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Economics of Torrefaction Plants and Businesses Buying Their Products

Heating the Midwest
April 25, 2013
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ACKNOWLEDGEMENTS

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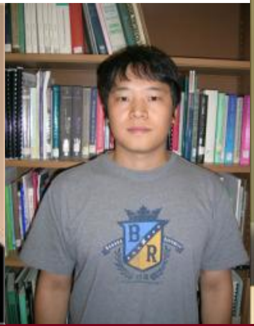
- Nalladurai Kaliyan and Vance Morey of BBE worked on the engineering and life cycle analysis.
- This project utilizes business modeling designed by Carrie Johnson of ApEc. Doug Tiffany and Won Fy Lee performed additional business modeling.



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Today's Discussion:

- Torrefaction is just starting in N. America to serve European markets and uses to make biofuels.
- Focus on economics for torrefaction plants and the purchasers of their products, which are biocoal, off-gasses or steam from combustion of off-gasses
- Analytical Tools and Assumptions
- Regulations Facing Coal Power Plants
- Modeled ROEs for Torrefaction Plants, Coal Power Plants and Ethanol Plants Buying Steam from Off-Gasses
- Presentation of Sensitivity Analysis of ROEs of Torref., Power Plants, Ethanol Plants due to Prices of Inputs, Products, Policy Incentives, Penalties

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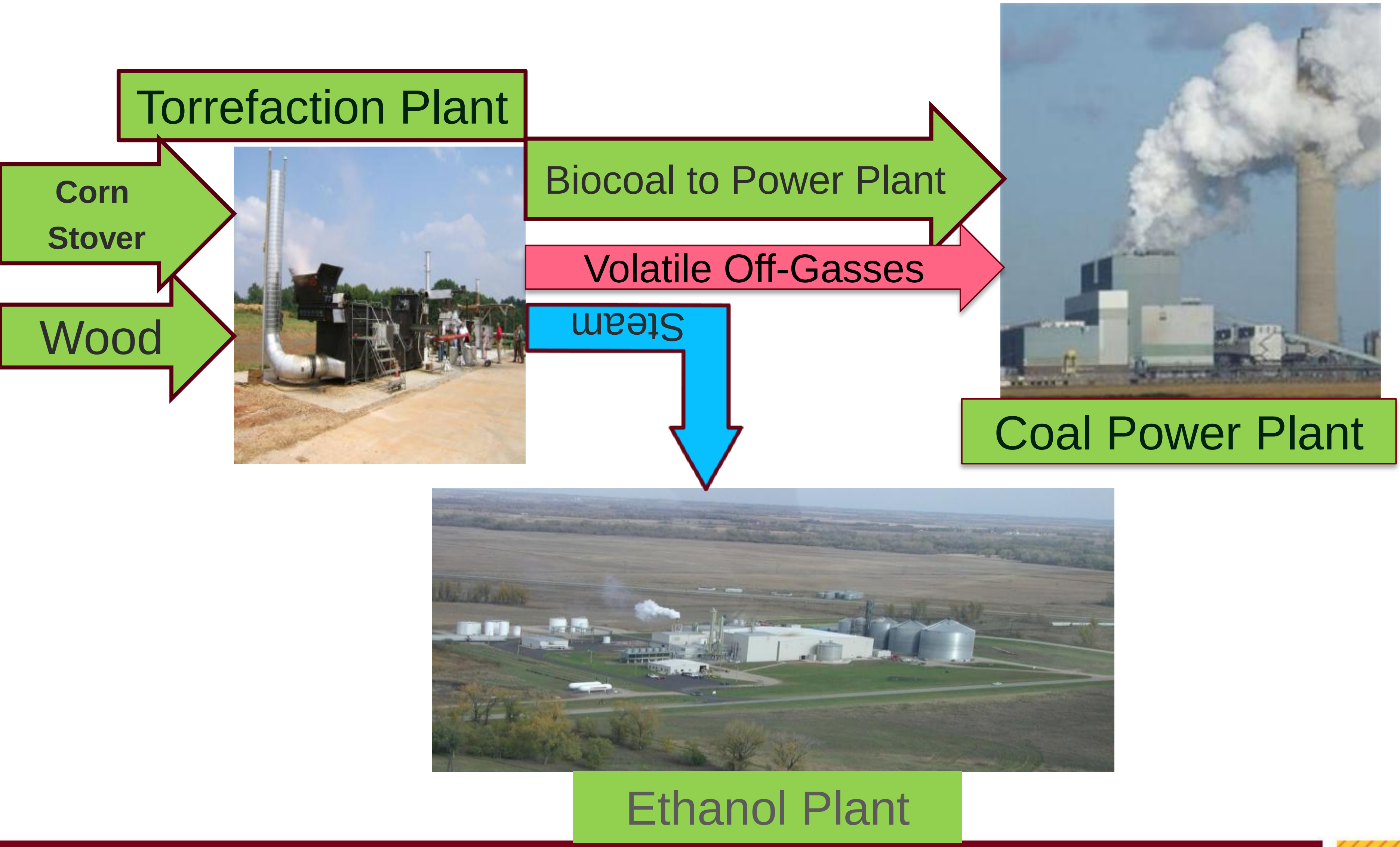
MAJOR FLOWS OF MATERIALS AND ENERGY



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TORREFACTION FOR WOODY OR HERBACEOUS BIOMASS

- Roast biomass at (250-320º C) at near zero oxygen to drive off water and VOCs while degrading hemicelluloses to release the heat needed to drive the reaction
- Depending upon initial moisture of biomass, there may be steam available after pre-drying for other purposes or sales.
- Use of inert gases (like CO_2), prevents combustion from occurring during roasting phase (15 to 20 minutes)
- Brittleness of densified torrefied biomass facilitates grinding at power plants.
- Torrefied biomass can replace coal in combustion or be used as a feedstock for further pyrolysis or gasification.

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TORREFACTION REDUCES MASS MORE THAN ENERGY CONTENT

- Mass lost is 30%--------.70 remains
- Energy lost is 10%--------.90 remains
- Energy density per unit of mass is increased

  .90/.70 = 130%

Source: Energy Research Centre, Netherlands

- Torrsys has developed equipment and tested biocoal.
- In South Carolina, Agri-Tech has designed equipment.
- ECN (Netherlands) has licensed production of their units
- Trade from Maine, Mississippi, Georgia, B.C selling biocoal to Great Britain, Netherlands, and Germany.

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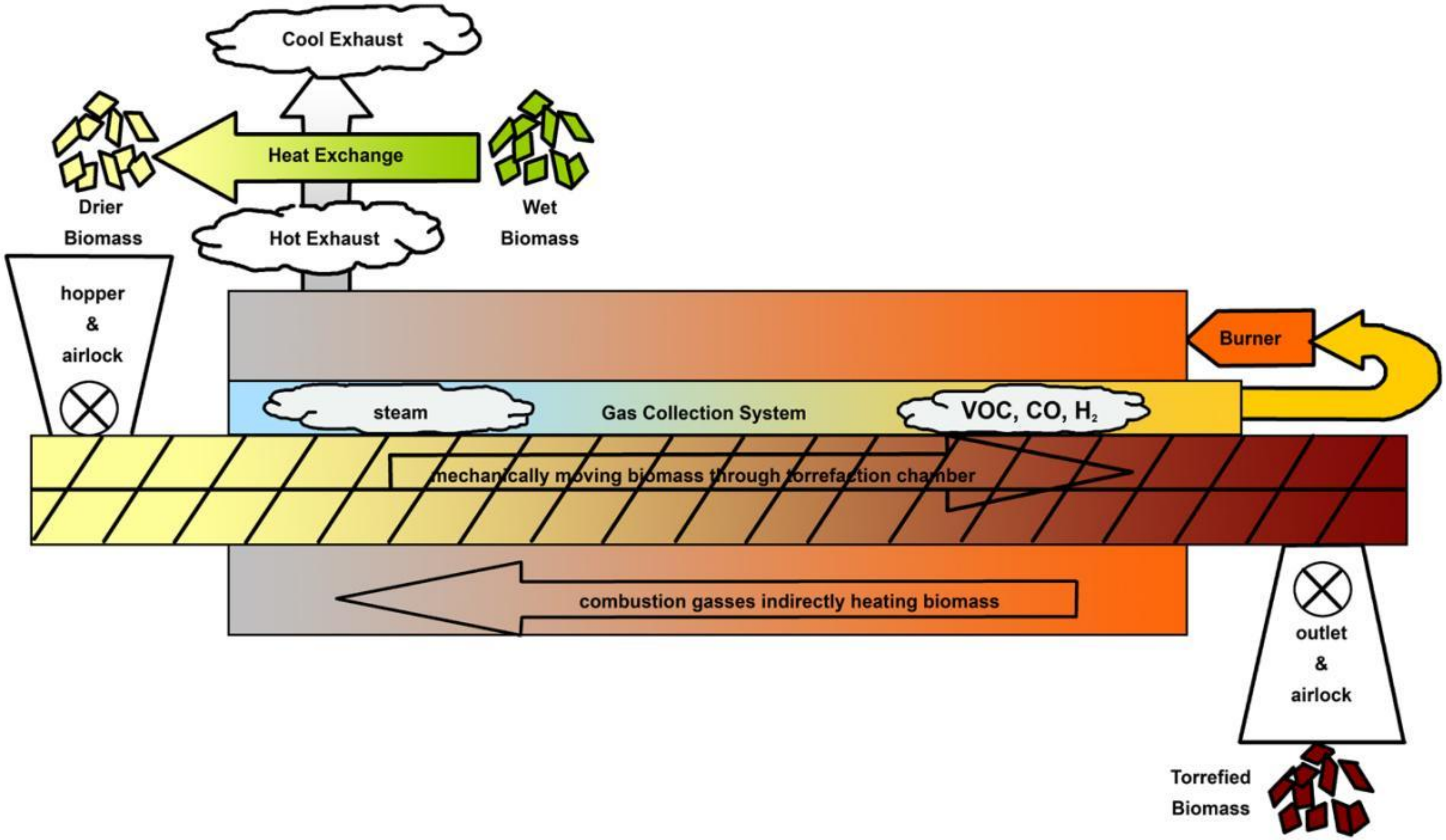
Schematic of Torrefaction Unit by Agri-Tech



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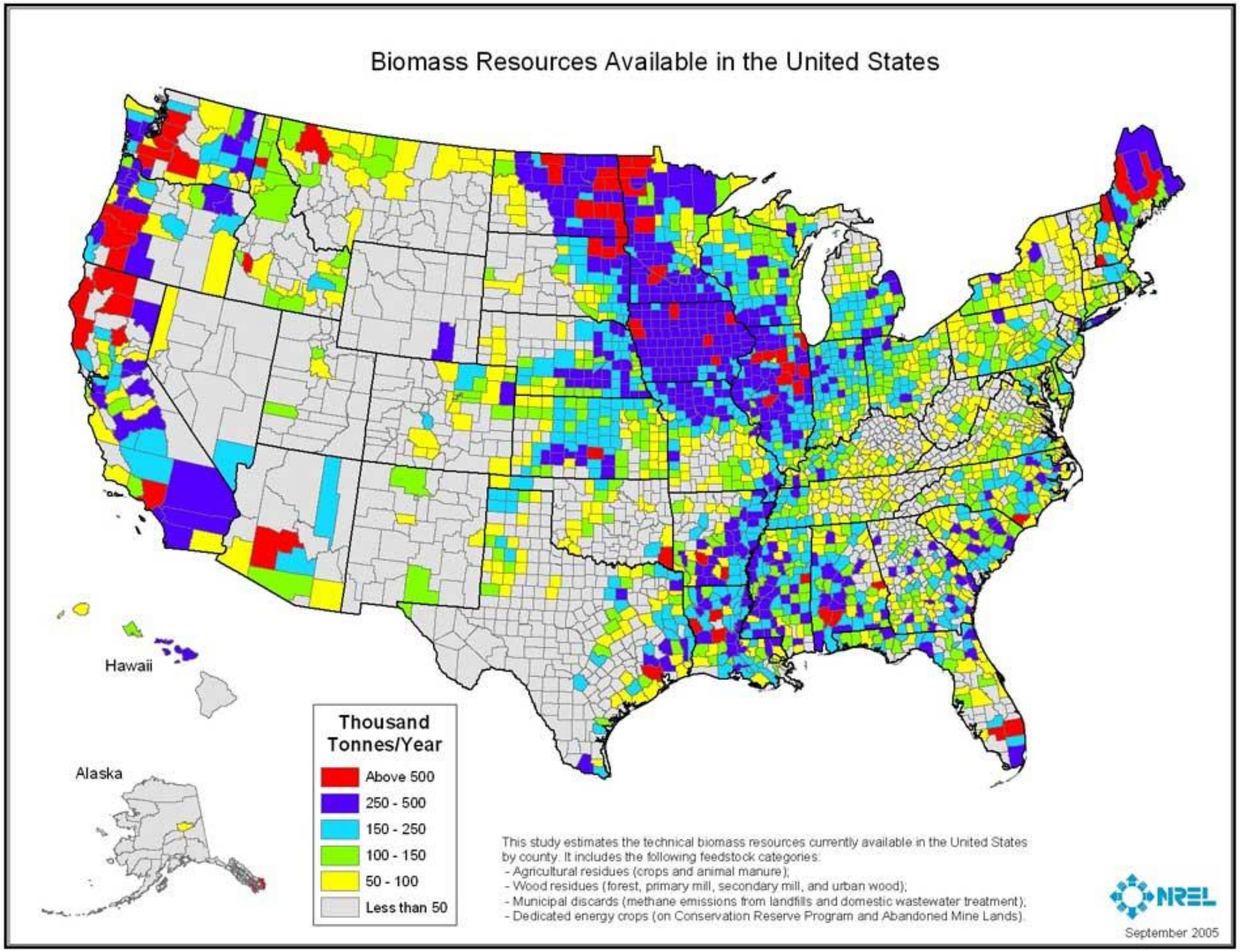
1.0 Billion Tons of U.S. Biomass per Year



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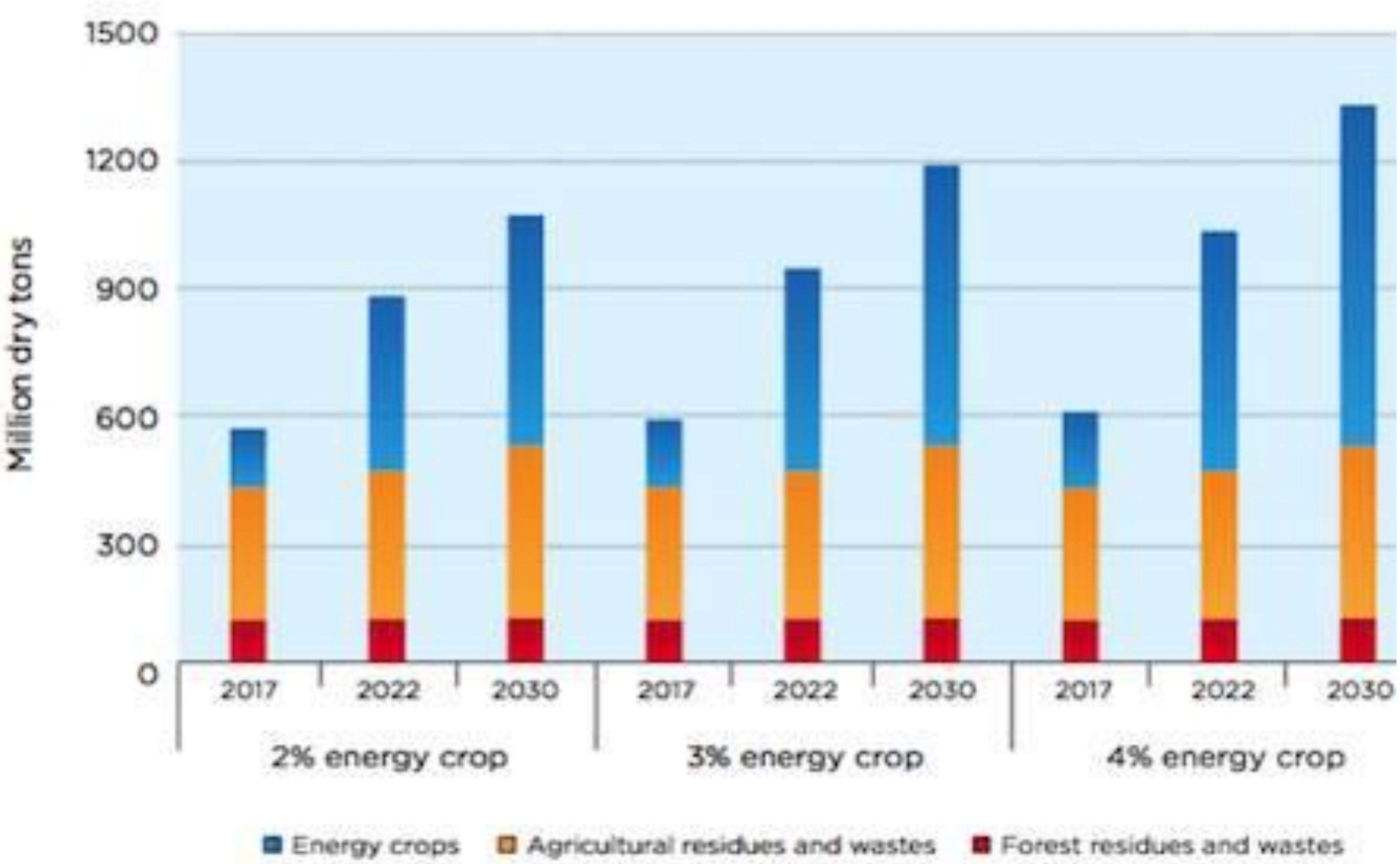
Projections for Biomass Supply

(U.S. Billion Ton Update, U.S. DOE, 2011)



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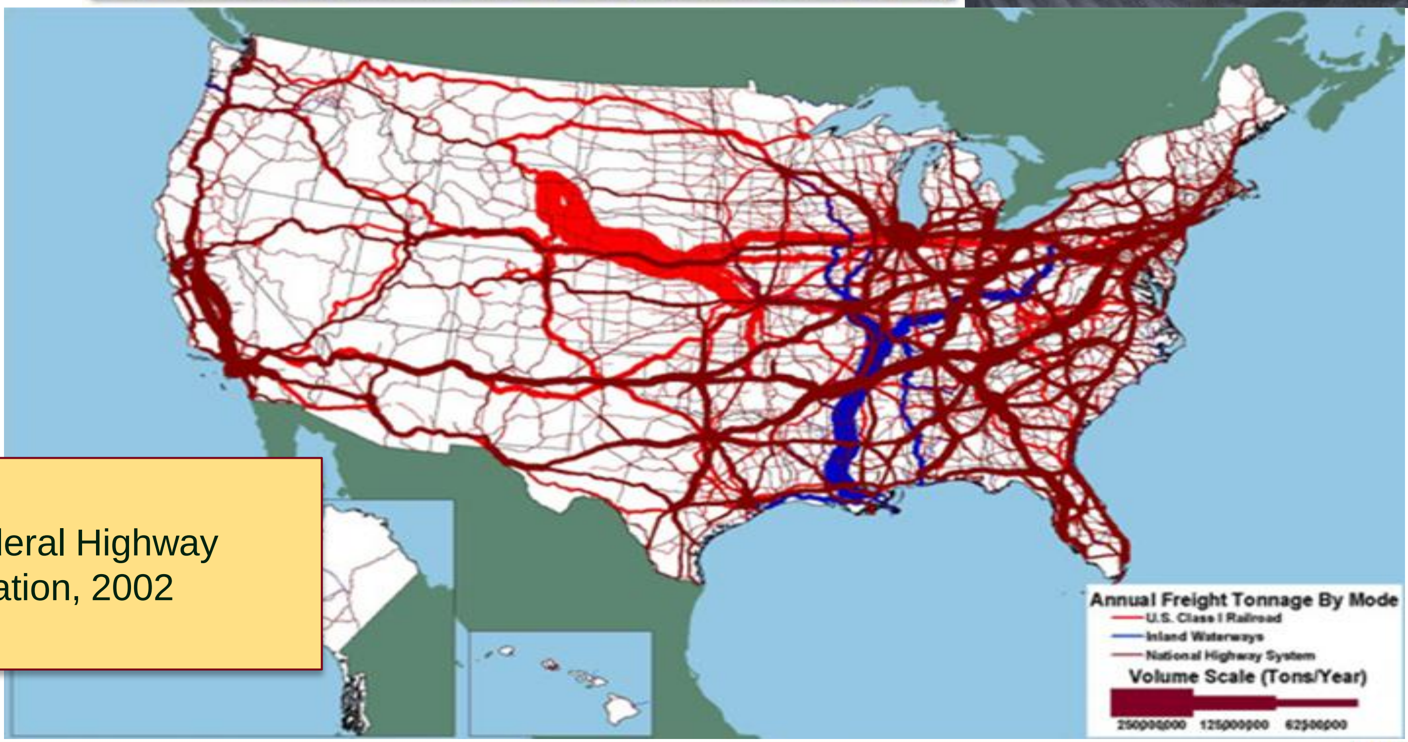
1.0 Billion Tons of Coal Dominate Surface Transportation

Source: National Renewable Energy Lab



Source: Federal Highway Administration, 2002

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Steps in the Analysis

- Develop spreadsheet to determine costs of converting biomass to biocoal, ethanol plants, coal-fired power plants
- Collect data on delivered biomass and coal costs
- Determine GHG emissions from pulverized coal power plants using various blends of "biocoal"
- Determine ROE of torrefaction plants and plants using products to comply with environmental regulations
- Determine if existing power plants will gradually reduce their GHG emissions by blending torrefied biomass in order to extend their economic lives

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Technical Worksheet for Torrefaction

Torrefaction Process	by Douglas G. Tiffany		20-Nov-12	**Biomass with Sale of Steam**		
	University of Minnesota			Return on Invested Capital		16.07%
				Return on Invested Capital (No Steam)		6.03%
Installed Capital Cost						Total
Nameplate Annual Output	150,000	Finished Tons	93.2%	Capacity Factor		
Installed Capital Cost	$228.00	per T of Capacity				$34,200,000
Percent Equity	40%					
Percent Debt	60%					
Interest Rate Charged on Debt	6%					
Operational Parameters						
Dry Matter Remaining	70%	BDT/BDT	(60-75%)			
BTUs used for drying at rate of	1200	BTUs/ lb. of Water Removed				
BTUs Released by facility per hour	95,950,000	from flow of	33.387	Tons of 17% Biomass =	2,873,873	BTUs/T @ 17% Moist.
lb.H2O Removed to Give Ton @17%	0		-	BTUs to Dry a Ton As Received to 17%		
Feedstock Grinding	37.8	kWh/ T Biomass	166,601.12	$ 0.07	440,826.57	
Torrefaction Reactor Electrical	56.25	kWh/ T BioCoal	139,800	$ 0.07	550,462.50	
Roll Press Briquetting Electrical	8.05	kWh/ T BioCoal	139,800.00	$ 0.07	78,777.30	
Natural Gas for Volatile Combustion	0.045	MMBTUof NG/T Bmass	166,601.12	$ 5.00	$ 37,485.25	
Water pumping for BioCoal Quenching	0.064	kWh/ T BioCoal	139,800	$ 0.07	626.30	
Fan Cooling of BioCoal Pellets	1.091	kWh/ T BioCoal	139,800	$ 0.07	10,676.53	
Revenues				Biocoal Production		
Sale of Biocoal (F.O.B.)	$140.00	at moisture of	1.10%	139,800	K lb of ST/hr	$ 19,572,000
BTUs Remaining After Drying	95,950,000	84,080	lb. of Steam/hr.		686,455	
Steam Price (Per 1,000 lb.)	$ 5.00		8164.32	Hours of Operation		$ 3,432,276
Total Revenues						$ 23,004,276
			(17%-62%)	Wet Tons Delivered		
Delivered Cost of Biomass	$70.00	at moisture of	17.00%	166,601.12		$ 11,662,079
Gross Margin						$ 11,342,197
Operating Costs and Depreciation			Costs per Ton Produced			
Salaries and Benefits	Rate/Fin. Ton		$ 4.50			$ 629,100
General & Administrative	Rate/Fin. Ton		$ 1.00			$ 139,800
Maintenance Expenses	Rate/Fin. Ton		$ 3.20			$ 447,360
Natural Gas Expense						$ 37,485
Electrical Expense						$ 1,081,369
Interest	Rate/Fin. Ton		$ 8.81			$ 1,231,200
Depreciation (SL) for asset life of	15	years	$ 16.31			$ 2,280,000
Total Operating Costs and Depreciation			$ 33.82	$ 41.82		$ 5,846,314
Net Margin				Margin Per Finished Ton		$ 5,495,883
Return on Invested Capital				$ 39.31		16.07%
Return on Invested Capital (No Steam)				$ 14.76		6.03%

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Co-located Advantage for Torrefaction

- After cost of biomass, independent torrre. plant may have costs of production of $42 per finished ton.
- With sales of steam, costs of process, $17 per finished T. of biocoal, a $25/T. advantage.
- Co-located torrefaction plants can enjoy a 16% ROE vs. 6% ROE over independent plants.
- Require 1.7 tons of 17% biomass to yield 1.0 T. of biocoal D.M.

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Life Cycle Assessment (LCA)

- Determination of GHG emissions associated with the production and use….
- Three Businesses:
  - 150,000 ton/year torrefaction plant
  - 100 MM gpy eth plant co-located w/torref. plant
  - Coal power plant co-firing biocoal
- Sources
  - Bepex
  - USDA, ERS model, Aspen Plus
  - Greet Model, Argonne National Lab

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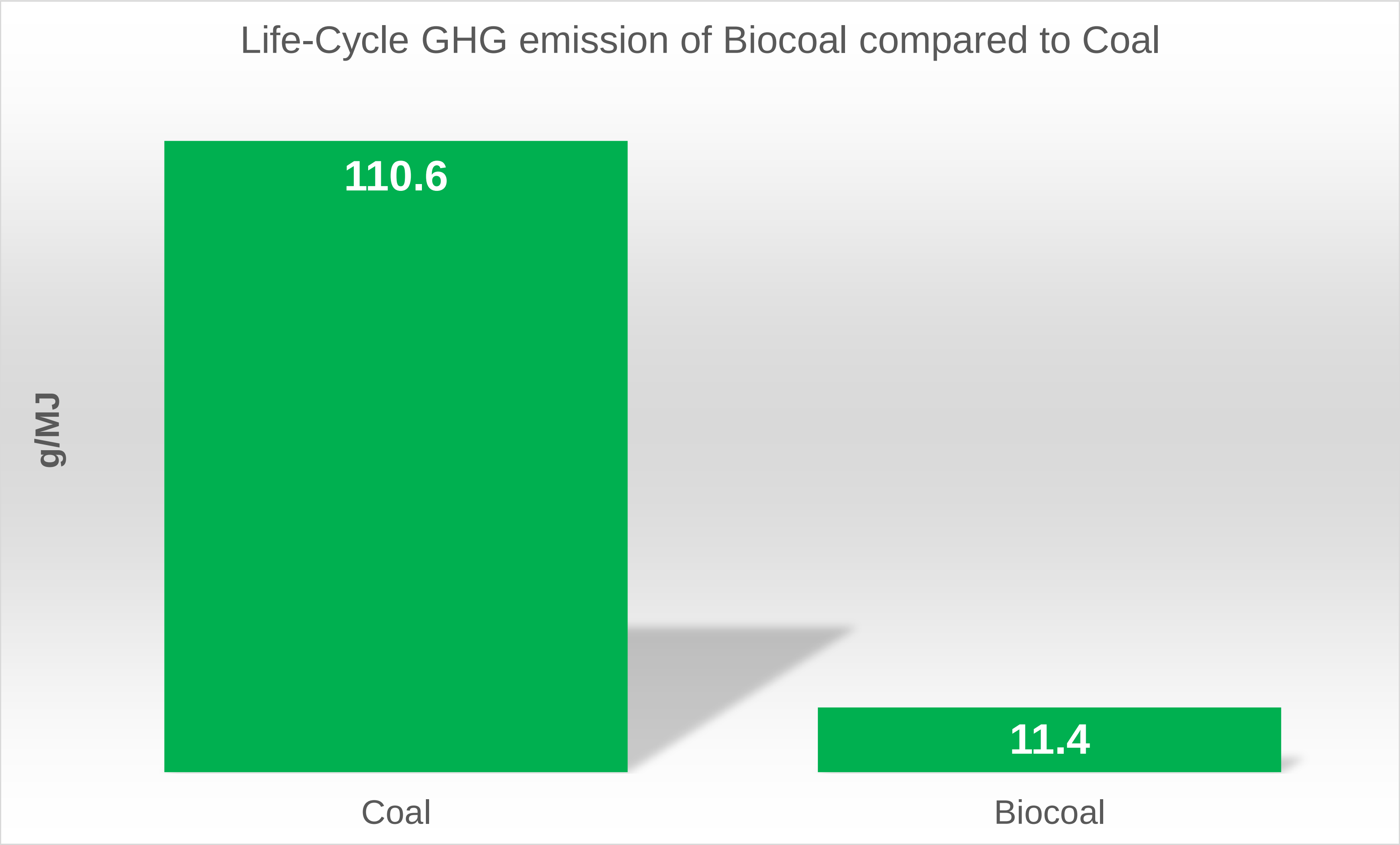
Life-Cycle GHG Emissions of Biocoal vs. Coal



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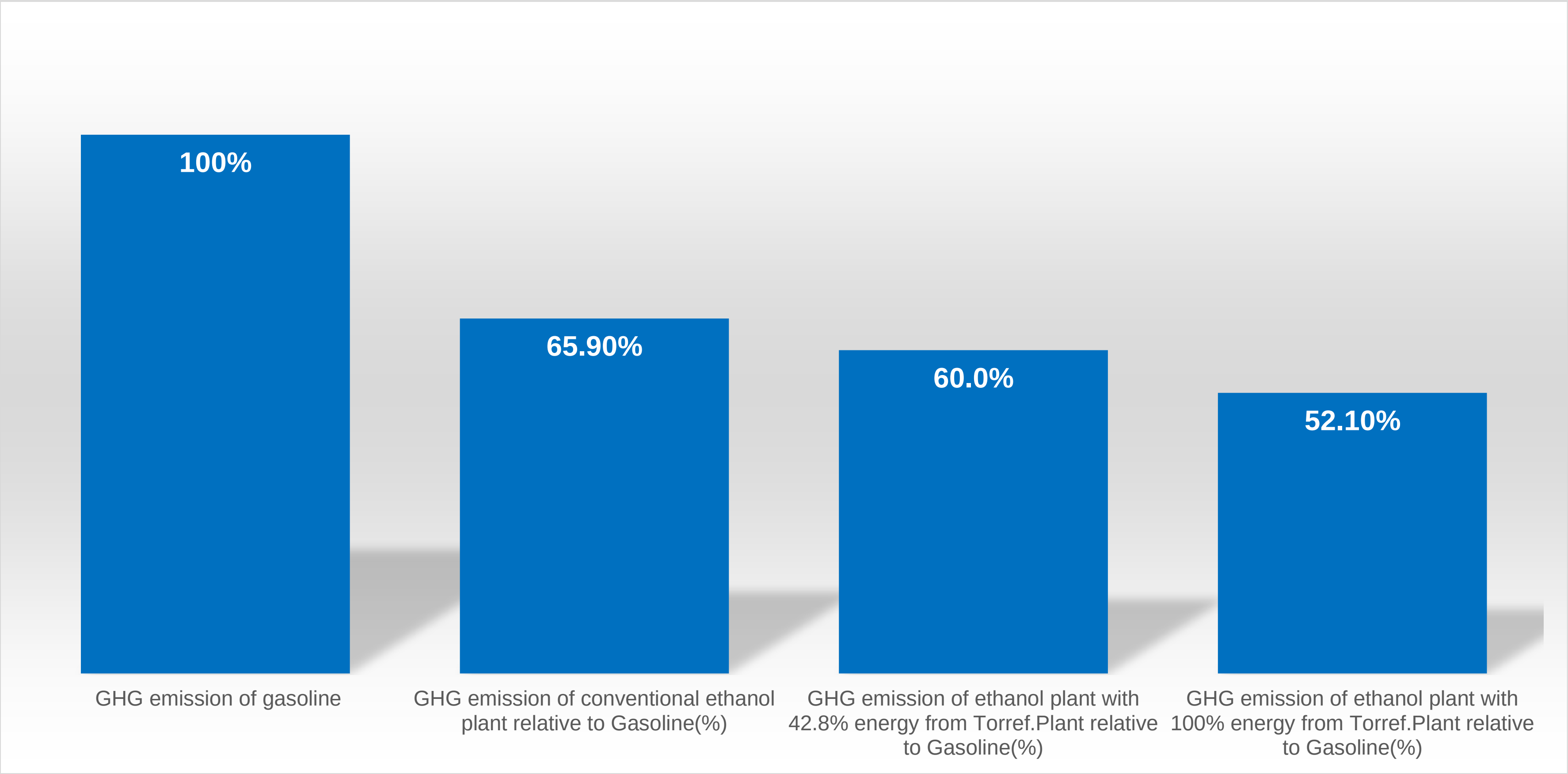
Torrefaction + Ethanol Plant Co-location

A 150,000 ton/year torrefaction plant can produce excess heat in the torrefaction off-gas volatiles, which can meet 42.8% of process energy needs in the ethanol plants.



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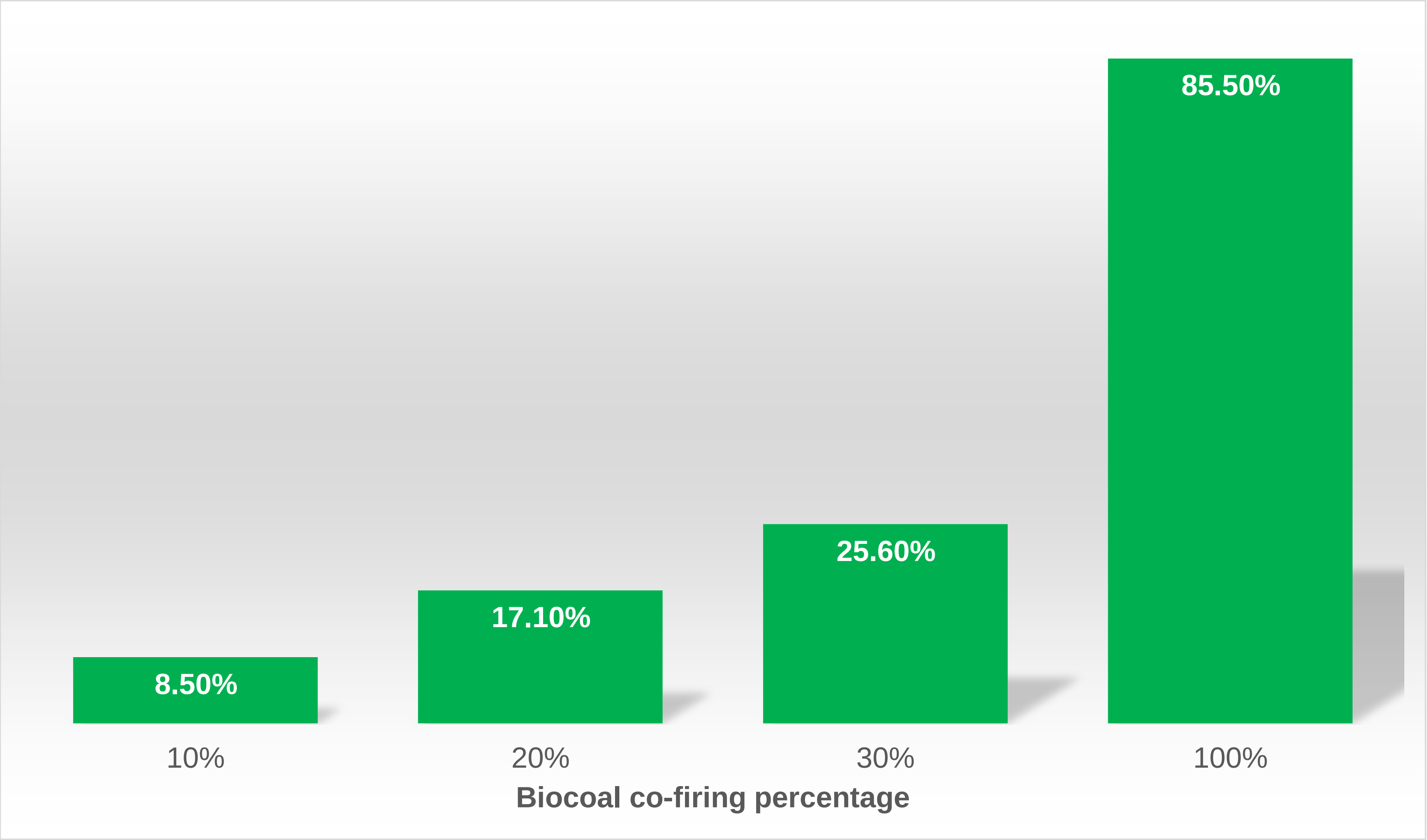
GHG Reductions of Coal PP Co-firing Biocoal



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Policy Drivers in the U.S.

- EPA Regulations under Clean Air Act rules
  - Mercury and Air Toxics Standards(MATS), Dec 2011
  - Cross-State Air Pollution Rule (CSAPR), July 2011
  - Carbon Pollution Standard, March 2012
  - Renewable Portfolio Standard (RPS)

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State Renewable Portfolio Standards

- State policies designed to increase generation of electricity from renewable resources.
- Encourage electricity producers within a given jurisdiction to supply a certain minimum share of their electricity from designated renewable resources.
- No RPS program in place at the National level.
- 29 states and the District of Columbia had enforceable RPS as of Feb 2013.

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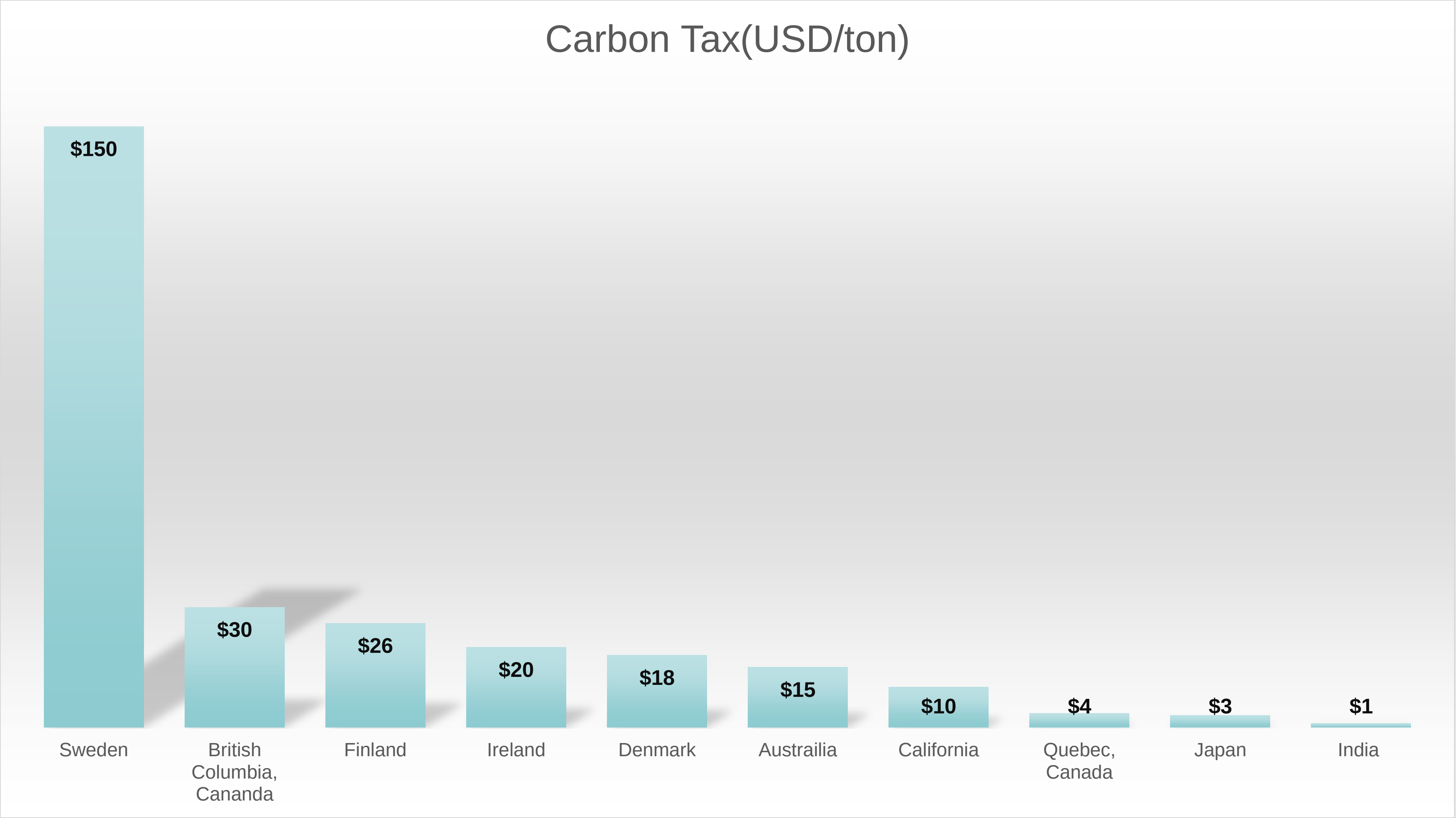
Carbon Taxes around the World



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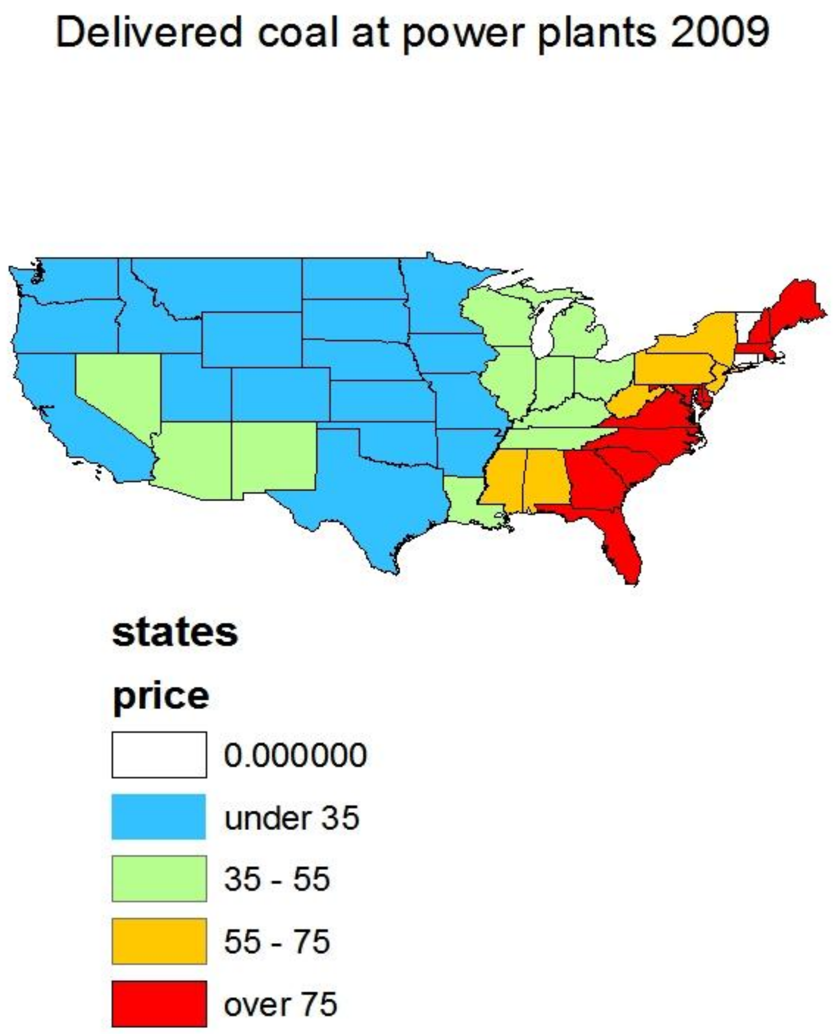
2009 Delivered Cost of Coal at Power Plants $/Ton

(Source: U.S. Dept. of Energy



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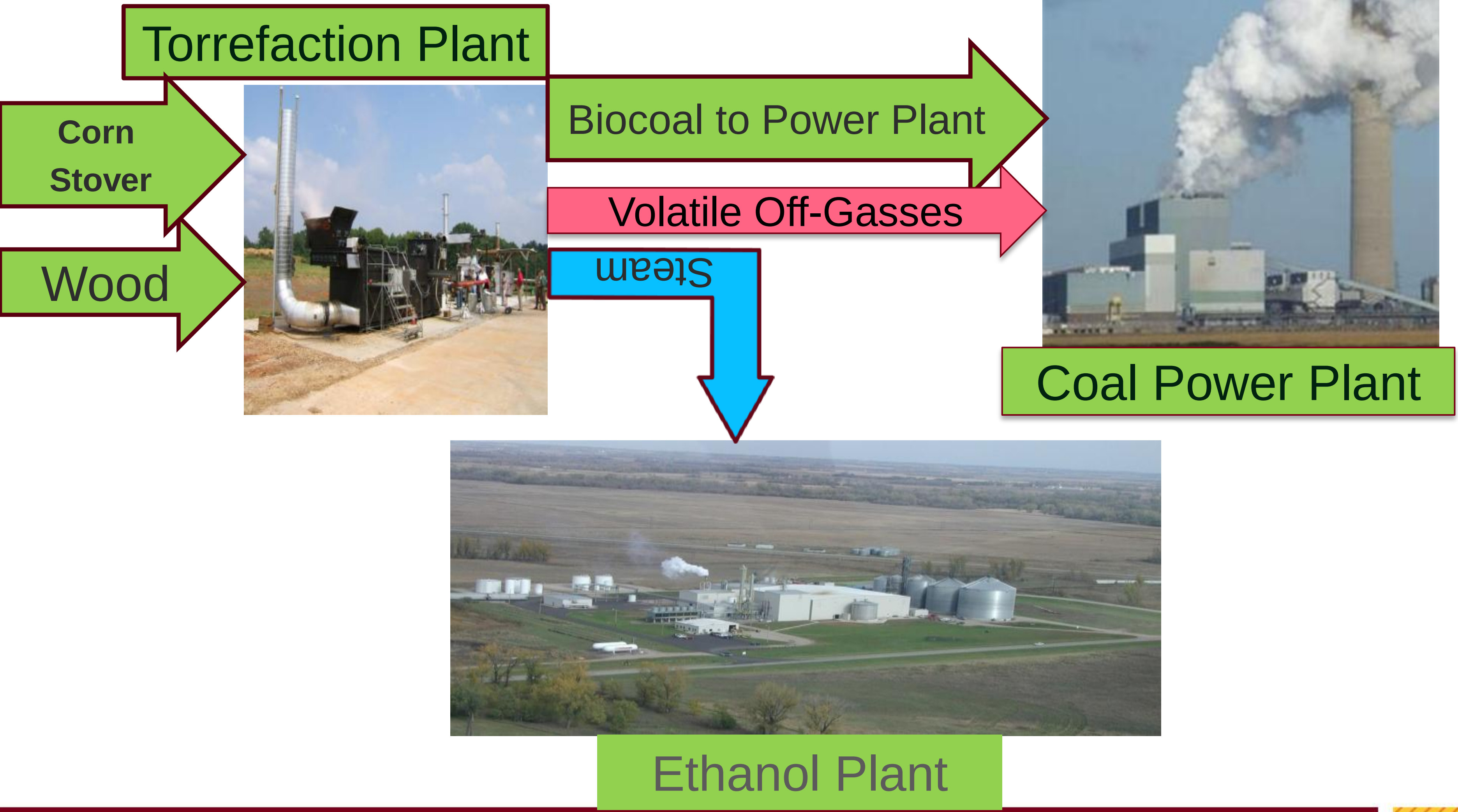

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Assumptions Applied in Workbook

Ethanol Plants				Torrefaction Plants		Coal Power Plants			
Name Plate Capacity	100 MM gal/ yr.	Steam Purch. fr. Torre. plant. per 1,000 lb.	$5.00	Number of Torrefaction Trains	2	Name Plate Capacity (MW)	550 MW	Capacity factor	90%
Factor of Equity	80%	Natural Gas Price Purchased MM BTU	$5.00	Capacity of Torref. Train (T./ Yr.)	150,000 T	Factor of Equity	57%	RPS requirement	30%
Factor of Debt	20%	Elect. Purchase from Grid per kWh	$0.07	Capacity Factor	93.20%	Factor of Debt	43%	REC price ($ per MWh)	$0
Interest Rate on Debt	6%	Propane Purchase ($ per gallon)	$1.65	Factor of Equity	40%	Interest Rate Charged on Debt	4.30%	Loan Duration	30
Depreciation Method Chosen (SL or DDB)	SL	Denaturant Price / gal	$2.57	Factor of Debt	60%	Co-firing Rate for Biocoal	10%	Deprec Method (SL or DDB)	SL
Depreciation based on asset life (years)	15	Denat /100 gal Anhyd.	2	Interest Rate Charged on Debt	6%	Delivered Cost of Coal (per ton)	$68.50	Deprec based on asset life for SL (years)	35
Ethanol Price (denat. price at plant) $/gal.	$2.25	Ethanol Yield (anhydrous gal per bushel)	2.75	Loan Duration	15 yrs	Del. Cost of Biocoal (per ton)	$150	Income Tax Rate	38%
DDGS Price $/T	$290.00			Deprec. Method Chosen (SL or DDB)	SL	SO_2 Allowance Market Cost (per ton)	$0	Price of Electricity (Cents per kWh)	7 Cents
CO_2 Price sold for Food and Industrial Uses	$10.00			Price of Biocoal ($ per Ton)	$140.00	NOx (Annual)Allowance Market Cost(per ton)	$0	Prod Tax Credit (PTC) per kWh Of Renewable Electricity	$0.01
Corn Price ($ per bu.)	$7.00			Delivered Cost of Biomass	$70.00	NOx (Ozone) Allowance Market Cost (per Ton)	$0		
CO_2 Tax	$0			Moisture of Biomass to be Torrefied	17.00%	CO_2 Tax(per ton)	$0		

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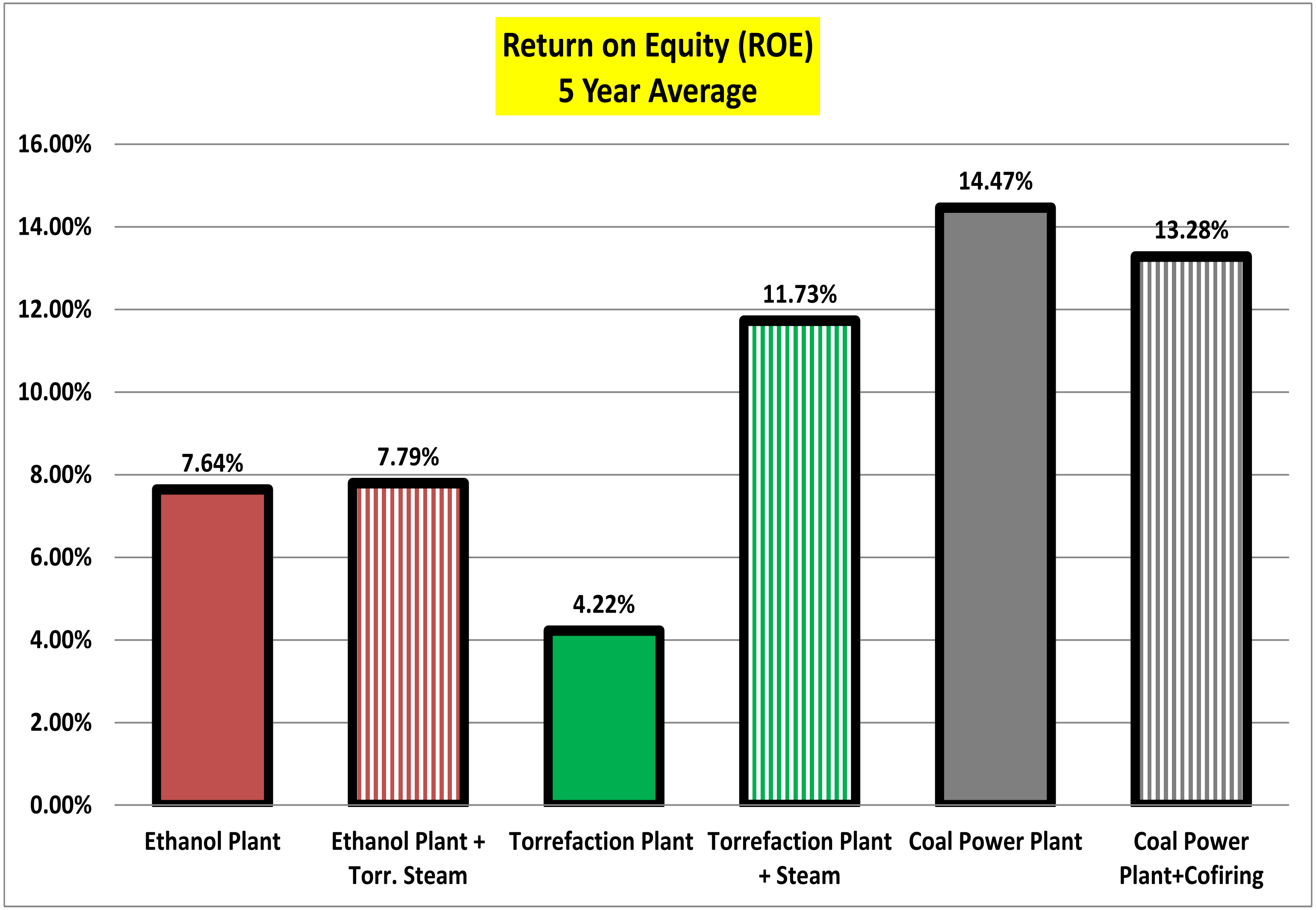
Baseline Returns on Equity



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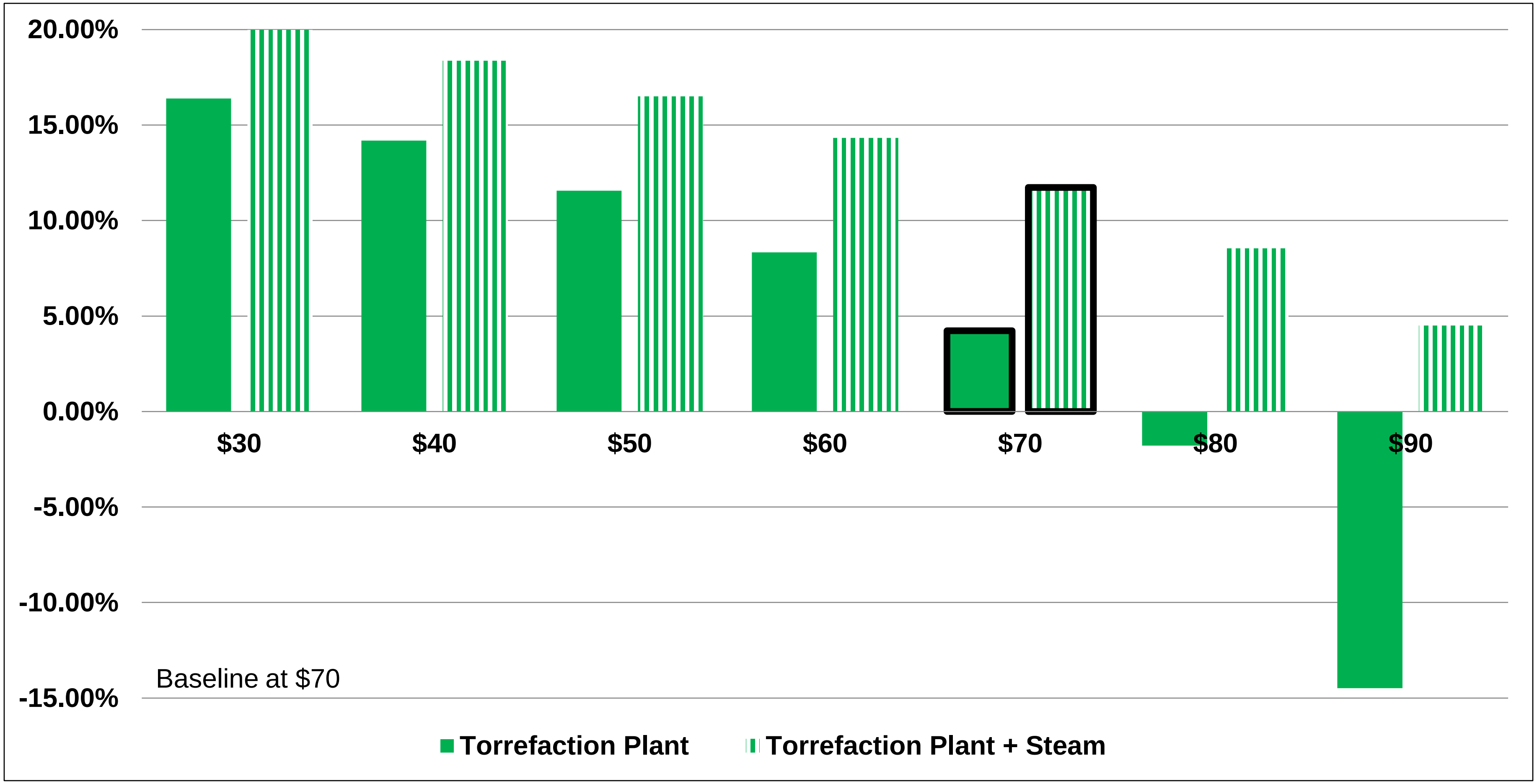
ROE of Torrefaction Comparison: By Delivered Cost of Corn Stover



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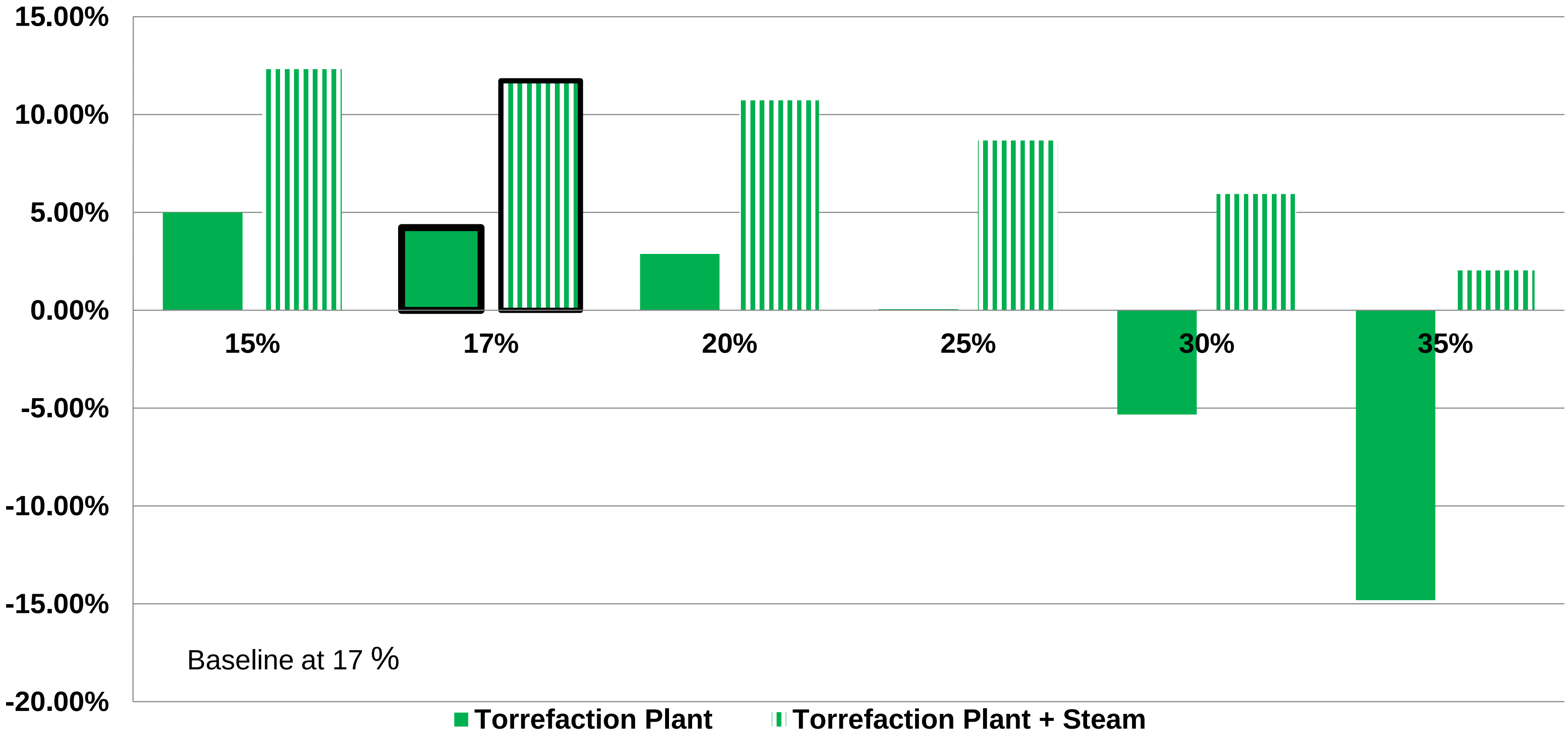
ROE of Torrefaction Comparison: By Percentage of Moisture Content



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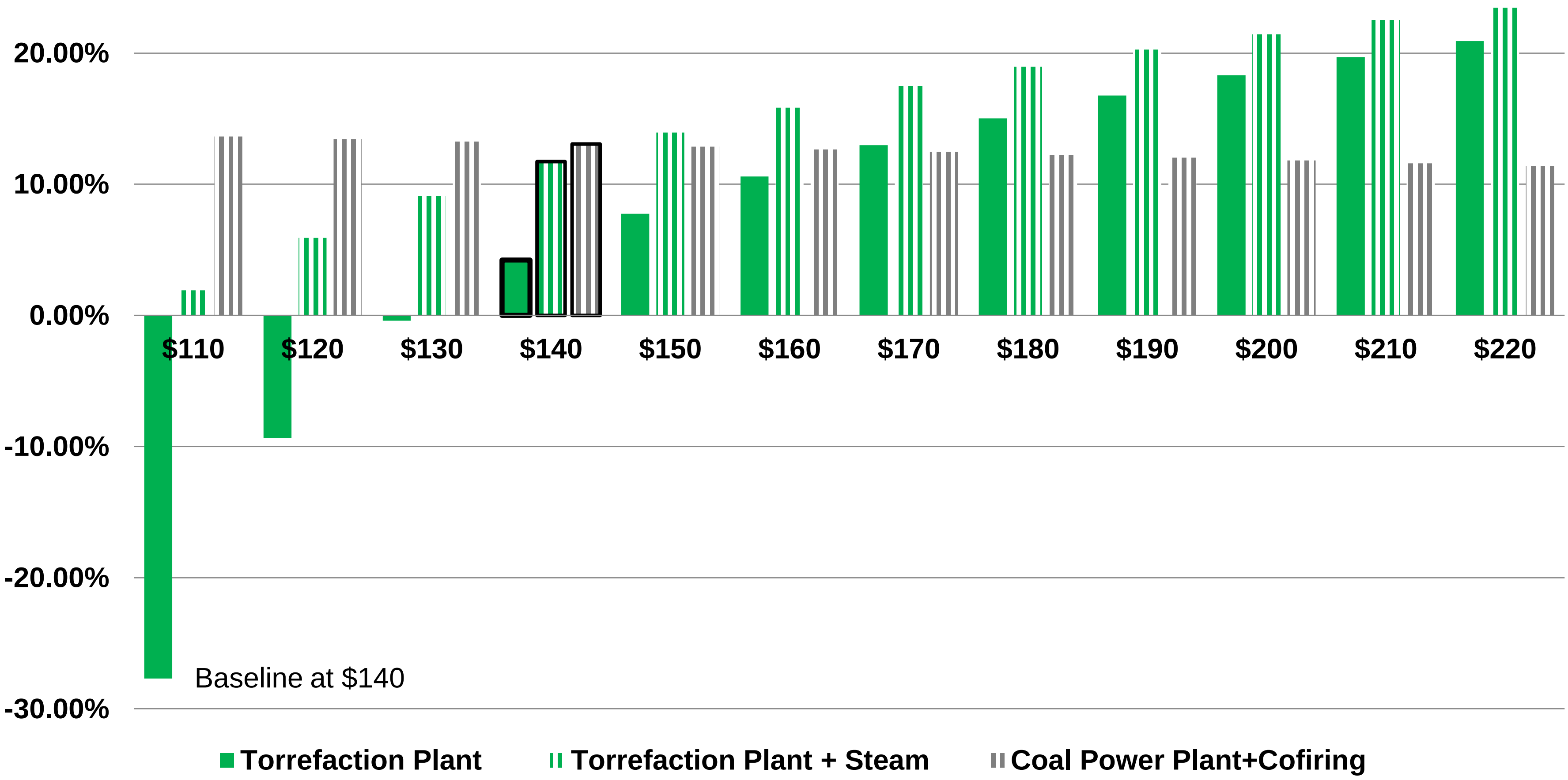
ROE Comparisons of Torrefaction & Power Plants By Sale Price of Biocoal



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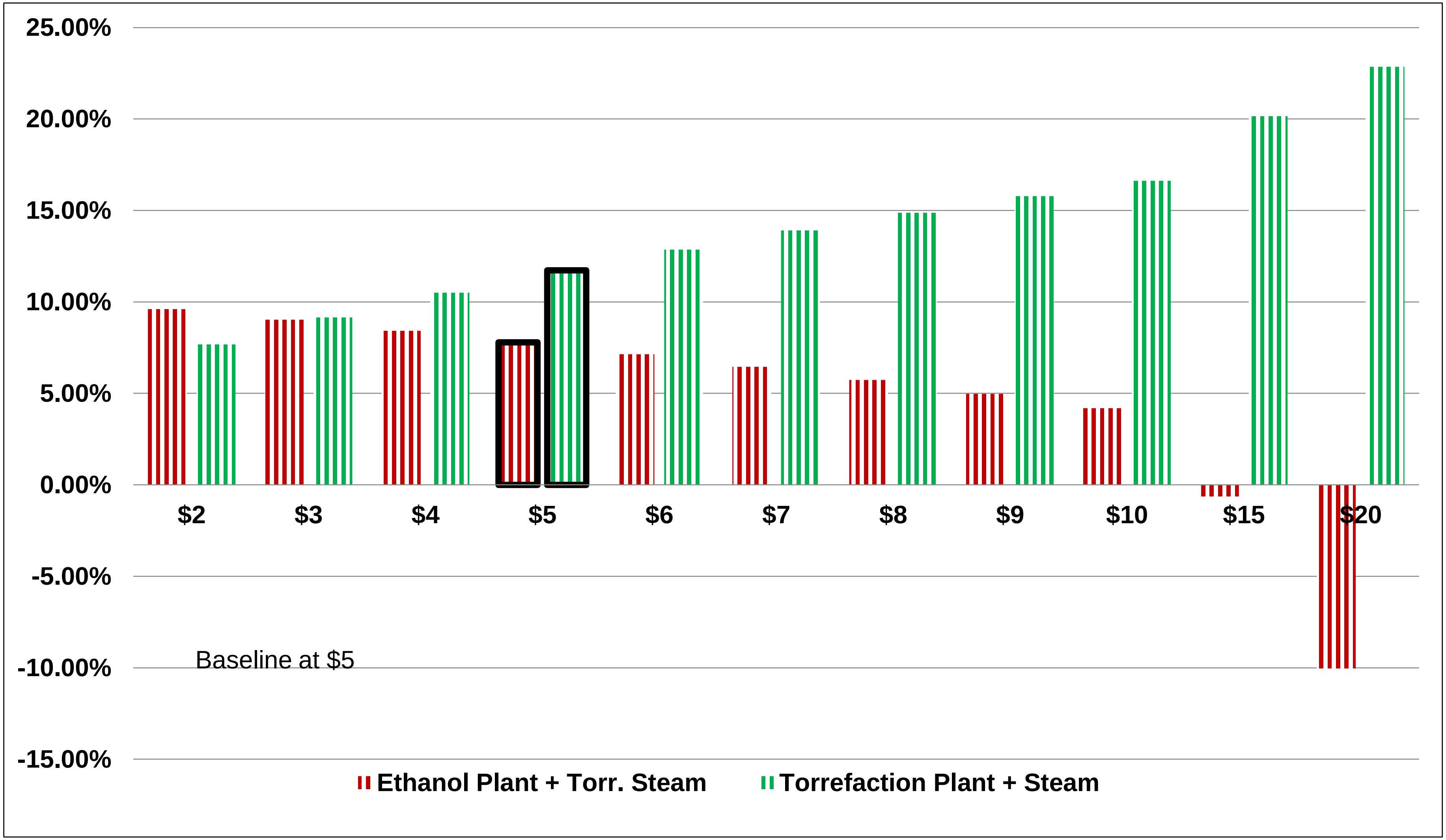
ROE at Torrefaction Plants Selling Steam and Ethanol Plants Buying Steam as Steam Prices Vary with NG price fixed at $5 per Decatherm



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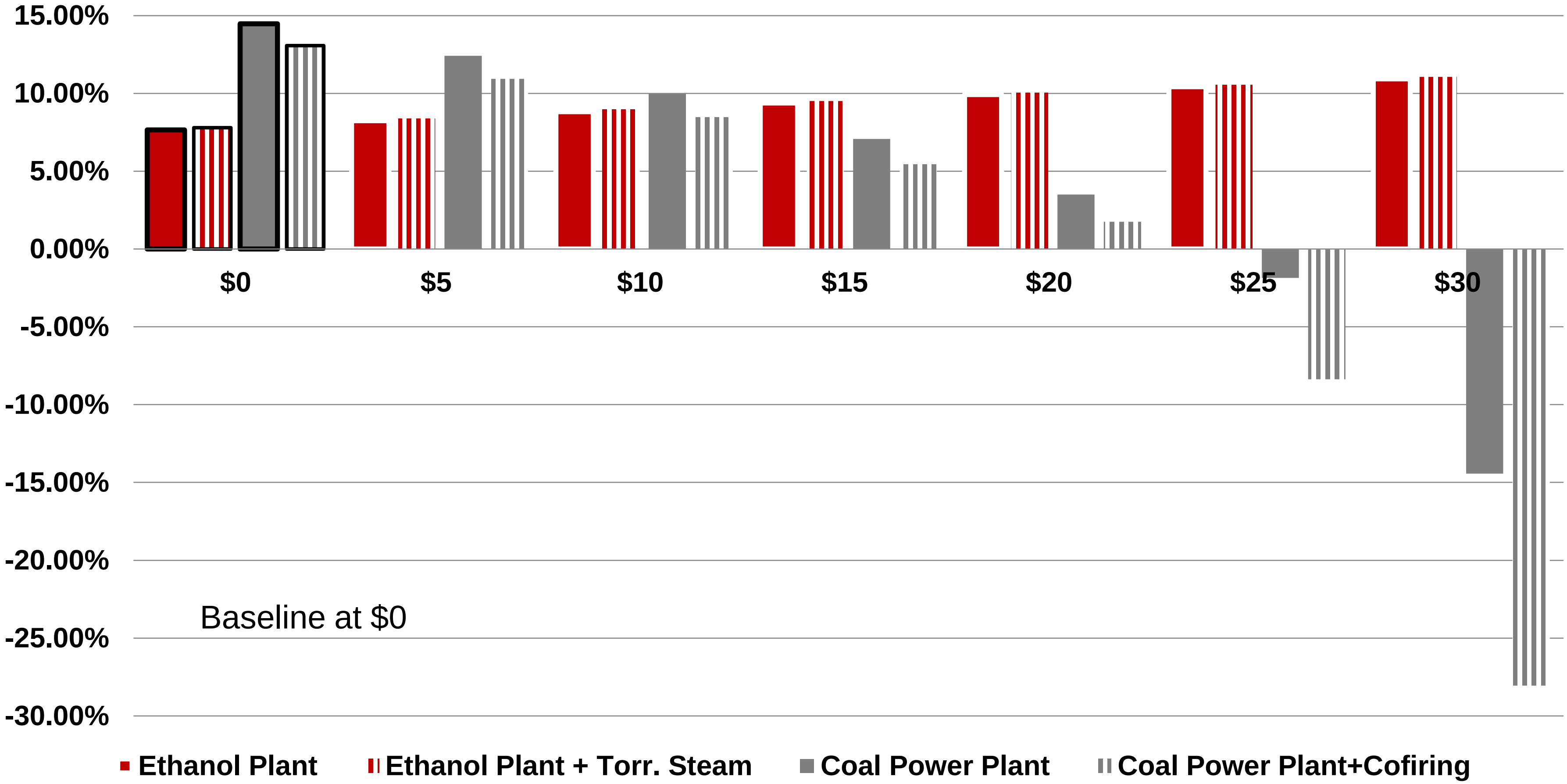
ROEs of Ethanol & Coal-fired PPlants: By Price of Carbon Tax



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Conclusions

- Torrefaction economics favor use of dry biomass so that more energy from the volatiles can be put to beneficial use.
- Although biocoal can improve emissions of coal-fired power plants, biocoal will not be used unless price of bituminous coal is higher than the U.S. average price of $68 per delivered ton. NG offers a cheaper alternative than coal for environmental compliance at current NG price.
- High CO2 fees & coal prices > ($100/T.) favor torrefaction adoption.
- Power utilities may try to extend the lives of some of their plants by using biocoal to comply with new laws and state renewable stds.
- Biocoal has favorable attributes for integration with coal infrastructure.
- GREET model predicts greater GHG reduction is possible by generating electricity from biomass than from trying to make biofuels. (also see Campbell, et al., 2009)
- Further analysis is planned for co-located torrefaction plant using wood at coal power plant.

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THANK YOU!

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