Report on Co-utilization of Coal and Mixed Scrap Plastics via Syngas Production with Carbon Capture, Utilization, and Storage

March 24, 2022

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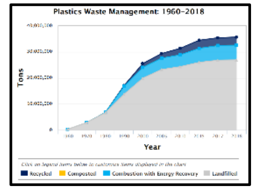
USEA United States Energy Association BATTELLE

Acknowledgements

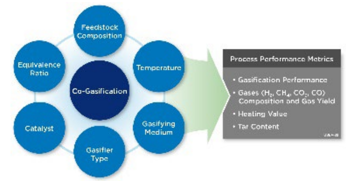
Project funded by United States Department of Energy (USEA) under Cooperative Agreement # DE-FE0031812 with the U.S. Department of Energy - Office of Fossil Energy and Carbon Management

Overview

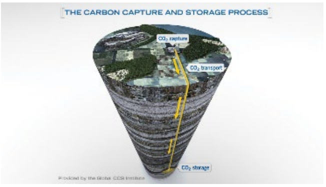
- Introduction



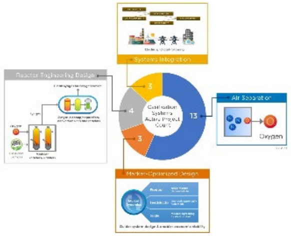
- Co-gasification as a Potential Solution



- Carbon Capture Utilization and Sequestration

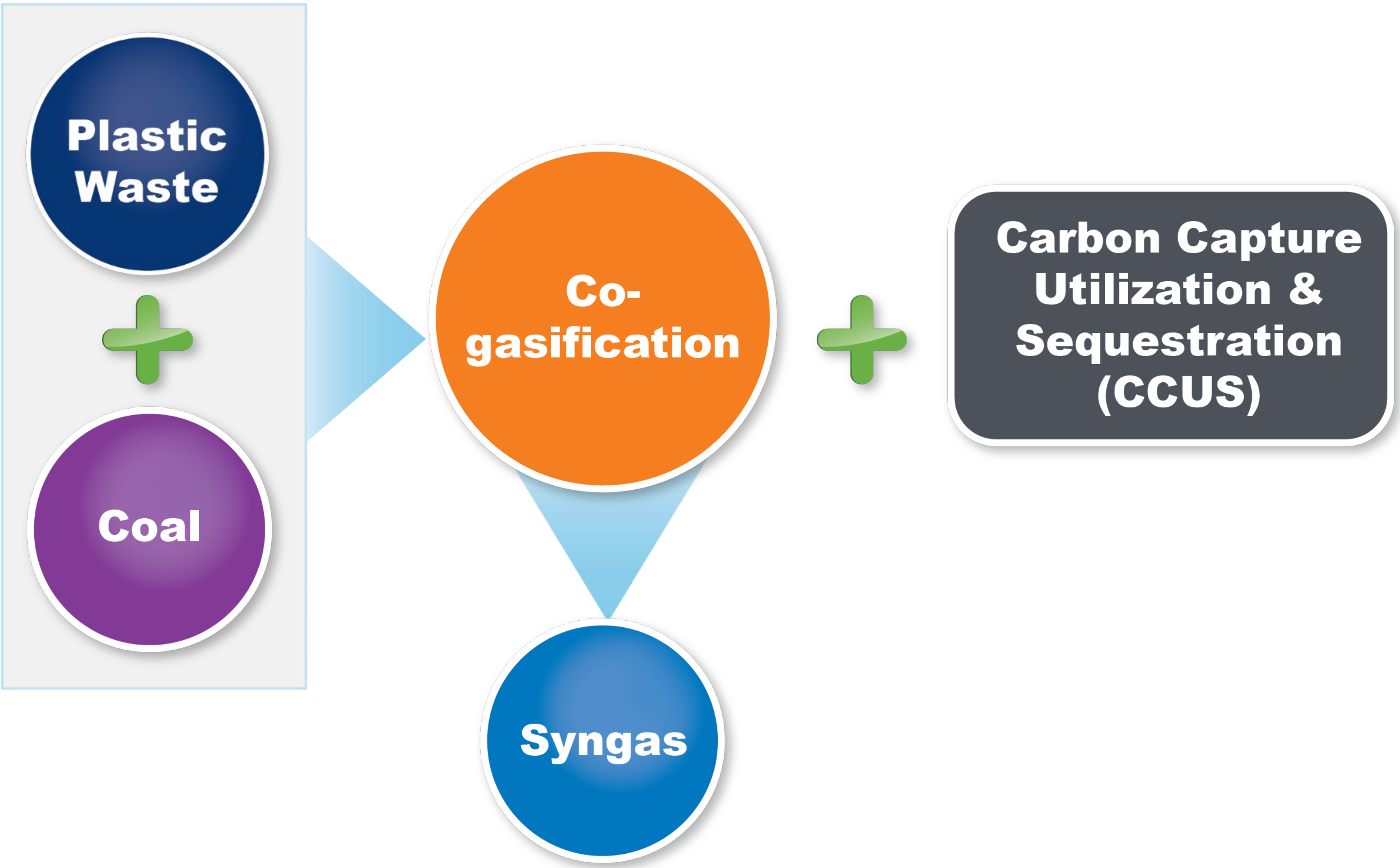


- State-of-the-Art and Future Steps



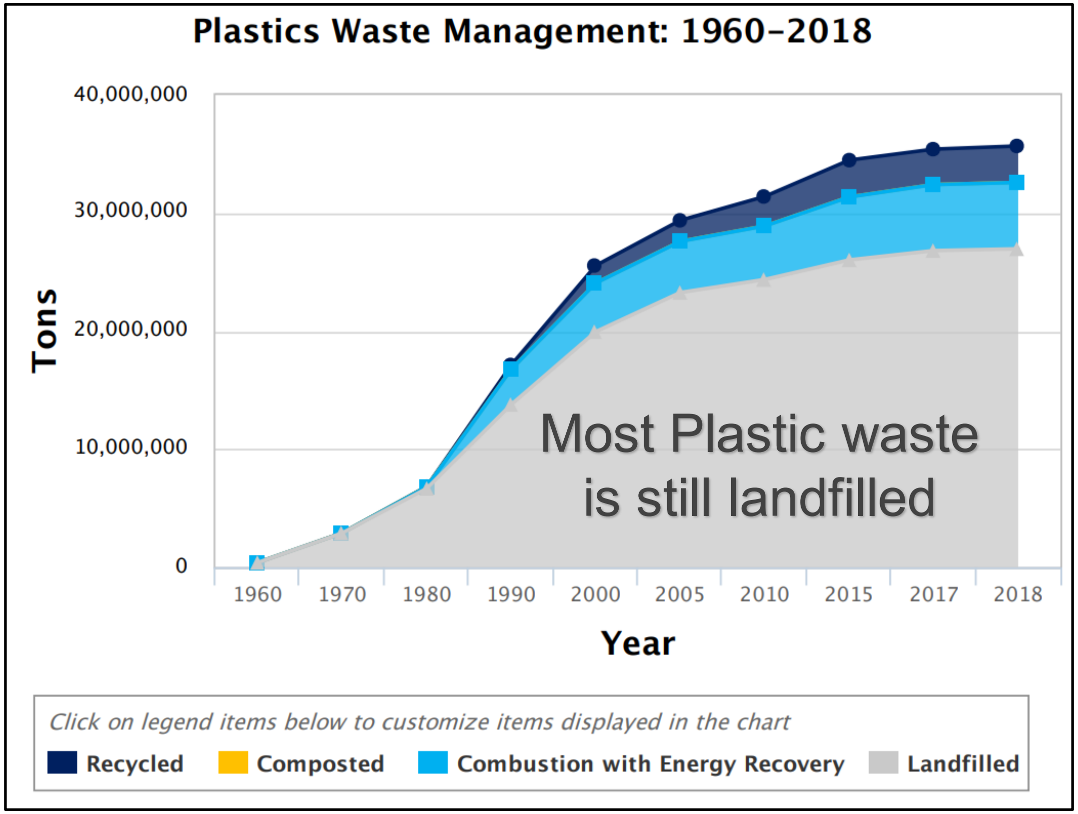
Introduction

Stage-Setting and Goals



Introduction
Problem Description

- Growth in plastics continues with packaging as a significant and growing contributor
- We have made progress, but plastic is still seen as waste product and not a valuable resource

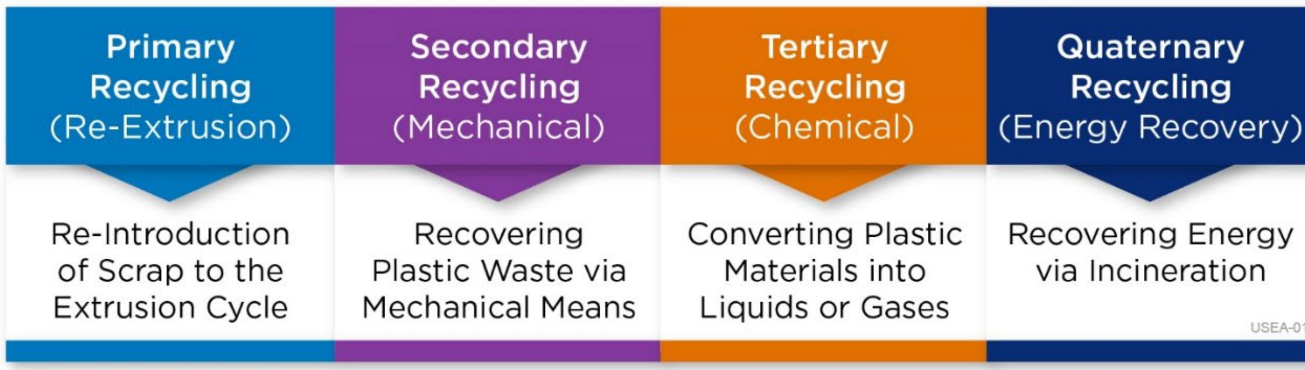


Introduction
Problem Description

- Need a fundamental conceptual shift from “plastics are waste” to “plastics are valuable resource”
- Progression from linear to circular typically happens in stages
- The US currently recycles only 8.7% of plastics

Introduction

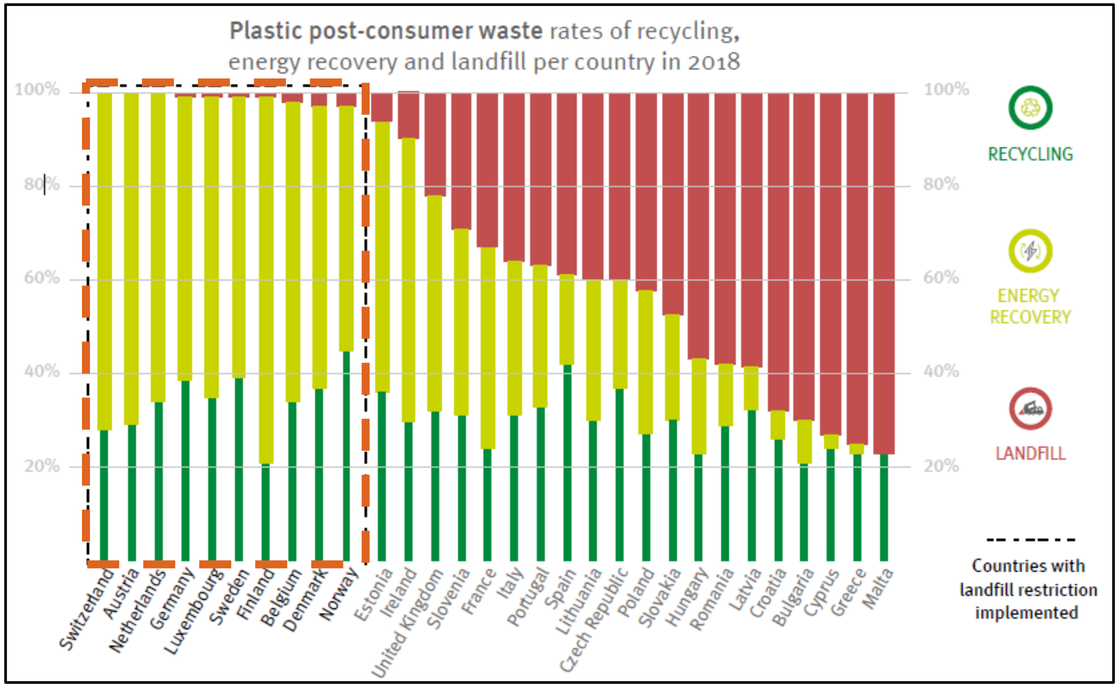
Problem Description

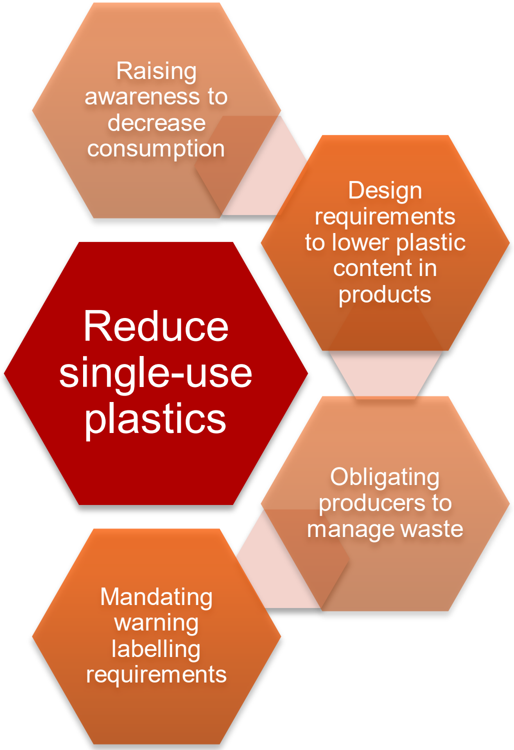


- Primary recycling can only be done with clean scrap
- Secondary recycling is limited to single polymer plastics and is energy intensive
- Tertiary recycling uses gasification and other processes to create syngas – more complicated but creates higher value products
- Quaternary recovers energy from the plastic by incineration – potential emissions issues

Global Strategies for Plastic Waste

- EU, Japan have stringent restrictions on PSW disposal and advocate circular plastics economy.
- EU directive to reduce use of single-use plastics and their landfilling.





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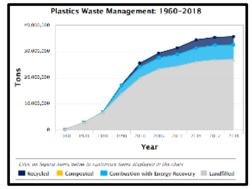

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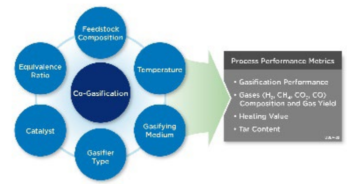

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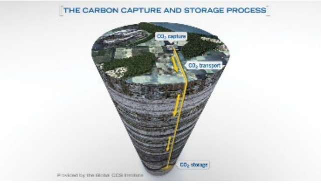

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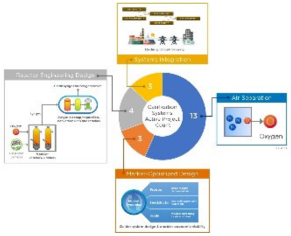

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Co-Gasification as a Potential Solution
Background

Gasification

- Chemical recycling treatment technology
- Pure plastic feedstock
- High calorific value, low moisture, low ash content of plastics desirable
- Operational problems that chokes equipment

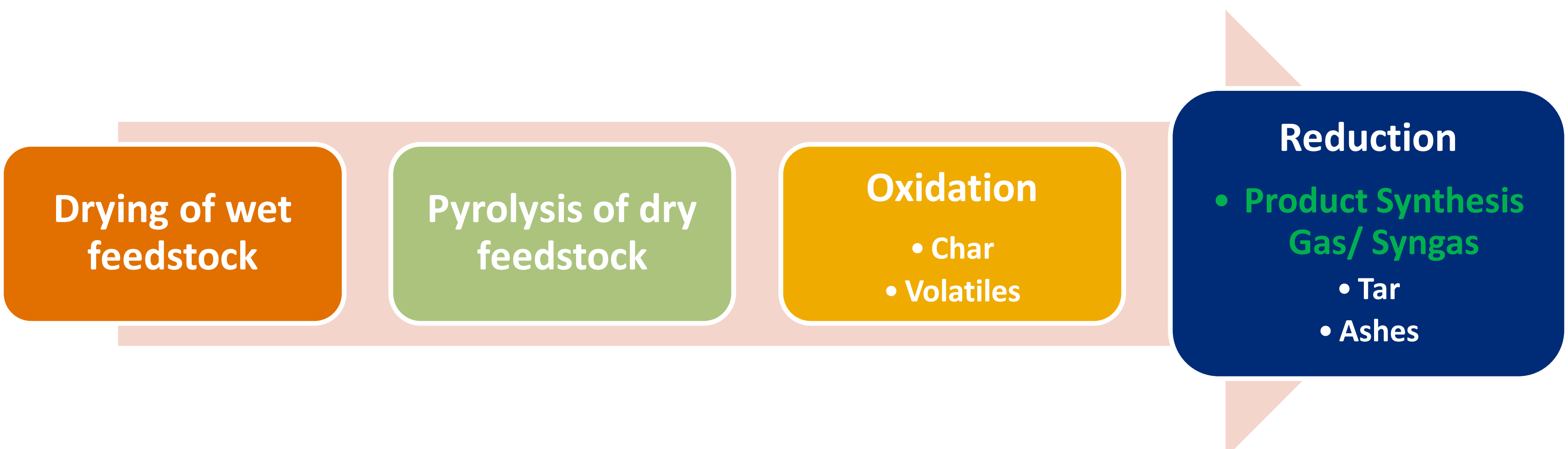
Co-gasification

- Chemical recycling treatment technology
- Mixed, various feedstock options
- Control product gas specification by blending plastics with other carbonaceous feedstock
- Emerging versatile technology

Co-Gasification as a Potential Solution

Technology Description

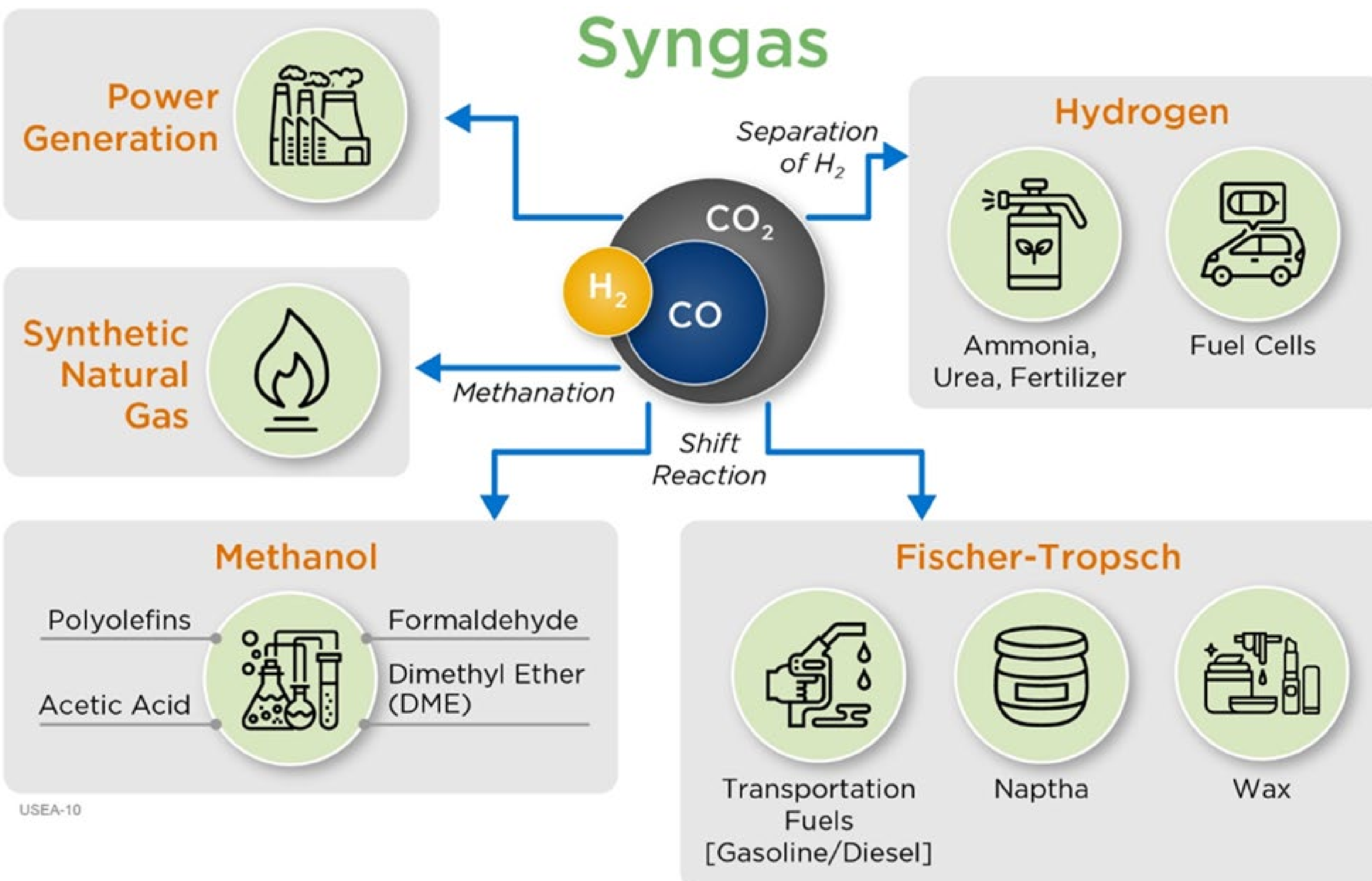
- Plastic waste can be added to mature technologies such as coal (and/or biomass) gasification without major changes to the process.
- Co-gasification has been studied by researchers at the laboratory and pilot scales for the utilization of wastes with coal and biomass.
- Main operations involved:



Co-Gasification as a Potential Solution

Versatile Syngas Product

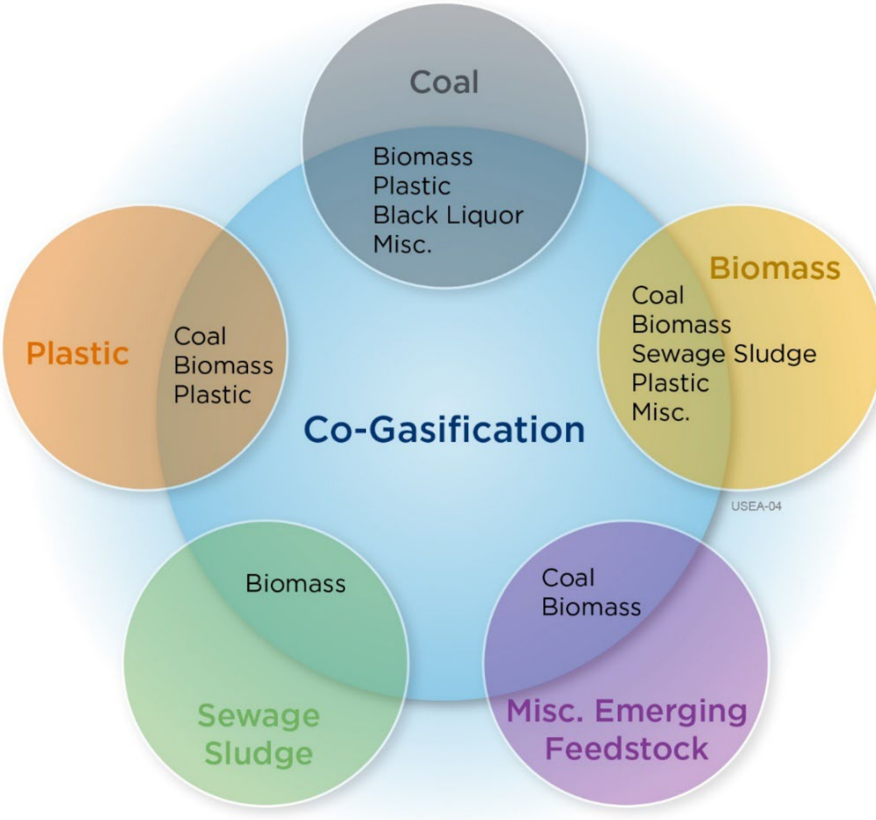
Syngas is a fundamental building block for versatile applications.



Co-Gasification

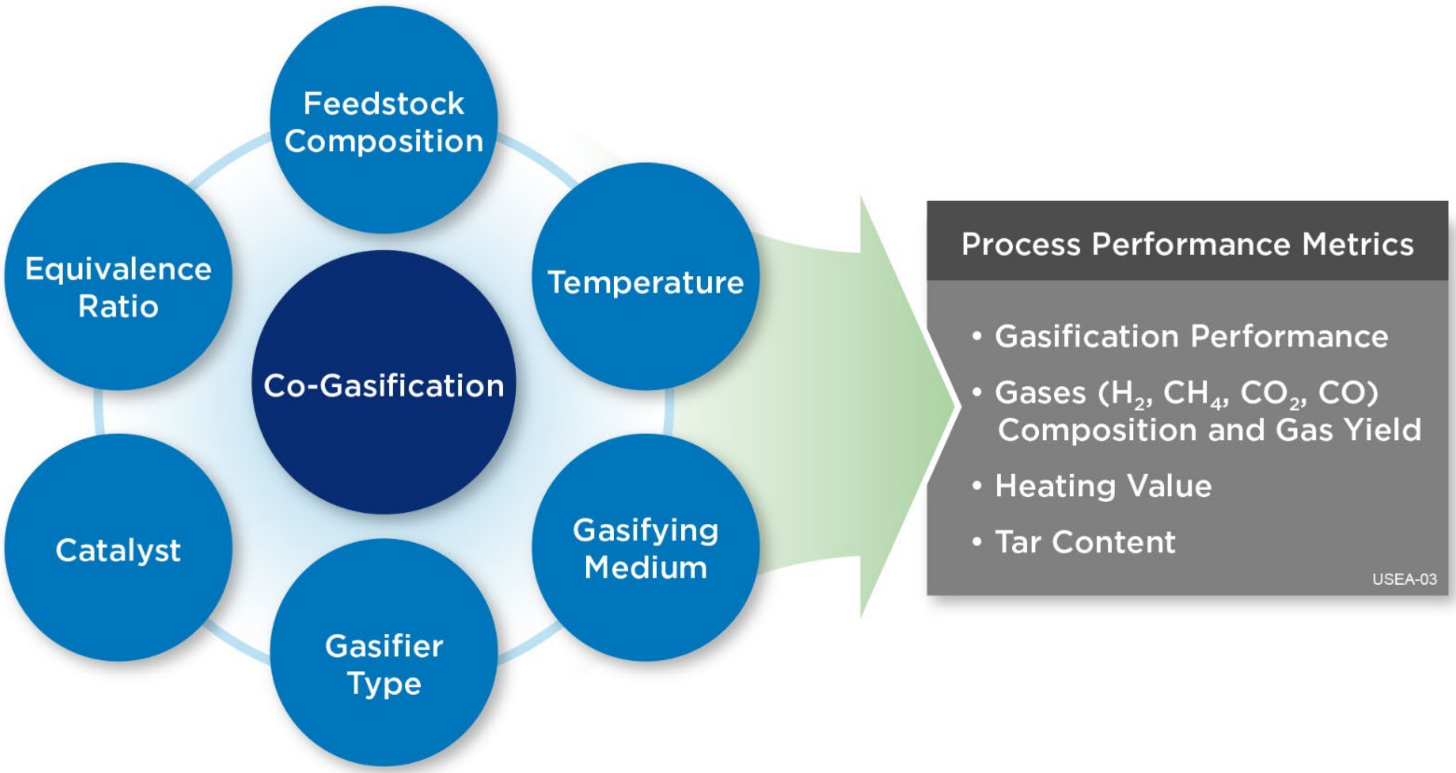
Feedstock Combinations

Process versatility and potential synergies with different feedstock combinations has encouraged the study of plastic waste co-gasification.



Co-Gasification
Process Parameters

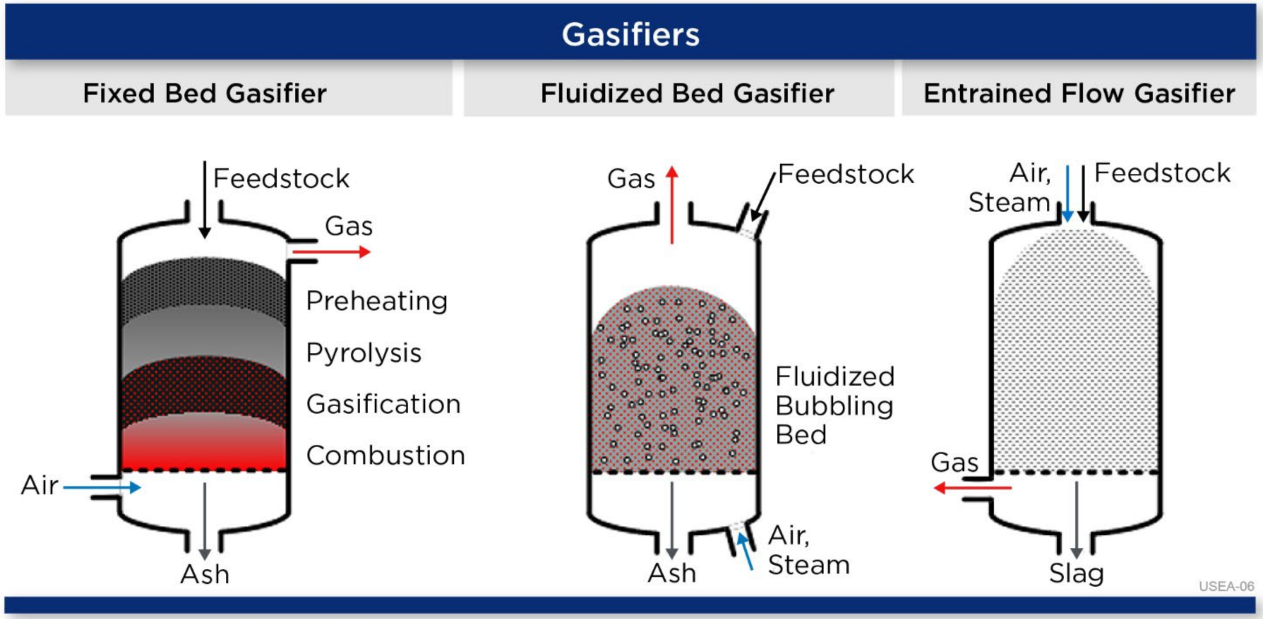
Process parameter conditions drive product yield and gasification performance.



Co-Gasification

Gasifier Types

Co-gasification of coal and biomass has been sufficiently demonstrated globally using all three types.



- Simple design
- Primarily used for small-scale applications
- Low tar formation typical

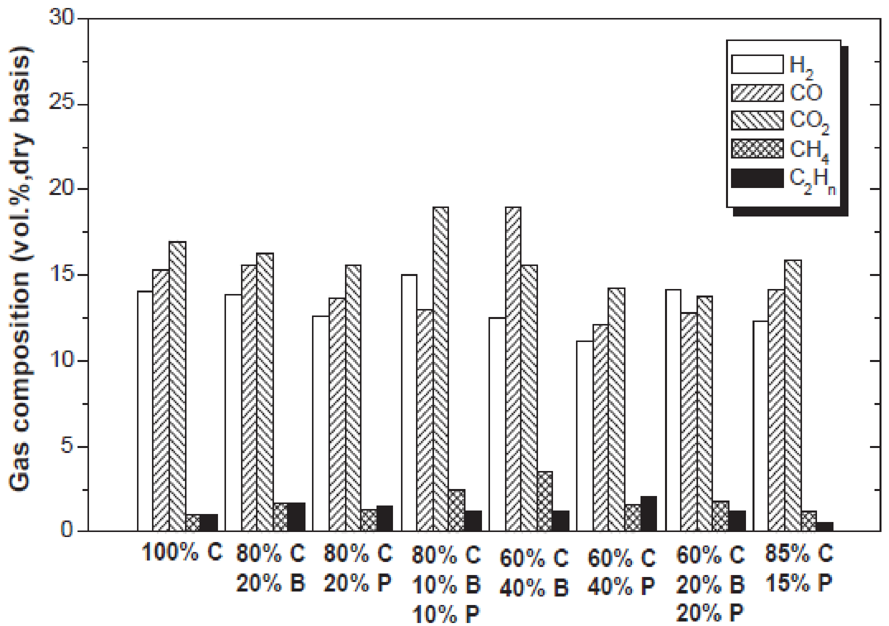
- Widely used for plastic gasification
- Suitable for large-scale applications
- Require mixed uniform size feed

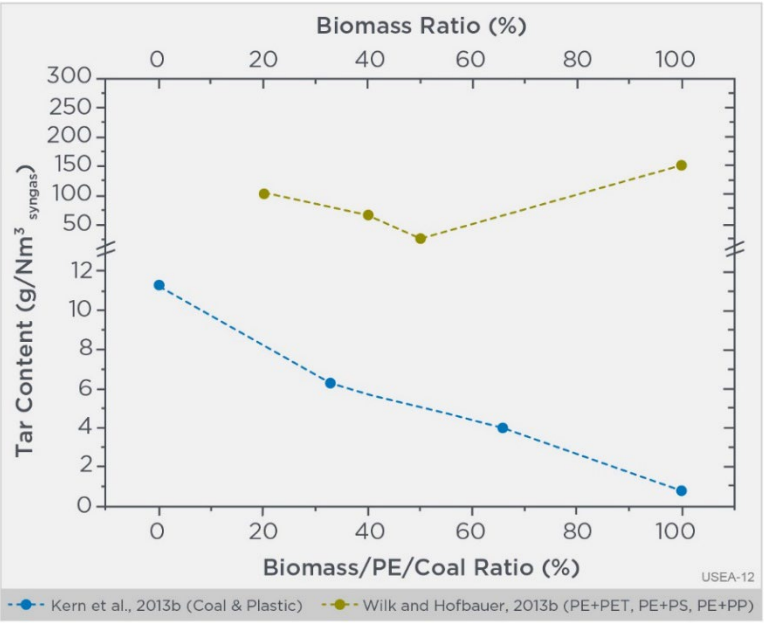
- Can handle varying moisture content
- Suitable for large-scale applications
- Short residence time and small particle size typical

Co-Gasification

Effect of Feedstock Blends

Example investigation of the effect of feedstock blends on performance metrics such as gas composition and undesirable tar content.





Co-Gasification

Key Research Findings

- In general, a high H_2 content and heating value, low char yield and tar content, and high gas yield is desirable.
- Optimal process considerations typically depend on the use of the exit gas (product synthesis gas).
- The H/C ratios in plastics and lignite played an important role in the synergistic effect in co-gasification.

Feedstock/Blend Ratio	Gasifier Type	Temperature	Catalyst/Bed Material	Gasifying Agent	Syngas Quality	Co-Gasification Performance	Reference
Coal (60 wt.%), biomass (20 wt.%), plastic (20 wt.%)	Air gasified bubbling fluidized bed (BFB) reactor	850°C	Silica sand with dolomite catalyst	Air	H_2: 7–15% CO: 10–20% CO_2: 14–23% CH_4: 2–10%	Gas yield: 3 m^3_n/kg feedstock Tar: < 0.5 g/Nm^3	(Aznar et al., 2006)
Coal (60 wt.%), pine (20 wt.%), PE plastic (20 wt.%)	Fluidized bed	850-900°C (890°C)		Air/Steam	H_2: 39.8 vol% CO: 17.3 vol% CO_2: 20.4 vol% CH_4: 14.9 vol%		(Pinto et al., 2003)
Coal, PE plastic	Dual fluidized bed	850°C	Olivine bed material	Steam	H_2: 40.4–49.4 vol% CO: 20.3–29.5 vol% CO_2: 3.6–12.9 vol% CH_4: 4.4-15.6 vol%	Tar: 0.8-11.2 g/Nm^3	(Kern et al., 2013)
Coal, plastics, wood **Coal (50 wt.%), mixed plastics**	BFB	850°C	Quartz sand bed material	Oxygen-enriched air	H_2: 13.8 vol% CO: 19.3 vol% CO_2: 16.3 vol% CH_4: 6.0 vol%	Tar: 13.5–21.8 g/Nm^3	(Mastellone, Zaccariello, & Arena, 2010)

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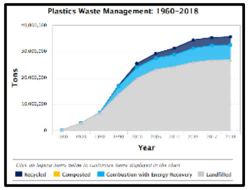

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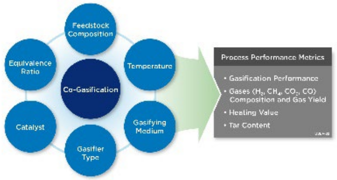

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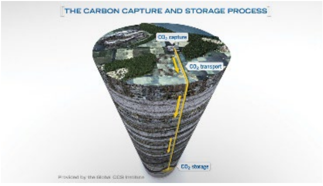

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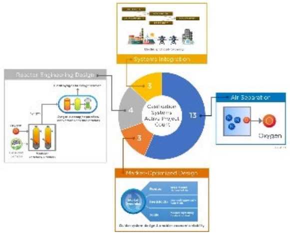
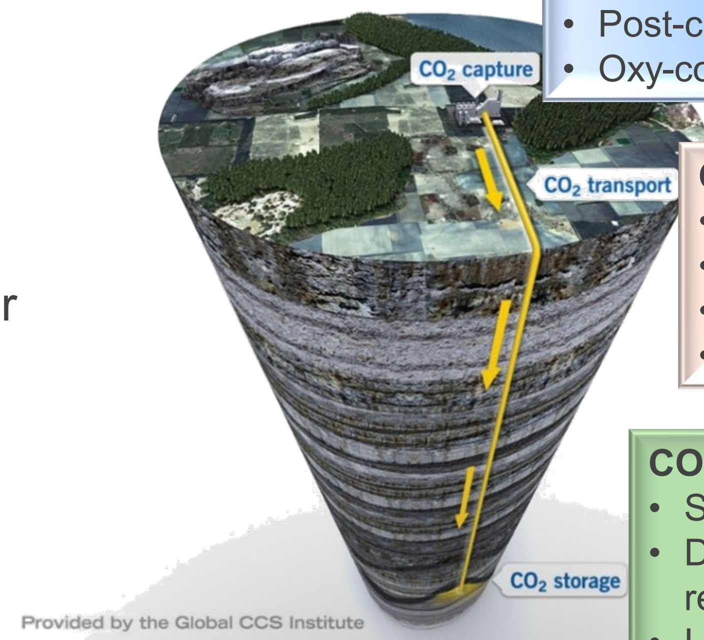


Carbon Capture Utilization and Sequestration

Plastics co-gasification facilities would release significant amounts of CO_2.

CCUS = Economic Benefit + Environmental Benefit

Coupling a CCUS system enables CO_2 removal and redirects it either to a process that utilizes the CO_2 or into permanent geologic storage.



CO_2 Capture:
- Pre-combustion
- Post-combustion
- Oxy-combustion

CO_2 Transport:
- Pipeline
- Truck
- Rail
- Ship

CO_2 Storage:
- Saline Formations
- Depleted oil and gas reservoirs
- Un-mineable coal seams

Carbon Capture Utilization and Sequestration

Well-established commercial implementation of flue gas capture and geologic storage spans multiple decades.

Estimates of CO_2 Stationary Source Emissions and Estimates of CO_2 Storage Resources for Geologic Storage Sites

RCSP or Geographic Region	CO_2 Stationary Sources		CO_2 Storage Resource Estimates (billion metric tons of CO_2)								
	CO_2 Emissions (million metric tons per year)	Number of Sources	Saline Formations			Oil and Gas Reservoirs			Unmineable Coal Areas		
			Low	Med***	High	Low	Med***	High	Low	Med***	High
BSCSP	115	301	211	805	2,152	<1	<1	1	<1	<1	<1
MGSC	267	380	41	163	421	<1	<1	<1	2	3	3
MRCSP	604	1,308	108	122	143	9	14	26	<1	<1	<1
PCOR*	522	946	305	583	1,012	2	4	9	7	7	7
SECARB	1,022	1,857	1,376	5,257	14,089	27	34	41	33	51	75
SWP	326	779	256	1,000	2,693	144	147	148	<1	1	2
WESTCARB*	162	555	82	398	1,124	4	5	7	11	17	25
Non-RCSP**	53	232	--	--	--	--	--	--	--	--	--
Total	3,071	6,358	2,379	8,328	21,633	186	205	232	54	80	113

Source: U.S. Carbon Storage Atlas – Fifth Edition (Atlas V); data current as of November 2014

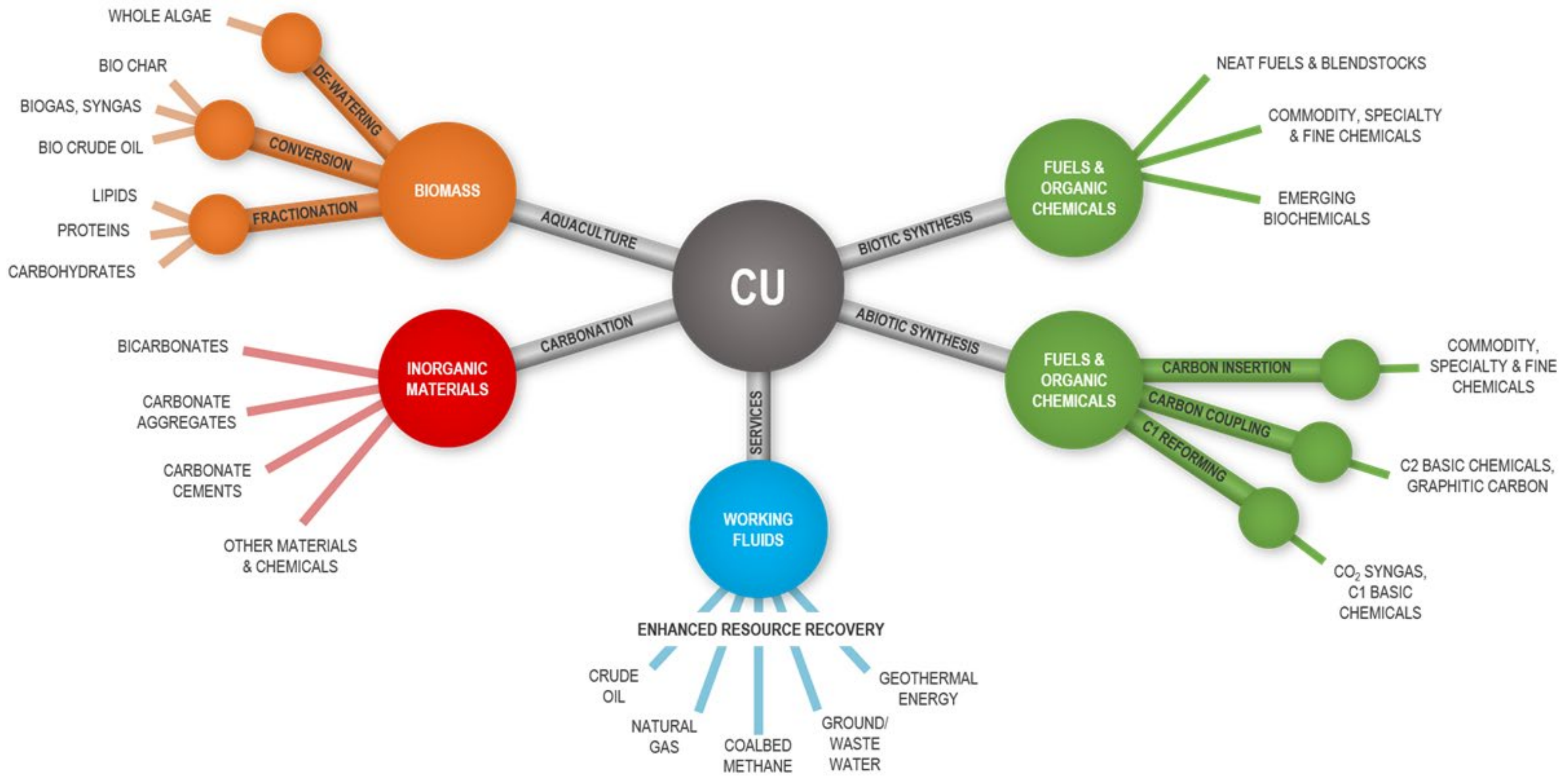
* Totals include Canadian sources identified by the RCSP

** As of November 2014, "U.S. Non-RCSP" includes Connecticut, Delaware, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, and Puerto Rico

*** Medium = p50

Carbon Capture Utilization and Sequestration

Numerous established and emerging technologies could provide additional pathways to new products using the CO_2 captured from plastics co-gasification.



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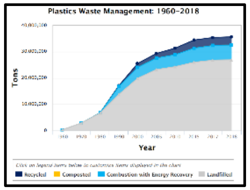

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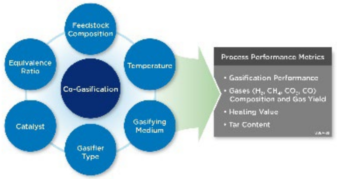

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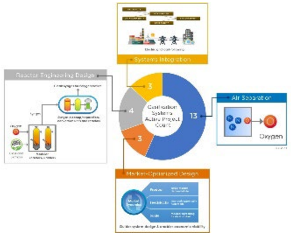
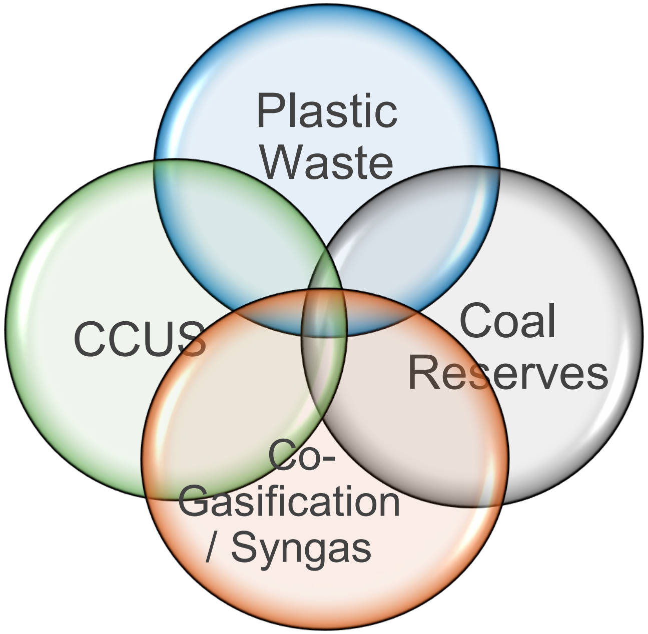
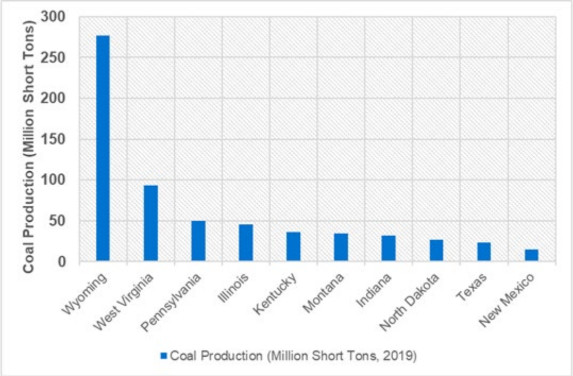
- State-of-the-Art and Future Steps



State-of-the-Art and Future Steps

Resource & Market Potential



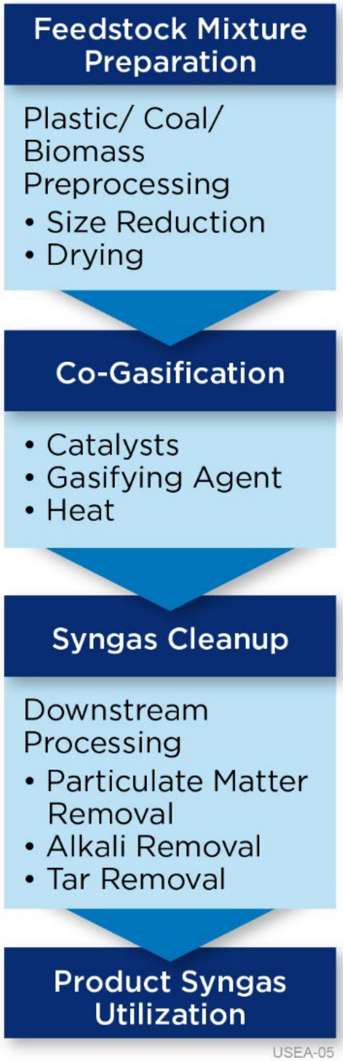


- Abundance of plastic waste – Only 8.7% recycled in 2018
- States with coal reserves can use plastic waste for co-gasification
- Co-gasification resulting in a versatile product syngas
- Coupling co-gasification with a CCUS to reduce GHG emissions

State-of-the-Art and Future Steps

Technical Challenges

- Feedstock preparation and post-processing cleanup operations.
- More complex due to combination of multiple feedstocks



State-of-the-Art and Future Steps

Non-Technical Challenges

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State-of-the-Art and Future Steps
Existing Facilities

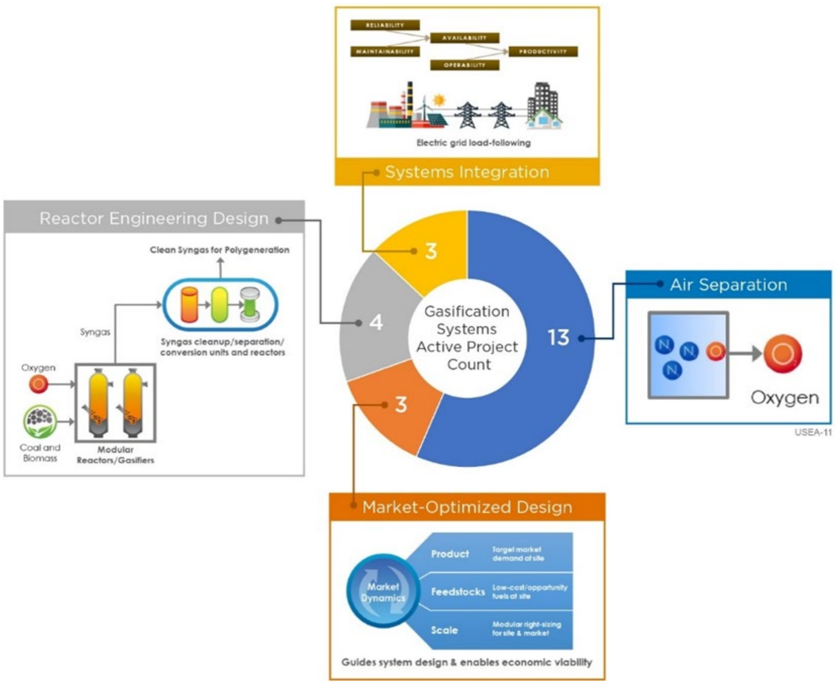
Operational facilities around the world with plastics feedstock component

Company	Project Name, Location	Status	Plant Capacity	Feedstock	Output
Sierra Energy	FastOx Pathfinder, Fort Hunter Liggett, California, USA	Operational since 2018	10 tonnes per day gasifier capacity	MSW and biomass	Electricity and Fischer-Tropsch Diesel (FTD)
Fulcrum	Sierra Biofuels Plant, Reno, Nevada, USA	Construction completed in July 2021; full operations in Q4 2021	480 tonnes per day	MSW	Synthetic crude for transportation fuels
JGC Group	Showa Denko plant, Kawasaki, Japan	Operational since 2003	192 tonnes per day	Plastic waste	Syngas for chemical products like ammonia
Enerkem	Enerkem Alberta Biofuels, Edmonton, Alberta, Canada	Operational since 2017	274 tonnes per day (dry)	MSW	Ethanol

MSW- Municipal Solid Waste

State-of-the-Art and Future Steps

Ongoing Research Efforts – DOE/NETL



Adapted from National Energy Technical Laboratory (NETL), 2019

Auburn University (Auburn, AL)
Fluidized Bed Gasification of Coal-Biomass-Plastics for Hydrogen Production

Electric Power Research Institute, Inc. (Palo Alto, CA)
Performance Testing of a Moving-Bed Gasifier Using Coal, Biomass, and Waste Plastic Blends to Generate White Hydrogen

University of Kentucky Research Foundation (Lexington, KY)
Development and Characterization of Densified Biomass-Plastic Blend for Entrained Flow Gasification

University of Utah (Salt Lake City, UT)
Enabling Entrained Flow Gasification of Blends of Coal, Biomass and Plastics

DOE's Office of Fossil Energy and Carbon Management

State-of-the-Art and Future Steps

Policy Framework

Policy framework drivers that support commercialization

- Reframe landfill policies
- Awareness at the City/Municipality-level on PSW management
- Federal/state initiatives can promote use of chemical recycling technologies for PSW
- Government, Coal and Plastic Industry consortiums can promote value recovery; evaluate the use of recylcates instead of virgin plastic

Summary Findings

Untapped Potential in the U.S.

Utilize plastic waste for supplementing syngas production via co-gasification

Plastic waste a revenue source

Value proposition for utilization of coal while managing plastic waste

Co-gasification of plastic waste and coal

CO_2 storage potential

Leverage established CCUS technology for reduced environmental impacts

Gaps in Policy Framework

Reduce single-use plastics and avoid landfilling

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It can be done

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