

# Recycled Energy Basics and Benefits

Arizona Recycled Energy in Action  
January 26, 2012



U.S. DEPARTMENT OF ENERGY  
**Clean Energy Application Centers**

# U.S. DOE Clean Energy Application Centers (formerly CHP “RAC”s)

Develop regional strategies to support:

- Combined Heat and Power
- Waste Heat Recovery
- District Energy

## 1. Education and Outreach

- Website, workshops, webinars

## 2. Project Specific Support

- Audits, feasibility studies, assistance

## 3. Policy Development

- Regulatory and policy outreach



# Overview

1. Why Recycled Energy
2. Definitions and Technologies
3. Basics and Benefits - Examples
4. Barriers
5. Resources and Contacts



# Why “Recycled” Energy

What do we mean, why do we care



# We Aren't Really Interested in Energy

→ We are interested in Energy **Services**

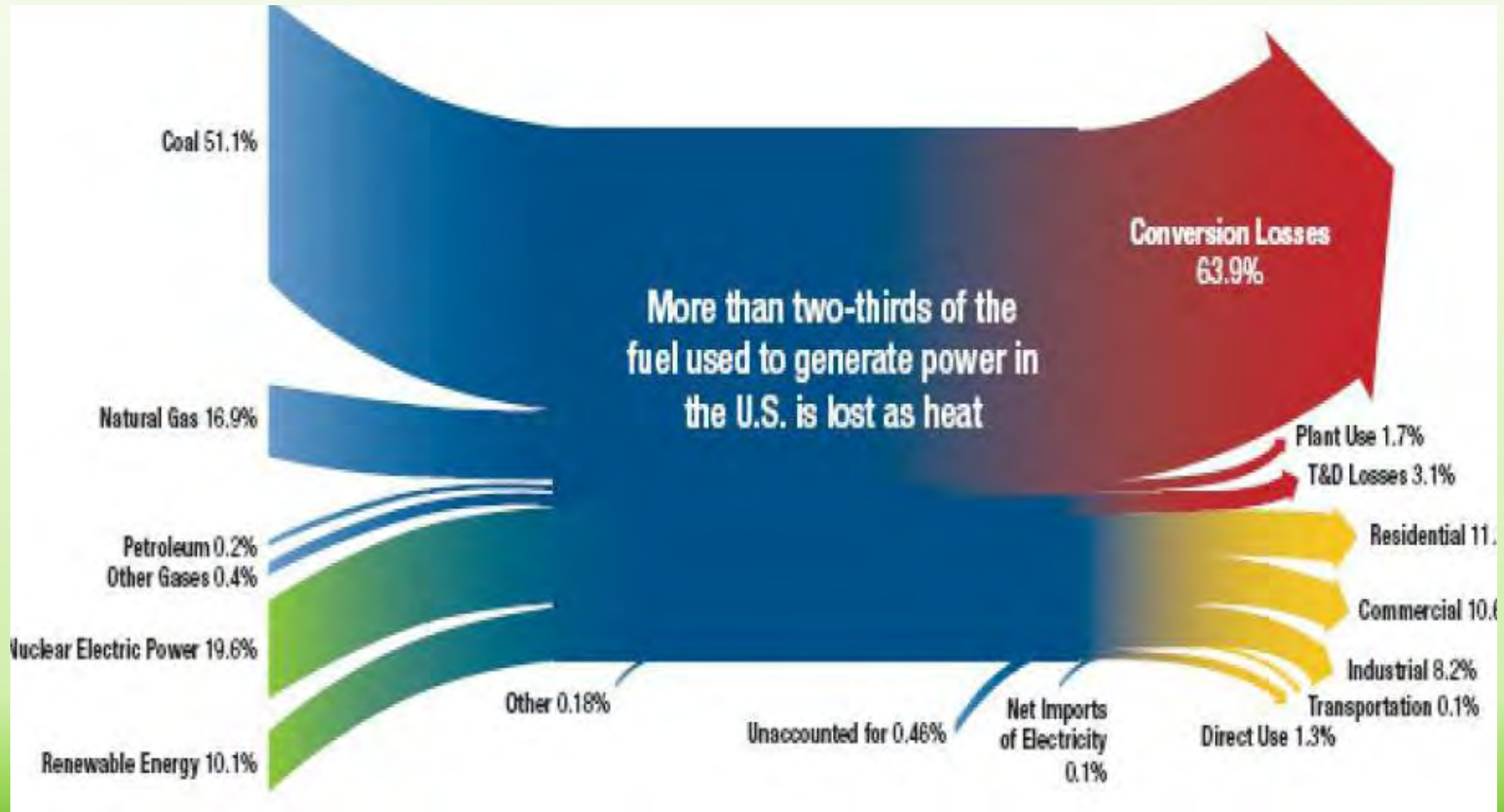
## Source

- Fossil
- Biomass
- Geothermal
- Wind
- Solar
- Nuclear
- etc.

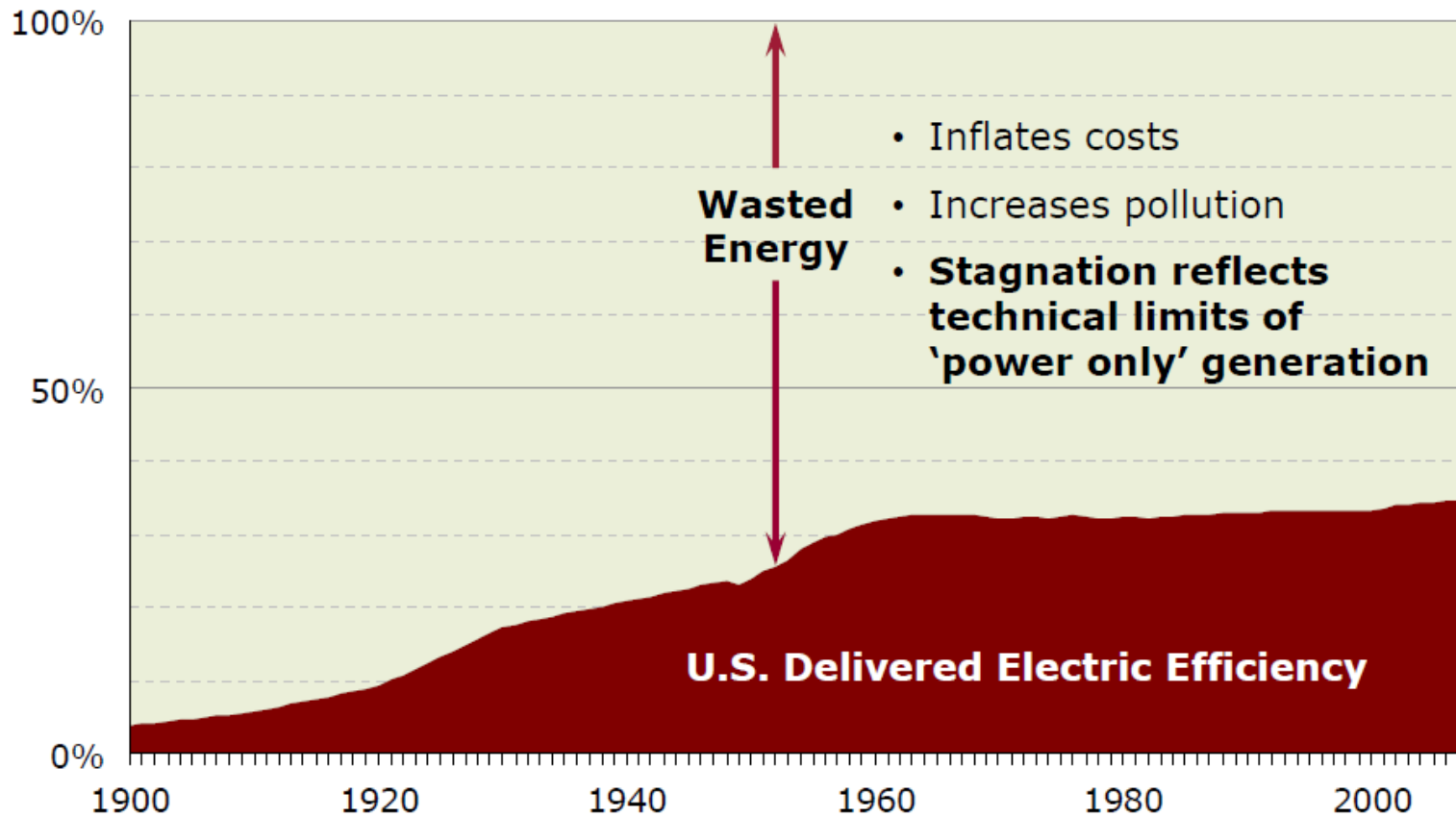
- Heat
- Light
- Cooling
- Work
- Transport

# Our energy infrastructure is very inefficient

- Take the electrical grid for example

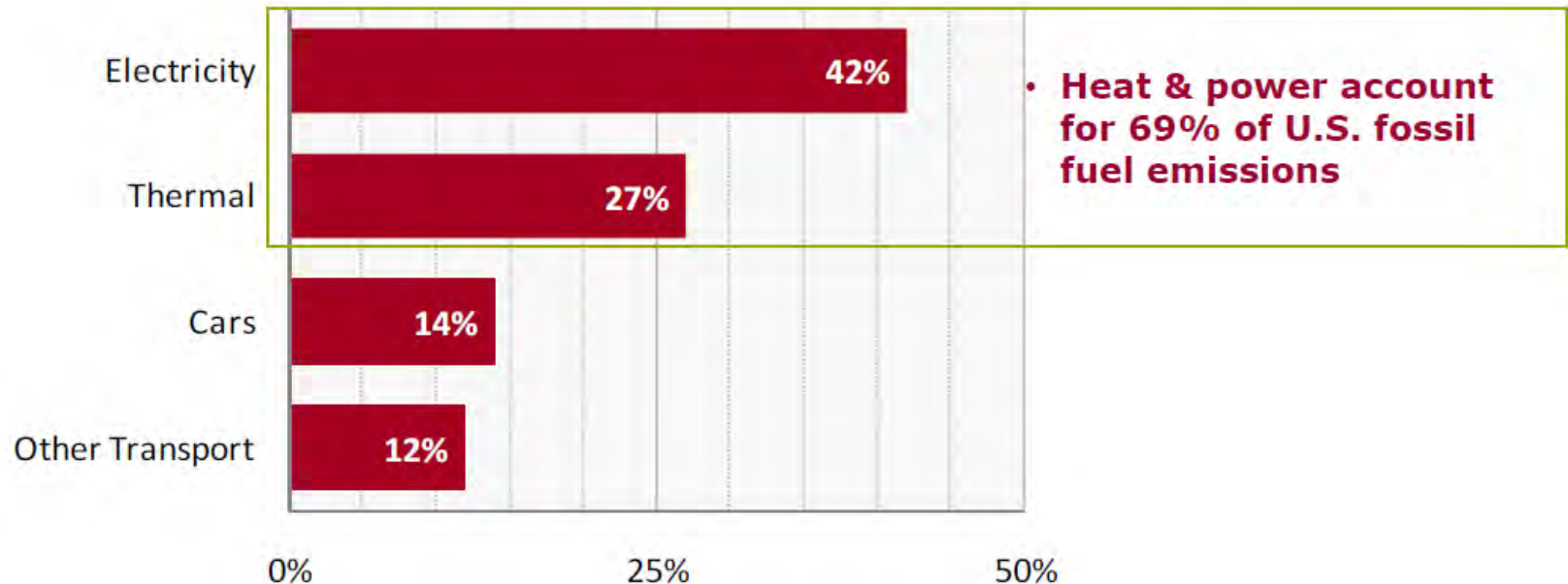


# Not only is generation inefficient, it's stagnant



# Heat and Power are Responsible for Two-thirds of U.S. CO<sub>2</sub>

Emissions of U.S. CO<sub>2</sub> from Fossil Fuels



Source: RED calculations based on data from the U.S. Energy Information Agency and the U.S. Department of Transport

**Much of the waste is caused by our silo approach to energy**

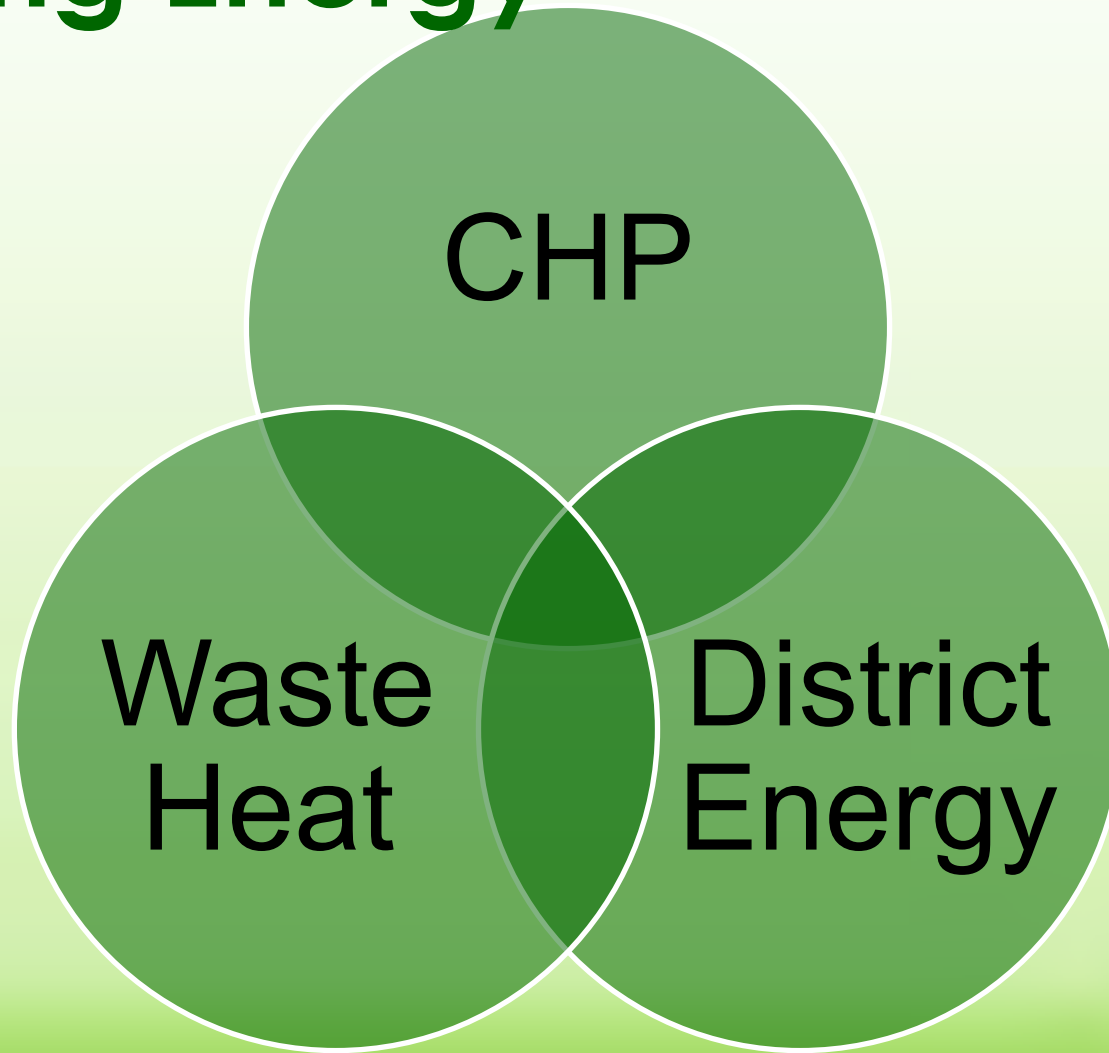


# Recycling energy breaks the silos

- Bypass the power-only efficiency limits
- Integrate systems inside the plant (or campus, building, etc)
  - Electrical
  - Thermal (both heat and cooling)
  - Process



# Recycling Energy

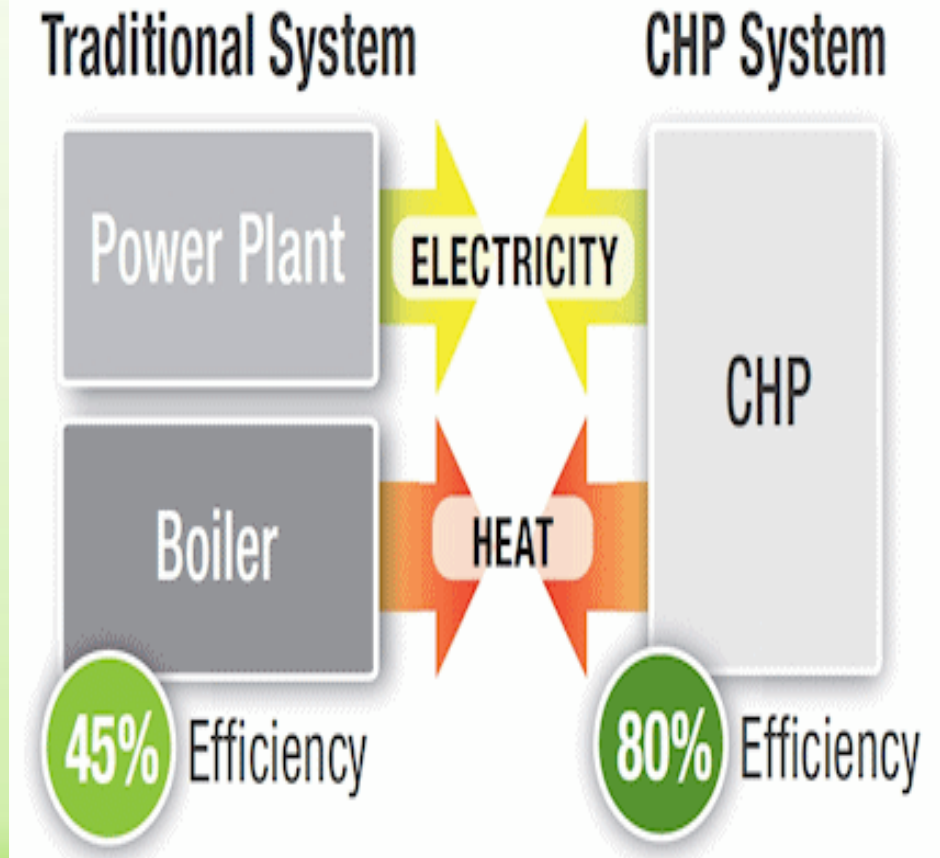


# Definitions and Technologies

What do we do, and how do we do it?



# Combined Heat and Power (Co-generation)



Concurrent production of electrical, mechanical, and/or thermal energy (heat and or cooling) from a single fuel source.

# Waste Heat Recovery

- Capturing waste heat or pressure and turning it into;
  - Electricity (renewable)
  - Mechanical
  - Thermal
- No extra fuel
- No extra emissions



# District Energy

- Central generation of some combo of:
  - Electricity
  - Heating
  - Cooling
- Distribution to:
  - Network of buildings, facilities, processes
- Enables integration/energy recycling



# Key AZ CHP installations

City	Site name	Size (kw)	Prime mover	Fuel
Flagstaff	Wildcat Hill WWTP	292	Eng	Gas/Biogas
Kingman	Kingman Hosp	915	Eng	Gas
Snowflake	Abitibi	70,500	Steam Turb	Coal
Tempe	ASU	16,000	Comb Turb	Gas
Tucson	Tucson Med Center	750	Comb Turb	Gas
Tucson	U of AZ	14,000	Comb Turb	Gas
Tucson	Tucson Dist Heating	1,800	Eng	Gas
Tucson	Ina Rd WWTP	4,200	Eng	Gas/Biogas

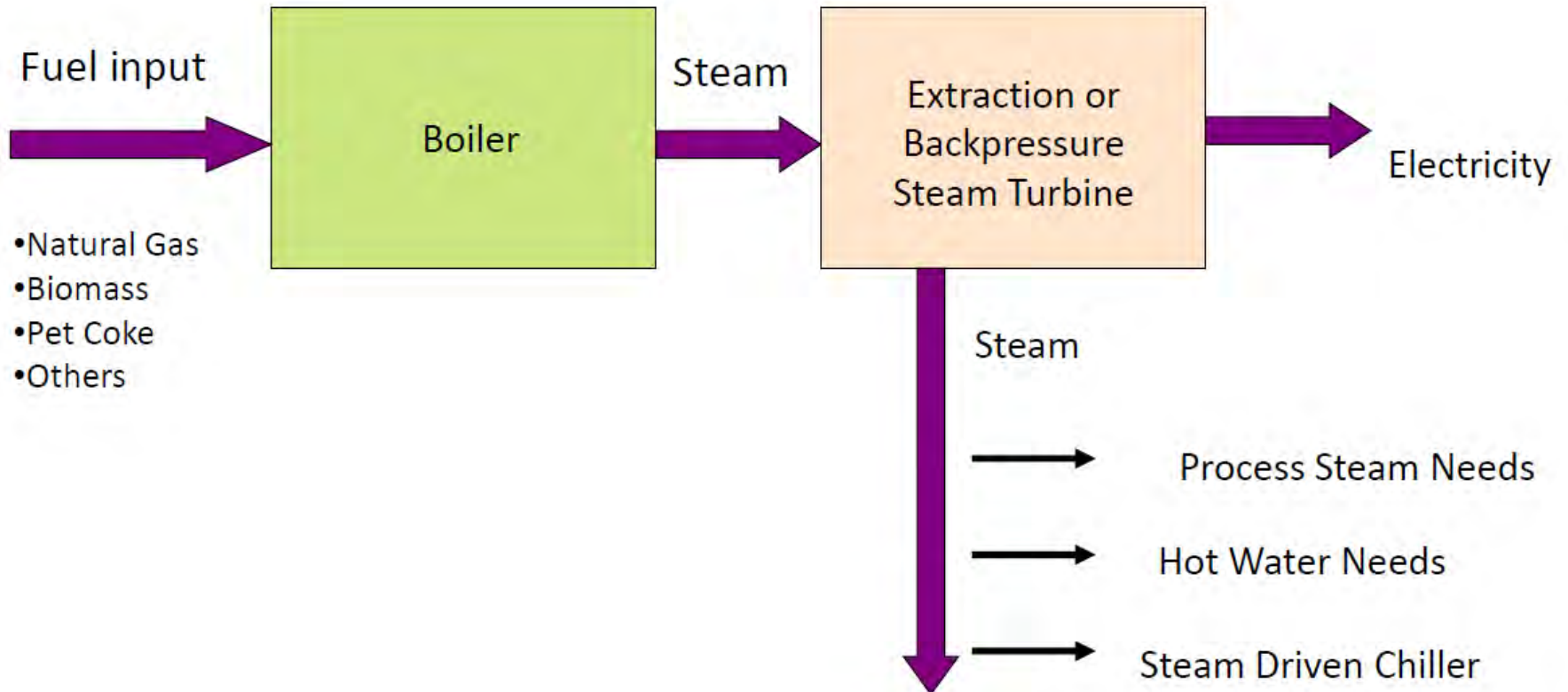


# CHP (co-gen) Terminology

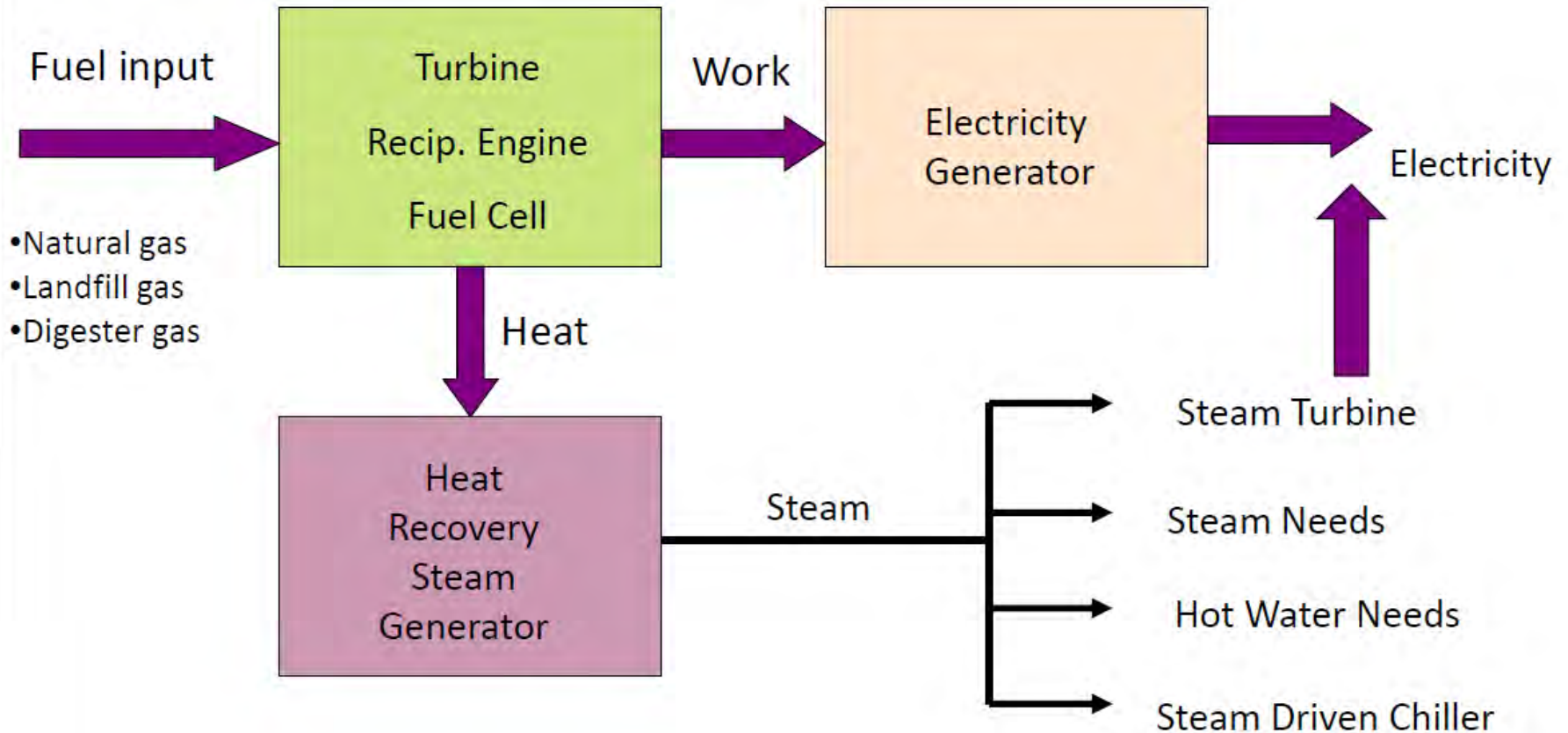
- Topping cycle - Electricity/work then use heat. Classic installation is steam turbine with heat recovery condenser
- Bottoming cycle – Heat first then power typically high temperature operations/stacks, newer low-temp systems are emerging
- Combined cycle (not really CHP) Electricity, heat-recovery=>steam, more electricity (utility gas turbine systems)



# Classic Co-Gen: Boiler/Steam Turbine



# CHP: Fueled Prime Mover



# CHP Technologies -Electrical

- Reciprocating Engines
- Steam Turbines
- Gas Turbines
- Microturbines
- Fuel Cells



# CHP Equipment Types:

## Engines

- 100 kW to 2,000 kW
- Electrical efficiency: 24-38%
- Heat produced: 4-5000 BtuH/kW
- Load-follows well
- Good match for under 200F heating loads



# CHP Equipment Types:

## Gas Turbines

- 250 kW- 50,000 kW
- Electrical efficiency: 24-36%
- Heat produced: 5-6,000 BtuH/kW
- A little more heat, a little less electricity
- Better match for steady base loads
- Good match for steam heating loads
- Lower capital and operating cost than engines



# CHP Equipment Types:

## Steam Turbines

- 200 kW to 10,000 kW
- Electrical efficiency: 15-40%
  - Condensing higher, backpressure lower
- Heat produced: Varies widely
- Load-follows well
- Good match for existing steam system or when fuels are combusted in boiler (Need high pressure steam.)



# CHP Equipment Types:

## Microturbines

- 30 kW to 1000 kW
- Electrical efficiency 25-30%
- Heat produced 6-7,000 BtuH/kW
- A little more heat, a little less electricity than turbines or engines
- Good match for hot water heating loads
- Higher capital cost per kW, similar operating cost to engines



# CHP Equipment Types:

## Fuel Cells

- 5 kW to over 1,000 kW
- Electrical efficiency: 33-60%
- Heat produced: Varies
- No combustion, very low emissions
- Very expensive: 3 times capital cost of engines/turbines



# CHP Applications

- Two major characteristics of favorable applications for CHP
  1. High electric costs compared to CHP fuel cost (Large “Spark Spread”)
  2. CHP waste heat is usable through nearly all the year



# CHP Applications

- Electric rate structure determines operating strategy
  - High demand, low energy → peak shaving
  - Lower demand, high energy → baseload
- Use the wrong strategy, get lower savings



# CHP Applications

- For example:
- APS 32L, APS 34, TEP LGS13 are all baseload rate structures
- TEP LL14 is a peak shaving structure



# CHP Applications

- Assuming \$4.50 gas, and 100% heat utilization, simple paybacks of 4.5-7 years are achievable under these 4 rates for large APS and TEP customers



# CHP: Emissions Reduction

	CHP	Grid Power	Base Thermal	Emission reduction	% reduction
NOX (tons/yr)	1.40	14.99	2.21	15.8	92%
SO2 (tons/yr)	0.02	9.89	0.01	9.88	100%
CO2 (tons/yr)	4,463	6,256	2,582	4,475	50%
Carbon (mton/yr)	1,103	1,547	638	1,082	28%
Number of cars removed				723	
EPA CHP Partnership CHP emissions calculator <a href="http://www.epa.gov/chp/basic/calculator.html">http://www.epa.gov/chp/basic/calculator.html</a>					

# Waste Heat “Technologies”

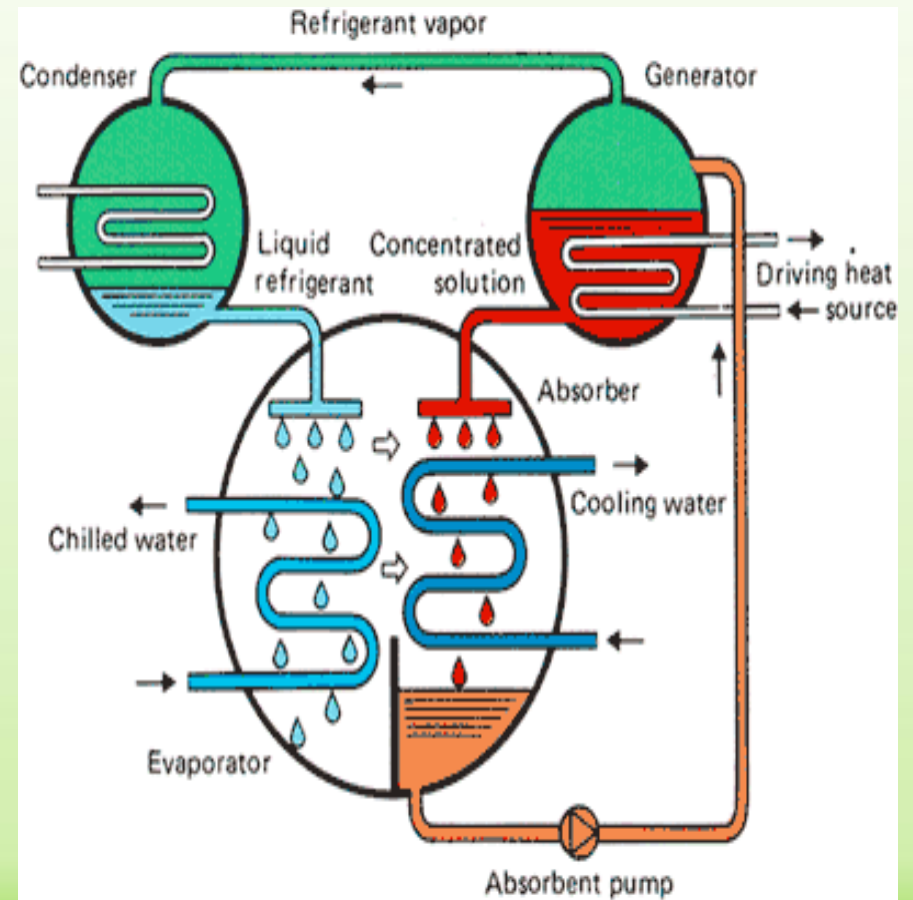
## - Simplest to most complex

- Recycle back into same process
- Recycle into other process
- Transport to other process/location
- Waste heat to power
- Back pressure turbine



# CHP/Waste Heat Technologies

- Heat Exchanger / Heat Recovery
- Heat Recovery Steam Generators (HRSG)
- Absorption Chillers
- ORC Generators
- Back Pressure Turbines



# Waste heat example

## - Trailblazer Pipeline Heat to Power

- Natural gas pipeline compressor station
- Two 14,500 hp gas turbines
- 900 F exhaust gas
- Organic rankine cycle heat to power
- 4.5 MW turbine
- 70% capacity factor
- Export power to 12,47 kV line
- Energy Output 27,600 MWh/yr



# Waste Heat Economics

- Yearly savings \$600,000
- Pipeline owner is paid for heat
- Estimated 20-yr savings of \$10 million
- Joint project by:
  - Co-op (Highline Electric Association)
  - G&T (Tristate Generation and Transmission)
  - Pipeline owner (Kinder Morgan)
  - Project developer/equipment supplier (Ormat)



# Waste Heat: Emissions Reductions

	Savings
CO <sub>2</sub>	27,600 tons/yr
NO <sub>x</sub>	34,500 kg/yr
SO <sub>2</sub>	124,200 kg/yr
Renewable energy credits used to meet RPS requirement (Colorado)	

# Recycled Energy Benefits

## ○ For owners

- Improved fuel efficiency
- Reduced cost
- Enhanced energy security
- Improved power quality & reliability
- Improved energy cost predictability

## ○ Global

- Reduced emissions per unit of useful output
- Reduced water use
- Reduced land use impacts
- Creation of new-high tech jobs
- Improved grid economics



# Barriers

Well, if recycling energy is so great, why don't we do more?








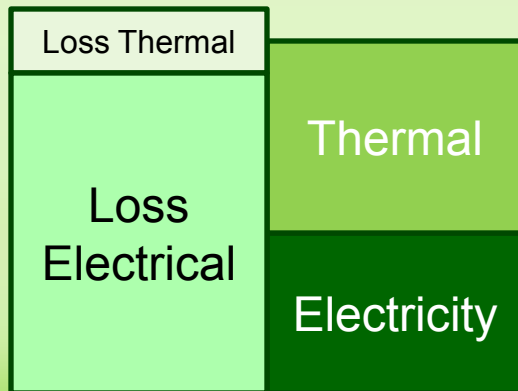
# Barriers to Recycled Energy

- Economic “playing field” is different for consumers and utilities
- Misaligned costs and benefits
- High transaction costs for projects
- Policy and regulatory structures don't recognize benefits

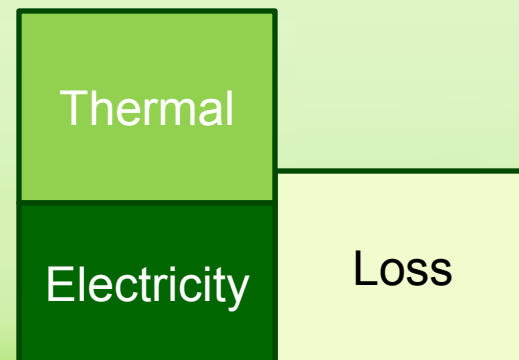


# Example of Economic Disconnect

	Electric Utility Sells	Owner Buys	Gas Utility Sells
Baseline	\$373,000 	\$373,000 and \$222,000 	\$222,000 
CHP		\$411,000 	\$411,000 



Baseline (45 %)



CHP (70 %)



# Barriers – Gory Details

- **Interconnection** delays, costs, inconsistencies
- **Standby charges** from the utility
- **Air regulations** that don't recognize benefits
- **Environmental permitting** (non-standardized, time-consuming)
- **Complex local ordinances** (siting, zoning, fire code, etc...)
- **Volatile natural gas prices** and "spark spread"
- **Facility managers unaware** of the benefits
- **Lack of a tax depreciation category** (multiple categories depending on config, period ranging from 5-39 years)
- **Utilities' lack of experience** (lack of data/models/analysis tools for evaluating DG, lack of practices for incorporating DG into electric system planning and operation)



# Resources and Contacts

Our goal is to promote energy efficiency.

We provide information and technical assistance to end users,  
regulators and policy makers



# What We Actually Do

- Inform prospective end users on the benefits, business models, & resources available for their specific application
  - Workshops, trainings, webinars, guides, websites, advice
- Help potential projects “take the next step”
  - Free project feasibility screenings
  - Help on permitting issues, tariffs/rate assessments, equipment questions, convincing upper management, 3<sup>rd</sup> party review of proposals...
- Promote CHP as an effective clean energy **policy** solution:
  - Educate state policymakers and regulators, remove barriers



# Technical Assistance for Potential Projects

**1.**  
PRE-SCREEN /  
SITE QUALIFICATION

**2.**  
LEVEL 1  
SCREENING ANALYSIS

**3.**  
LEVEL 2  
CONCEPTUAL & FINANCIAL

**4.**  
LEVEL 3  
INVESTMENT GRADE ANALYSIS

**5.**  
PROCUREMENT, OPERATION,  
& MAINTENANCE

- We provide free Pre-Screening, Level 1 Analyses, and Level 2 Analyses
- We advise businesses on all other steps



# Information Examples

- Basic info
- Market-specific applications
- Policies & regulations
- Installations and contacts
- Project profiles
- Technical reports/studies
- Evaluation tools
- News & events
- Presentations



**PROJECT PROFILE**

**Trailblazer Pipeline**  
4-MW Waste Heat Recovery System

**Site Description**

The 430-mile Trailblazer natural gas pipeline winds through parts of Wyoming, Colorado, and Nebraska. The pipeline is

**Quick Facts**

LOCATION: Near, Colorado  
MARKET SECTOR: Pipelines  
FUEL: None (uses heat only)  
INSTALLATION YEAR: 2008  
AVERAGE CAPACITY FACTOR: ~70%  
ENERGY OUTPUT: 27,000 MWh per year  
% OF FACILITY LOAD: None  
EQUIPMENT: Other organic Rankine cycle  
USE OF ELECTRICAL ENERGY: Renewable energy for Highline Electric Association members  
ESTIMATED YEARLY SAVINGS: Over \$10 million  
JOINT PROJECT W/TH: Highline Electric Association, Tri-State Generation & Transmission, Kinder Morgan, and Ormat  
ENVIRONMENTAL BENEFITS: 27,000 tons of CO<sub>2</sub>, 34,000 kg of NO<sub>x</sub>, and 124,200 kg of SO<sub>2</sub>



**PROJECT PROFILE**

**Kennecott Utah Copper Smelter**  
32-MW Waste Heat Recovery System

**Quick Facts**

LOCATION: Salt Lake County, Utah  
MARKET SECTOR: Primary metals  
SMELTER SIZE: 300,000 tons of copper anodes produced annually  
EQUIPMENT: waste heat boilers, heat recovery system, steam turbine generator  
ELECTRIC CAPACITY: 32 MW nameplate, 65-85 MW average  
PERCENT OF FACILITY LOAD: ~50%  
WASTE HEAT SOURCE: Smelter exhaust, acid plant  
IN OPERATION SINCE: 1995  
ENVIRONMENTAL BENEFITS: Pollution-free electricity from waste heat, improved energy efficiency

**Site Description**

Kennecott Utah Copper, a subsidiary of Rio Tinto, produces copper, silver, gold, molybdenum and sulfuric acid. It is the second-largest copper producer in the U.S., providing about 25 percent of the country's copper needs.

The copper smelter is the key facility that processes copper concentrate through heat and oxidation in furnaces, into 99.9% copper metal called anodes (which are then transported to the nearby refinery to be processed into copper cathodes and sold to customers). The smelter produces about 300,000 tons of copper anodes per year.

**Reasons for Waste Heat Recovery**

The smelter has re-designed and modernized in 1995 to be among the lowest-emission smelters in the world, and a pollution-free, waste-heat-to-power generation system was a key component of the modernization. The Kennecott Utah Copper smelter has the highest level of energy recovery of any smelter in the world.

Since the copper production process is energy intensive and energy is a key component of Kennecott's costs, the company strives for continual improvement in how it manages, generates, and uses energy. Based on forecasts of rising energy costs, the company determined that it would be a wise long-term investment to generate power from thermal energy that would otherwise be wasted. The company's on-site engineers continue to improve the system design to optimize the energy output and reliability.

**Over 100 Project Profiles**



# [www.intermountaincleanenergy.org](http://www.intermountaincleanenergy.org)



U.S. DEPARTMENT OF ENERGY

## Intermountain Clean Energy Application Center

Promoting CHP, District Energy, and Waste Heat Recovery

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[Project Profiles](#)

[Events](#)

[Resources](#)

### Policy Success

In Utah, recycled energy is eligible for the Renewable Portfolio Goal.



In Colorado, recycled energy is eligible for the Renewable Portfolio Standard.

In Arizona, recycled energy is eligible for the Energy Efficiency Resource Standard.

In New Mexico, recycled energy is eligible for tax incentives.

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**Combined Heat and Power (CHP) is...** generating electricity right near where it will be used, and then recycling the thermal energy for heating or cooling. It's very efficient, it already supplies 10% of our nation's energy, and it can and should supply more.

**District Energy is...** CHP, heating, and/or cooling for an entire university, office park, medical campus, mixed use sustainable development, or downtown. Over 400 building networks in the U.S. already use district energy, and the number is on the rise.

#### News

**JULY 13 - UTAH RECYCLED ENERGY IN ACTION**

Free Webinar: Biomass CHP, June 30, 12pm MDT

New National Project Profile Search Tool

Don't Miss Out: \$700-800 per kW Incentives for CHP in Arizona

More REAP Grants for CHP and Waste Heat

White House Energy Plan Recognizes CHP (and us)

Utah's 10-Yr Energy Plan Includes Waste Heat Recovery

Recycled Energy Adds Jobs and Strengthens Manufacturing in New Mexico

Utah Gov: EE and Tech Initiatives Can Power Utah's Future

[E-NEWSLETTER >](#)

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# Contacts

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# Thank you!

Patti Case  
Christine Brinker  
Tom Broderick  
Lin Alder



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