for clean energy equipment like CHP.[54] NY Green Bank is working toward funding construction and permanent debt as a lender to GreenCity Power, LLC (GCP), a business which designs, builds, owns, and operates small-scale CHP projects in New York City's largest commercial buildings (hospitals, hotels, office buildings, etc.). GCP's projects will deploy high efficiency natural-gas-fired reciprocating engines to generate electricity, heating and cooling. NY Green Bank will co-invest, along with Tulum Management, in GCP's first five projects. Once a target portfolio of operating projects has been developed, institutional investors are expected to provide permanent financing.[55]

[50]Oregon Tech. "Geo-Heat Center, Geothermal Information and Technology Transfer." (Accessed June 2015). http://geoheat.oit.edu/bulletin/bull31-4/art3.pdf.

[51]Coalition for Green Capital. "What is a Green Bank?" (Accessed June 2015). http://www.coalitionforgreencapital.com/whats-a-green-bank.html.

[52]Ibid.

[53]Energize Connecticut. "Combined Heat and Power Pilot Program." (Accessed June 2015). http://www.energizect.com/businesses/programs/Combined-Heat-Power.

[54]Sims, Doug. "First New York Green Bank Deals to Bring up to $800MM in Clean Energy Investments to New York State." Switchboard Natural Resources Defense Council Staff Blog. (2014, October 22). http://switchboard.nrdc.org/blogs/dsims/first_new_york_green_bank_deal.html.

[55]NYGreenBank. "NY Green Bank's Initial Transactions." (Accessed June 2015). http://greenbank.ny.gov/initial-transactions.

The City of Boulder has its own PBF, termed the Climate Action Plan Fund. A specific tax is defined for residential, commercial, and industrial customers. Xcel Energy collects the tax for the city through its monthly customer utility billing. The current tax rate is set to expire March 31, 2018.[56] The tax has gone primarily towards residential projects and there are some business programs (although none that focus on more complicated energy efficiency measures such as recycled energy projects).[57]

Establishing a green bank in Colorado is an option for increasing financing available for recycled energy projects. The recently established green banks also seek to leverage private financing for clean energy projects. However, green banks are a relatively new financing mechanism for clean energy projects, and there are few experiences and/or lessons learned to draw from at this point.

State Tax Credits

Another way to encourage recycled energy projects is through the availability of state tax credits for installing this type of project. Kansas provides a property tax credit for waste heat projects. Waste heat utilization system property is exempt from all property taxes levied under Kansas state law for the first 10 taxable years in which construction or installation of the project is complete.[58] Waste heat utilization system means facilities and equipment for the recovery of waste heat generated in the process of generating electricity and the use of such heat to generate additional electricity or to produce fuels from renewable energy resources or technologies.

Tax credits can serve as an effective way of encouraging clean energy projects. However, at the state level, tax credits are less often used as compared to other forms of incentives such as grant and rebate programs. Colorado may want to consider a tax credit, in addition to other incentive type as a way to spur growth in recycled energy projects.

Standby Rates

The way in which utility standby rates are designed has a significant impact on recycled energy project economics. For example, some state standby rates have demand ratchets, meaning that the utility continues to apply some percentage of the customer's highest peak demand in a single billing month for up to a year after its occurrence. Ratcheted demand charges may result in recycled energy customers overpaying for utility-supplied electricity relative to full requirements customers. Currently, Xcel Energy's tariffs are not considered favorable for recycled energy projects and CHP projects. Xcel Energy proposed in 2014 that premises generating electricity from recycled energy must be on the standby tariff. A judge ruled recycled energy projects have to be on the standby tariff until another tariff is proposed and approved. [59] Xcel Energy has been directed by the PUC to reassess their tariffs, and proposed changes earlier this year[60]; however a final ruling on Xcel Energy's standby rates for recycled energy projects is not expected until later this summer.

An example of a utility's standby rates that have been deemed favorable to distributed generation projects is Pacific Power's standby rates in Oregon. Pacific Power has established standby rates in Oregon that balance the value of onsite power generation and utility cost recovery needs. Several key elements of these standby rates include the following:

- Pacific Power assesses charges for shared distribution facilities, such as substations and transmission lines, based on 15-minute net demand for the month during on-peak hours. There is no annual ratchet.
- Cost recovery for local distribution facilities is based on the average of the two highest monthly peak demands for the past 12 months.
- Scheduled maintenance service must be scheduled 30 days in advance. Pacific Power offers customers the option to buy replacement energy at market prices.
- Energy service for unscheduled outages is based on real-time market prices. Demand and transmission charges during scheduled maintenance periods and unscheduled outages are based on daily demands and do not affect charges for T&D services under the base standby tariff.

Colorado may want to consider conducting a study on standby rate charges by utilities in the state and makes recommendations on elements of Colorado utility standby rates that should be reassessed. Revising standby rates to ensure that they are more favorable to forms of DG, like recycled energy projects, can be much more beneficial in encouraging new projects than other types of financial incentives. However, there are often numerous different utility standby rates within a state that may need to be assessed and modified. Implementing a single, incentive program for recycled energy projects may be easier from an administrative/rulemaking viewpoint as compared to modifying standby rates to make them more favorable to recycled energy projects.

[56]City of Boulder Colorado. "Climate Action Home Page." (Accessed June 2015). https://bouldercolorado.gov/climate.

[57]City of Boulder Colorado. "Your CAP Tax Dollars at Work." (2013). https://www-static.bouldercolorado.gov/docs/Tax_At-a-Glance_v05-1-201307081503.pdf.

[58]Kansas Department of Commerce. "Taxes and Incentives." (Accessed June 2015). http://www.kansascommerce.com/index.aspx?NID=447.

[59]Heat is Power (HiP). "2014 Waste Heat to Power Mid-Year Report." (2014, August 12). http://www.heatispower.org/2014-waste-heat-to-power-mid-year-report/.

[60]Colorado Public Utilities Commission. "Direct Testimony and Exhibits of Scott B. Brockett." (2015, February 23). https://www.google.com/url?sa=t&rct=j&q=&es-rc=s&source=web&cd=6&cad=rja&uact=8&ved=0CEUQFjAF&url=https percent3A percent2F percent2Fwww.dora.state.co.us percent2Fpls percent2Fefi percent2Fefi.show_document percent3Fp_dms_document_id percent3D462045 percent26p_session_id percent3D&ei=MqaRVbqjHsb8-AGRp4a4Bw&usg=AFQjCNGmrqf3br79N-rg27WTW5mT9JnguNQ&sig2=bguqbeVJsN1vMpHT4KKBqg

Excess Power Sales Laws

Another policy that can encourage recycled energy projects is the ability to sell any excess power that is produced and exceeds any onsite demand to adjacent customers. Often, states have policies in place that do not allow CHP systems or recycled energy projects to sell this excess generation off-site. However, some states have recently enacted laws allowing for such plants to sell to adjacent users. For example, New Jersey, California, New York and Texas have all enacted laws in recent years that loosen restrictions on CHP and/or recycled energy power sales to adjacent facilities, making such projects more economic.

Net Metering

Being explicitly mentioned as an eligible technology under net metering policies is also beneficial to recycled energy projects and other forms of distributed generation. Connecticut is the only state that explicitly calls out CHP and "waste heat recovery" projects as eligible. Connecticut allows virtual net metering for Class III resources (CHP + WHR)[61] from facilities up to 3 MW in size. If the customer produces more electricity than it consumes, the excess electricity will be credited to the account for the next billing period at the retail rate against the generation service component and a declining percentage of the transmission and distribution charges that are billed to the account. Excess credits rollover monthly for one year. The electric distribution company is to compensate the municipal or state host customer for excess virtual net metering credits remaining at the end of the calendar, if any, at the retail generation rate and the above declining percentage of transmission and distribution charges.[62]

Net metering does help the economics of a recycled energy project, if that project expects to produce more power than can be used onsite. Most states only allow for small, renewable systems to net meter and set an upper limit on the amount of capacity that can net meter. Extending net metering eligibility to other project types (such as recycled energy) can help tip the balance in favor of moving forward with such a project.

[61] Class III resources are defined as "the electricity output from combined heat and power systems with an operating efficiency level of no less than fifty per cent that are part of customer-side distributed resources developed at commercial and industrial facilities in this state on or after January 1, 2006, a waste heat recovery system installed on or after April 1, 2007, that produces electrical or thermal energy by capturing preexisting waste heat or pressure from industrial or commercial processes, or the electricity savings created in this state from conservation and load management programs begun on or after January 1, 2006."

[62] NC Clean Energy Technology Center, DSIRE. "Connecticut Net Metering." (2015, June 26). http://programs.dsireusa.org/system/program/detail/277.

Financial Incentives

The most popular form of support for recycled energy projects is through financial incentives. Most are offered in the form of rebates, with some loans, grants, Property-Assessed Clean Energy (PACE) financing, and tax credits. Some innovative incentive programs under which recycled energy is explicitly called out as eligible are noted as follows.

- Illinois Public Sector Combined Heat and Power (CHP) Pilot Program – this program provides cash incentive for CHP or WHP projects that increase energy efficiency of public, state or federal facilities in Illinois located in the service territories of ComEd, Ameren, Nicor, Peoples Gas or Northshore Gas. Incentives are capped at $2 million per project or 50 percent of the cost of the project (whichever is less). There are three different types of incentives available - design incentive of $75/kW, construction incentive of $175/kW and the a production incentive of $0.08/kWh for all useful electric energy produced by the WHP system. Waste Heat-to-Power is defined as an integrated system that is located at or near the building or facility (onsite, on the customer side of the meter) that:[63]
    - Utilizes exhaust heat from an industrial/commercial process and converts that heat to generate electricity (except for exhaust heat from a facility whose primary purpose is the generation of electricity for use on the grid).
    - Utilizes the pressure drop in an industrial/ commercial facility to generate electricity through a backpressure steam turbine where the facility normally uses a pressure reducing valve (PRV) to reduce the pressure in their facility.
    - Utilizes the pressure reduction in natural gas pipelines (located at natural gas compressor stations) before the gas is distributed through the pipeline to generate electricity, provided that the conversion of energy to electricity is achieved without using additional fossil fuels.
- New Jersey Clean Energy Solutions Large Scale CHP and Fuel Cells Program – this New Jersey program provides incentives for "heat recovery" projects defined as "powered by non-renewable fuel source. Heat recovery or other mechanical recovery from existing equipment utilizing new electric generation equipment (e.g., steam turbine)." Heat recovery projects $\leq$ 1 MW are eligible for an incentive of $1.00/Watt; incentives are capped at 30 percent of project costs or $2 million. For heat recovery projects greater than 1 MW, the incentive is $0.50/Watt; incentives are capped at 30 percent of project costs or $3 million.[64]
- New York State Energy Research and Development Authority's (NYSERDA's) GHG Reduction Pilot Program – earlier this year, NYSERDA released a RFP to demonstrate market-ready technologies that reduce GHG emissions from the power sector. Waste heat recovery projects that reduce the annual emissions rate at New York electric generating units (EGUs) with a nameplate capacity of at least 25 MW can receive funding of up to $2 million per demonstration project. Proposals were due by March 5, 2015.[65]
- California Self Generation Incentive Program (SGIP) – California's SGIP offers incentives to a number of project types including recycled energy projects defined as "Waste Heat to Power" projects. Beginning in 2008, the list of eligible technologies was expanded to include advanced energy storage systems coupled with renewable energy systems, waste heat to power systems and pressure reduction turbines. WHP projects are eligible for an incentive of $1.07/W. The incentive payment is capped at 3 MW (larger projects are eligible; they only receive incentives up to this size threshold). The maximum incentive available is $5 million or 60 percent of eligible project costs.[66] During the SGIP queue in 2014, there was one WHP sized at 0.1 MW that was awaiting funding.[67] In 2013, there was one WHP in the queue awaiting funding; sized at 0.05 MW.[68]
- Colorado – Local Option Improvement Districts for Energy Efficiency and Renewable Energy Improvements PACE financing effectively allows property owners to borrow money to pay for energy improvements. The amount borrowed is typically repaid via a special assessment on the property over a period of years. In 2008, Colorado authorized local governments to establish such programs. Heat recovery is generally considered as eligible; however, CHP and recycled energy is not explicitly called out as eligible under the PACE legislation.[69]

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[63] Illinois Energy Now. "Public Sector Energy Efficiency Program." (2014-2015). https://www.illinois.gov/dceo/whyillinois/KeyIndustries/Energy/Documents/Final_RFA percent20CHP percent20Guidelines percent207-7-14.pdf.

[64] New Jersey Board of Public Utilities (BPU), Clean Energy Program. "Combined Heat & Power – Fuel Cells- Incentives." (2015, July 1). http://www.njcleanenergy.com/commercial-industrial/programs/combined-heat-power/combined-heat-power-fuel-cells-incentives.

[65] Heat is Power (HiP). "Funding Opportunity for WHP Projects in New York State." (2015, June 12). http://www.heatispower.org/funding-opportunity-for-whp-projects-in-new-york-state/.

[66] NC Clean Energy Technology Center, DSIRE. "California, Self-Generation Incentive Program." (2015, February 18). http://programs.dsireusa.org/system/program/detail/552.

[67] Itron. "2013 SGIP Impact Evaluation." Submitted to PG&E and The SGIP Working Group. (2015, April). http://www.cpuc.ca.gov/NR/rdonlyres/AC8308C0-7905-4ED8-933E-387991841F87/0/2013_SelfGen_Impact_Rpt_201504.pdf.

[68] Itron. "2012 SGIP Impact Evaluation and Program Outlook." Submitted to PG&E and The SGIP Working Group. (2014, April). http://www.cpuc.ca.gov/NR/rdonlyres/25A04DD8-56B0-40BB-8891-A3E29B790551/0/SGIP2012ImpactReport_20140206.pdf.

[69] NC Clean Energy Technology Center, DSIRE. "Local Option – Improvement Districts for Energy Efficiency and Renewable Energy Improvements." (2014, August 28). http://programs.dsireusa.org/system/program/detail/3528.

> Nevertheless, energy efficiency organizations such as ACEEE list Colorado PACE laws as including "model language." For example, Colorado HB 08-1350, Session Law 299[70]: amends county and city authority to create improvement districts specifically for clean energy improvements.[71]

Colorado could consider some of the state incentive programs mentioned above such as Illinois or New York's CHP incentive programs, in addition to the incentive program that Xcel Energy recently announced. Colorado could draw upon some of the same general design concepts of these other state programs, but would need to revise some of the elements to reflect the specific types of projects being sought, and to reflect the energy and policy environment in the state.

Federal Proposals Related to Recycled Energy

The Federal Investment Tax Credit (ITC) has also helped incentivize CHP, although it has been criticized due to its exclusion of recycled energy projects, and credit limitations for CHP projects. The Emergency Economic Stabilization Act of 2008 added CHP system property to the list of technologies eligible for an investment tax credit under Section 48 of the Internal Revenue Code. Qualifying CHP projects are eligible for a 10 percent ITC through the end of 2016. Recycled energy projects do not qualify for the ITC. A recent study by HiP found that given equal tax treatment, industrial waste heat could provide enough emission-free electricity to power 10 million American homes, provide thousands of new American jobs, and support critical U.S. manufacturing industries.[72] HiP and other organizations have advocated that the ITC be extended to include recycled energy projects as eligible, has recommended extending the ITC past 2016, and has suggested increasing the ITC for CHP and recycled energy to 30 percent. The Power Act, which was introduced in 2014 and then reintroduced in 2015 proposes increasing the ITC from 10 percent to 30 percent, extending the tax credit through the end of 2018, including recycled energy projects as eligible, and removing size limitations for CHP.[73]

Another tax credit that has been available in the past to encourage CHP projects is the Modified Accelerated Cost Recovery System (MACRS). This tax credit expired at the end of 2014 and allowed for businesses to recover investments in CHP through depreciation deductions. The MACRS establishes a set of class lives for various types of property, which was 5 years for CHP, over which the property may be depreciated.[74] A number of advocacy groups have proposed reinstating MACRS and including recycled energy or waste heat to power property as explicitly eligible for depreciation.

EPA's Proposed Clean Power Plan

The EPA's proposed rule to regulate CO_2 emissions from existing large power plants in the U.S. provides a further opportunity for recycled energy projects. States have specific targets, but are allowed a number of flexible options to help meet their compliance obligations. Energy efficiency projects such as recycled energy can potentially be used to help meet state targets. Organizations, such as HIP, have suggested that recycled energy projects be explicitly listed in the EPA rule as a zero-emitting power source that states can use to offset carbon emissions.[75]

Recommendations for Colorado

Table 17 lists the key barriers to greater deployment of recycled energy projects that were discussed in the prior section and recommendations for the State of Colorado on how to address these barriers. The recommendations are discussed in detail further below in this section.

Based on the above recycled energy state policy examples, Colorado could consider a number of policies to further enhance the development of recycled energy systems. Recommendations for Colorado include, but are not limited to the following:

- Provide for additional utility financial incentives for recycled energy, e.g., recommend that Black Hills Energy develop a recycled energy incentive program similar to Xcel Energy's recent program.
- Conduct a study of utility standby rates in the state and recommend ways to improve upon existing tariff structures. For example, the Regulatory Assistance Project (RAP) conducted a study on utility standby rates that apply to CHP projects in 2014 and issued recommendations on how specific utility rates can be improved.[76] PSCo's standby rates.

70 General Assembly of the State of Colorado. "House Bill 08-1350." (2008). http://www.leg.state.co.us/clics/clics2008a/csl.nsf/fsbillcont/E62A0C34C01772C9872573D000830B58?Open&file=1350_enr.pdf.

71 http://aceee.org/sector/state-policy/toolkit/pace

72 Heat is Power (HIP) "Comments: Energy Tax Reform" Submitted to the House Ways and Means Tax Reform Working Group on Energy." (2013, April). https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0CCoQFjACahUKEwin-9bQoO_GAhVGOD4KHSV5Cf4&url=http percent3A percent2F percent2Fwww.heatispower.org percent2Fwp-content percent2Fuploads percent2F2013 percent2F04 percent2FHeat-is-Power-Association-letter-to-W-and-M-Energy-Tax-Reform-Working-Group-4-15-2013.pdf&ei=vNGvVaetK8bw-AGl8qXwDw&usg=AFQjCNGNDNx5ZKTWYu7iMwW1OwDbOYNGcA&sig2=JYQOuvDH7XkSWUcyQ7XgJw.

73 114th Congress (2015-2016). "H.R. 2657 – Power Act." (2015, June 4). https://www.govtrack.us/congress/bills/114/hr2657/text.

74 NC Clean Energy Technology Center, DSIRE. "Modified Accelerated Cost-Recovery (MACRS)." (2014, December 23). http://programs.dsireusa.org/system/program/detail/676.

75 Heat is Power (HiP). "Comments on the Clean Power Plan." (2014, December 1). http://www.heatispower.org/wp-content/uploads/2014/12/Heat-is-Power-Association-comments-on-Clean-Power-Plan-December-1-2014.pdf.

76 Regulatory Assistance Project (RAP), "Standby Rates for Combined Heat and Power Systems, Economic Analysis and Recommendations for Five States." (2014, February). http://www.raponline.org/document/download/id/7020.

were assessed as part of this RAP study. Xcel Energy issued comments to the PUC addressing RAP's recommendations in 2013, and did not propose making any changes until a comprehensive Phase II electric rate case filing is made in 2015.[77]

- Establish a working group to discuss the inclusion of CHP/recycled energy as a key component of the state's compliance plan with the EPA's Clean Power Plan.
- Consider lowering insurance requirements for interconnection, and removing the additional liability insurance requirement. DOE's Southwest CHP Technical Assistance Partnership (TAP) states that "customers with grid-tied DG systems already carry their own general liability insurance, and the rules already have provisions for indemnification, making the requirement for additional insurance redundant and an extra, unneeded expense."[78] Currently, Colorado utilities determine insurance requirements for CHP systems greater than 2 MW on a case-by-case basis, and insurance requirements are high compared to other states (e.g., $2 million in insurance is required for systems 2 MW or smaller in size). Establishing maximum insurance requirements for larger systems > 2 MW up to 10 MW would be helpful, as well as lowering insurance requirements for smaller systems. For example, some states do not require any additional liability insurance for systems under a certain size threshold.
- Consider establishing standardized interconnection procedures for systems larger than 10 MW. Some states have issued guidance for larger sized systems (> 10 MW) that include parameters for interconnection study requirements, technical requirements, insurance, utility approval timelines, and other guidelines. Colorado should consider establishing interconnection standards for systems greater than 10 MW.
- Study whether to include recycled energy systems larger than 15 MW as eligible under the RES.
- Advocate for the extension of federal tax credits to recycled energy projects
- Consider adopting a state tax credit for recycled energy projects
- Reinstate the State PBF and consider directing funds to a recycled energy incentive program
- Establish an outreach initiative to target good existing candidate sites for recycled energy installations, and provide these sites with necessary resources, including technical assistance and information on available financing and incentives.

TABLE 17: LIST OF KEY BARRIERS AND STATE RECOMMENDATIONS

Key Barrier	Recommendation
Standby rates	Conduct a study of utility standby rates in the state and recommend ways to improve upon existing tariff structures
Environmental permitting and regulatory issues	Consider lowering insurance requirements for interconnection Consider establishing standardized interconnection procedures for systems larger than 10 MW
Lack of recognition of environmental benefits	Establish a working group to discuss the inclusion of CHP/recycled energy as a key component of the state's compliance plan with the EPA's Clean Power Plan
Internal competition for capital	None
Financial risk	Consider new financial incentive programs to encourage the deployment of recycled energy
Access to favorable tax structures	Advocate for the extension of federal tax credits to recycled energy projects Consider adopting a state tax credit for recycled energy projects
Sales of excess power	PUC can assess restrictions in the state on sales of excess power, and recommend potential ways of eliminating unnecessary restrictions
Awareness of available incentives	Establish an outreach initiative to target good existing candidate sites for recycled energy installations, and provide these sites with necessary resources, including technical assistance and information on available incentives

[77] https://www.dora.state.co.us/pls/efi/EFI.Show_Filing?p_session_id=&p_fil=G_146223

[78] DOE, CHP Technical Assistance Partnerships, Southwest. "Colorado, Colorado Policies Affecting CHP." (Accessed June 2015). http://www.southwestchptap.org/states-co.

8 | Summary & Conclusions

Colorado does have some potential for further development of recycled energy systems, which could be enhanced by promulgating some new policies and incentives that include this technology type. ICF identified 108 MW of recycled energy technical potential at 70 sites throughout the state. Roughly 53 percent (58 MW) of the total technical potential are found in systems with capacities greater than 5 megawatts. However, 65 of the 70 sites have a technical potential smaller than 5 megawatts. This indicates that there are fewer candidate sites for large systems than there are for low capacity systems. Concerning utilities, Xcel Energy and Black Hills Energy service territories contain of roughly 60 percent (26 MW and 38 MW respectively) of the entire technical potential capacity. However, Xcel Energy's service territory contains almost 40 percent (27) of the candidate sites within the entire state, making this territory of particular importance for recycled energy potential within the state.

Concerning the economic potential for recycled energy projects, the best applications based on payback expectations are the primary metals and minerals industries. This is likely due to the very high quality and quantity of the heat available from these applications. By utility, Black Hills Energy contains three candidate sites that have a payback under five years. Xcel Energy also has three candidate sites that have a payback under five years. However, 17 of the 20 sites in Xcel Energy's territory have paybacks greater than five years. Overall, 54 percent (57 MW) of the recycled energy technical potential sites exhibit paybacks less than five years. It is important to note that studies have indicated that 50 percent of the market of potential investors will opt out of installing a recycled energy unit if the payback is greater than two years. For Colorado, this means that the market adoption of recycled energy will remain fairly low absent any changes in electricity rates and major incentives.

Based on the technical and economic potential results, Colorado may want to consider adopting some additional incentive programs to encourage recycled energy, and may consider revising current policies and tariffs to better promote this technology. Xcel Energy's new incentive of $500/kW for eligible recycled energy projects, will likely help achieve greater deployment. This program can be supplemented with additional incentive programs in other utility territories or a state-level program. Several innovative CHP programs have proven effective that provide for a few incentive payments throughout the project's implementation, e.g., provide an upfront incentive, one during the construction phase, and a final performance based incentive (CA SGIP, and Maryland EMPOWER program). Colorado may consider adopting a similar CHP incentive program. In addition, the Colorado PUC can carefully assess standby rates in the state, and may consider modifications to these tariff structures to make them more neutral towards distributed generation projects such as recycled energy. A well-designed incentive program applicable to recycled energy projects, along with strategic policy changes can help improve the economic potential for recycled energy in Colorado.

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