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Assessment of Biomass Energy Potential in New Jersey

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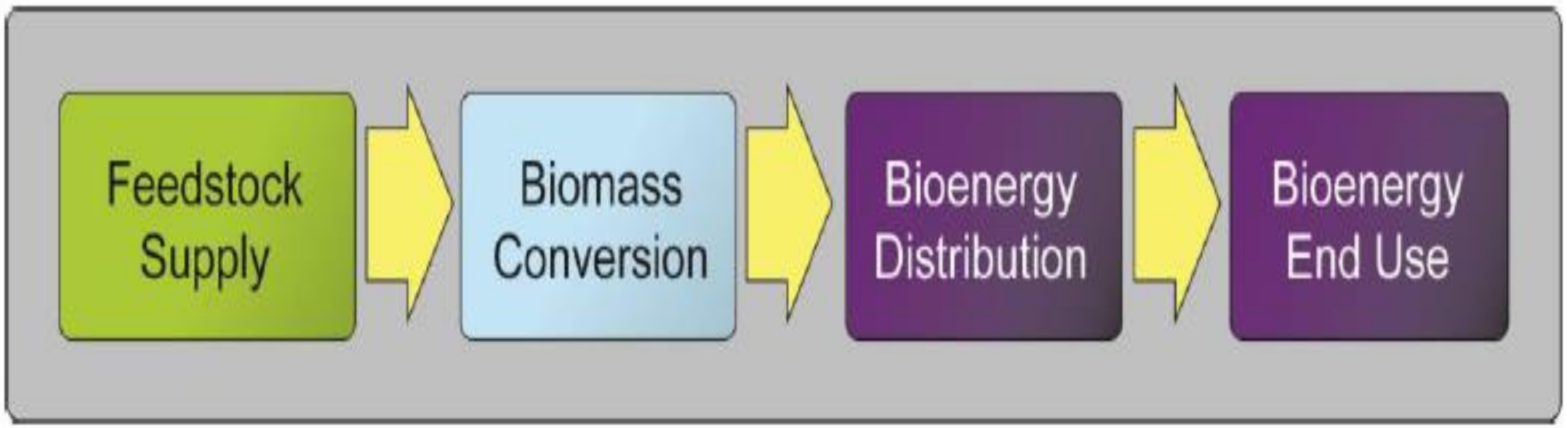
NJBPU Biopower Working Group Meeting , 9/28/2015, EcoComplex

Outline

- Need for an Assessment
- Findings
  - Biomass Feedstocks
  - Technology Assessment
  - GHG Emissions Reduction Potential
  - Policy recommendations

Biomass-to-Bioenergy Supply Chain



Feedstock Supply: Produce large, sustainable supplies of regionally available biomass and implement cost-effective biomass feedstock infrastructure, equipment, and systems for biomass harvesting, collection, storage, preprocessing, and transportation
Bioenergy Production: Develop and deploy cost-effective, integrated biomass conversion technologies for the production of biofuels and bioproducts
Bioenergy Distribution: Implement biofuels distribution infrastructure (storage, blending, transportation—both before and after blending and dispensing)
Bioenergy End Use: Assess impact of fuel blends on end-user vehicles.

https://www1.eere.energy.gov/bioenergy/pdfs/mypp_may_2013.pdf.

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ASSESSMENT OF BIOMASS ENERGY POTENTIAL IN NEW JERSEY

VERSION 2.0 JULY 2015

EcoComplex
Clean Energy Innovation Center

2.0 Project Team

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Version 2.0 is an updated and enhanced version of the 2007 NJAES study.[1]

[1]Brennan, Margaret, David Specca, Brian Schilling, David Tulloch, Steven Paul, Kevin Sullivan, Zane Helsel, Priscilla Hayes, Jacqueline Melillo, Bob Simkins, Caroline Phillipuk, A.J. Both, Donna Fennell, Stacy Bonos, Mike Westendorf and Rhea Brekke. 2007. "Assessment of Biomass Energy Potential in New Jersey." New Jersey Agricultural Experiment Station Publication No. 2007-1. Rutgers, The State University of New Jersey, New Brunswick, NJ.

Assessment of Biomass Energy* Potential in New Jersey 2.0

Project Goals

- Update the 2007 Feedstock Assessment - characteristics and quantity of biomass feedstocks.
- Update the 2007 Technology Assessment – updated efficiencies and technology adoption information.
- Update statewide mapping of waste/biomass resources and bioenergy potential.
- Estimate potential greenhouse gas emissions reductions based on various scenarios.
- Develop policy recommendations for moving New Jersey into the forefront of bioenergy innovation.

- The ultimate goal is for these deliverables to establish a well-informed base upon which to develop viable bioenergy programs for New Jersey.

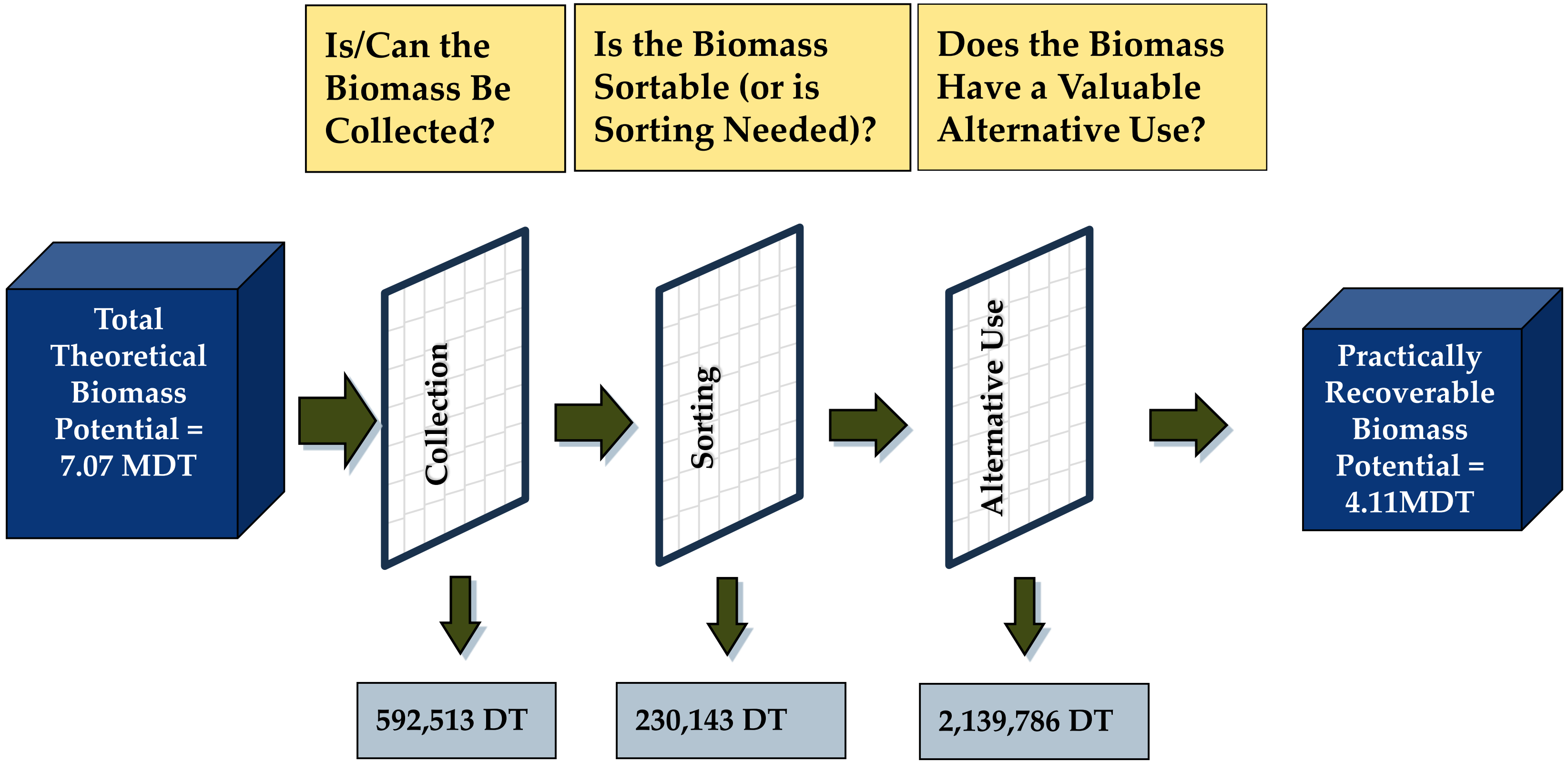
**Biomass energy is a broad definition for biologically-derived renewable materials that can be used to produce heat, electric power, transportation fuels and bio-based intermediaries, products and chemicals.*

Major Findings

1. New Jersey produces an estimated **7.07 million dry tons** (MDT) of biomass[1] annually.
2. Almost **72%** of New Jersey's biomass resource is produced directly by the state's population, much of it in the form of solid waste (e.g., municipal waste).
3. Biomass is primarily concentrated in the counties of central and northeastern New Jersey.
4. Agriculture and forestry management are also important potential sources of biomass, and account for the majority of the remaining amount.
5. A screening process was developed to estimate the practically recoverable quantity of biomass, in the state. Approximately **4.11 MDT** (~58%) of New Jersey's biomass could ultimately be available to produce energy, in the form of power, heat, or transportation fuels.
6. New Jersey's estimated 4.11 MDT of biomass could deliver up to 654 MW of power, (**~ 6.4%** of NJ's electricity consumption) **or** 230 million gallons of gasoline equivalent **(~ 4.3%** of transportation fuel consumed) **if** the appropriate technologies and infrastructure were in place.

[1]This total includes biogas and landfill gas quantities converted to dry ton equivalents on an energy basis. This does NOT include biomass that is currently used for incineration or sewage sludge because these are not classified as Class I renewable feedstocks in New Jersey

The results of this process indicate that approximately 4.11 MDT (~58%) of New Jersey's biomass could ultimately be available to produce energy in the form of power, heat, or transportation fuels.



Note: This screening process is preliminary and would require considerably more analysis to reach any final conclusions. The screening analysis has been incorporated into the database, and provides flexible "scenario analysis" capabilities for the user.

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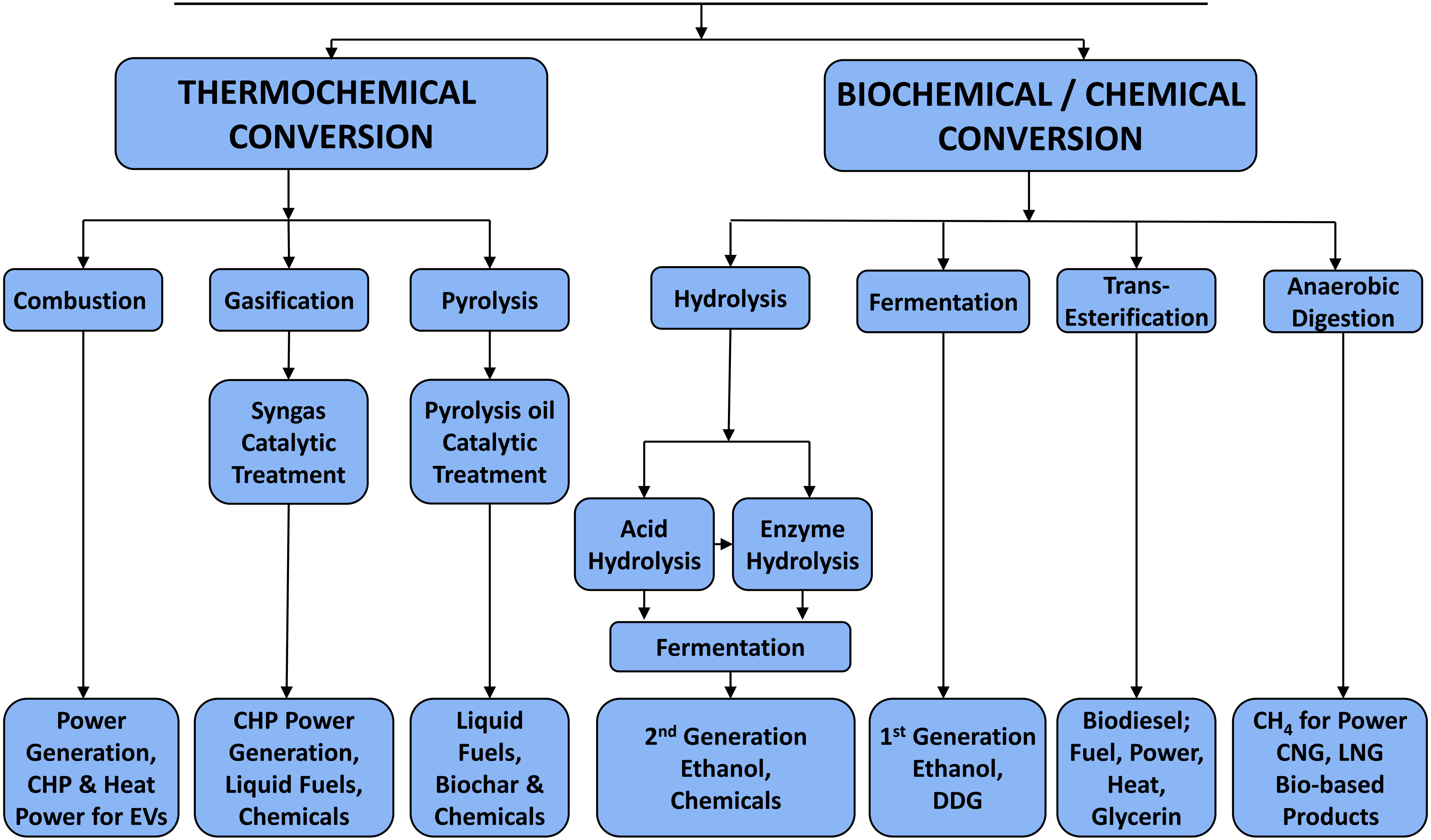
BIOMASS-to-BIOENERGY & BIOPRODUCTS CONVERSION PATHWAYS



New Jersey has waste and biomass resources that would result in potential GHG emissions reductions if more efficient technologies are utilized.

- In Section IV, several scenarios provide GHG reduction potentials based on available waste and biomass feedstocks and conversion technologies.
- This section also compares GHG emissions with fossil fuel emissions which waste and biomass energy may displace.
- The example scenarios for potential GHG reductions in New Jersey are:
  - Flared portion of landfill gas (LFG) utilization for power generation and transportation fuels production.
  - Potential biogas production from food waste and yard waste AD (Anaerobic Digestion) for power generation and transportation fuels production.
  - Biodiesel, produced from yellow grease, utilized for transportation fuel.
  - Second generation ethanol from forestry biomass through gasification with mixed alcohol synthesis, utilized as gasoline blendstock (E10).

II. Biomass Supply Analysis

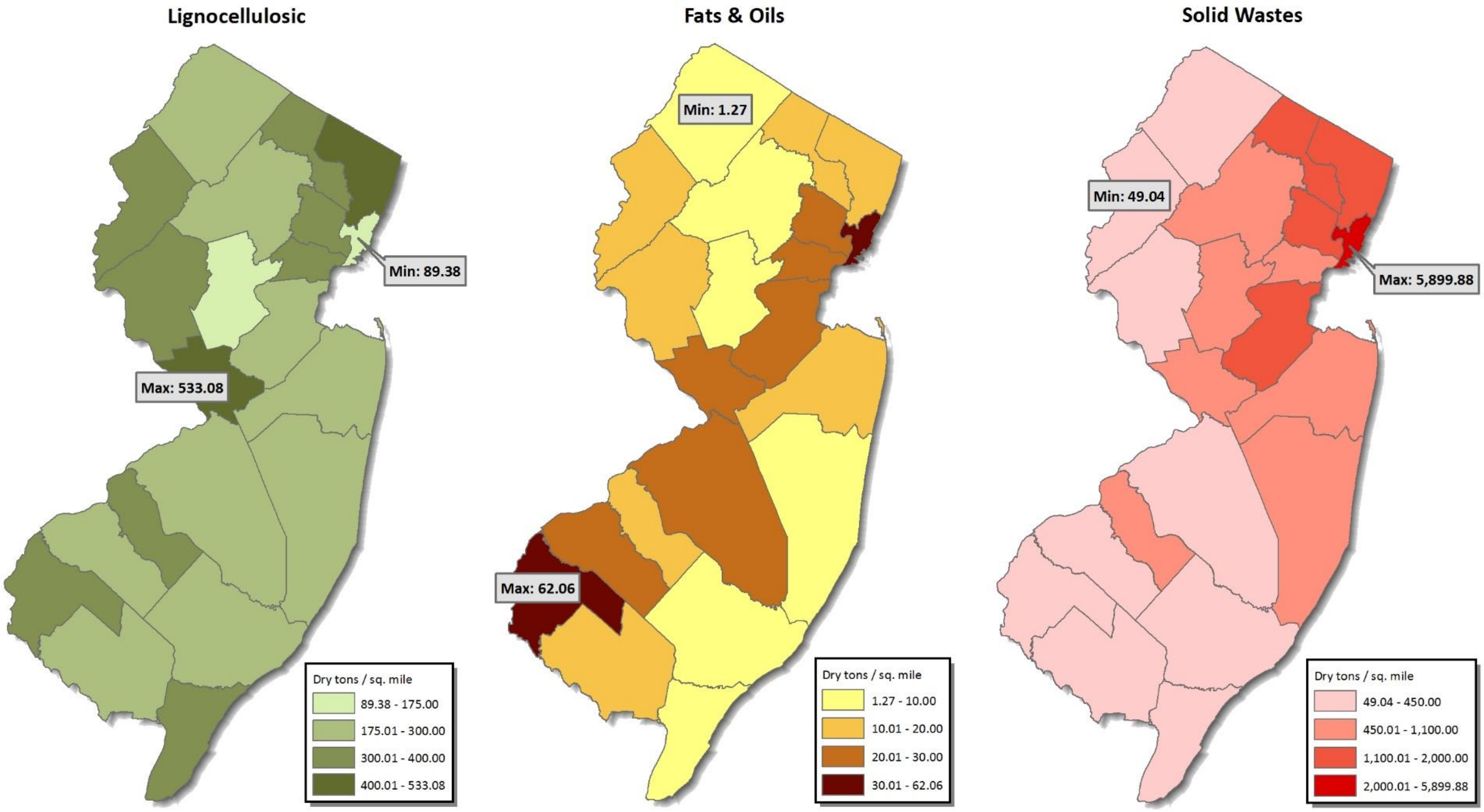
Biomass Supply Analysis: Theoretical Potential

New Jersey produces an estimated 7.07 million dry tons (MDT) of biomass annually. Individual county amounts range from 128,474 to 611,410 dry tons per year.

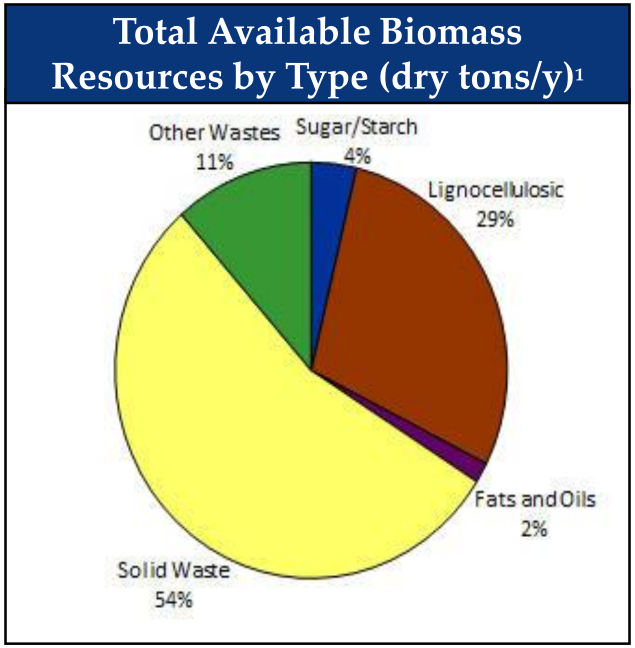
Current Gross Quantity (dry tons)								
County	Sugar/Starch	Ligno	Fats & Oils	Solid Waste			Other Wastes	Totals
				Recycled	Landfilled Biomass	C&D non-recycled wood		
Atlantic	2,549	118,397	1,266	37,947	84,846	20,944	50,564	316,512
Bergen	4	93,737	3,790	166,837	195,159	86,593	65,289	611,410
Burlington	32,090	214,810	21,093	77,962	95,210	23,711	86,409	551,286
Camden	2,444	73,270	2,337	75,827	30,227	20,583	15,225	219,914
Cape May	772	90,167	407	22,539	32,505	21,897	31,893	200,181
Cumberland	27,282	128,487	8,877	34,772	40,639	6,815	15,768	262,641
Essex	0	40,659	3,283	112,229	36,171	19,283	38,772	250,398
Gloucester	18,272	81,807	9,438	76,846	9,064	10,686	131,590	337,704
Hudson	0	4,129	2,656	114,940	131,773	25,802	5,393	284,693
Hunterdon	27,926	134,938	4,727	16,169	17,525	8,298	26,905	236,487
Mercer	8,511	119,709	5,377	70,081	84,207	20,757	22,470	331,112
Middlesex	9,513	73,388	6,882	197,133	190,952	31,407	88,379	597,654
Monmouth	9,428	125,283	7,561	99,977	153,488	64,421	51,189	511,347
Morris	3,297	113,251	2,295	101,478	101,154	19,766	40,024	381,265
Ocean	1,007	158,073	2,675	91,931	139,858	88,561	46,770	528,874
Passaic	4	57,969	2,099	104,049	119,978	50,443	4,304	338,846
Salem	63,270	118,525	20,597	7,507	14,301	2,480	35,486	262,166
Somerset	8,088	50,999	2,447	46,273	71,276	33,212	16,974	229,270
Sussex	9,414	151,081	660	15,611	26,896	3,523	28,111	235,294
Union	0	36,023	2,247	43,600	10,202	22,938	13,466	128,474
Warren	51,380	139,757	4,963	11,293	5,335	874	37,422	251,024
New Jersey	**275,250**	**2,124,461**	**115,675**	**1,524,999**	**1,590,766**	**582,996**	**852,403**	**7,066,550**

Biogas and Landfill Gas (in Other Wastes) has been converted to dry tons.
Other Waste: Agricultural Livestock Waste , Waste Water Treatment Plant Waste and Biogas, and Landfill Gas.

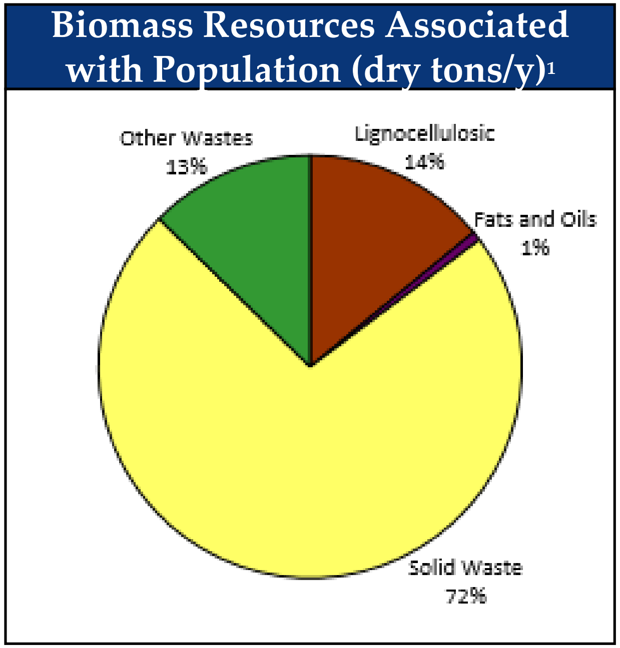
Biomass Resources by Feedstock Category 2010



Almost 72% of New Jersey's biomass resource is produced directly by the state's population, much of it in the form of municipal solid waste.



The chart on the left shows NJ's total biomass. The chart on the right shows just the population-related biomass waste stream.

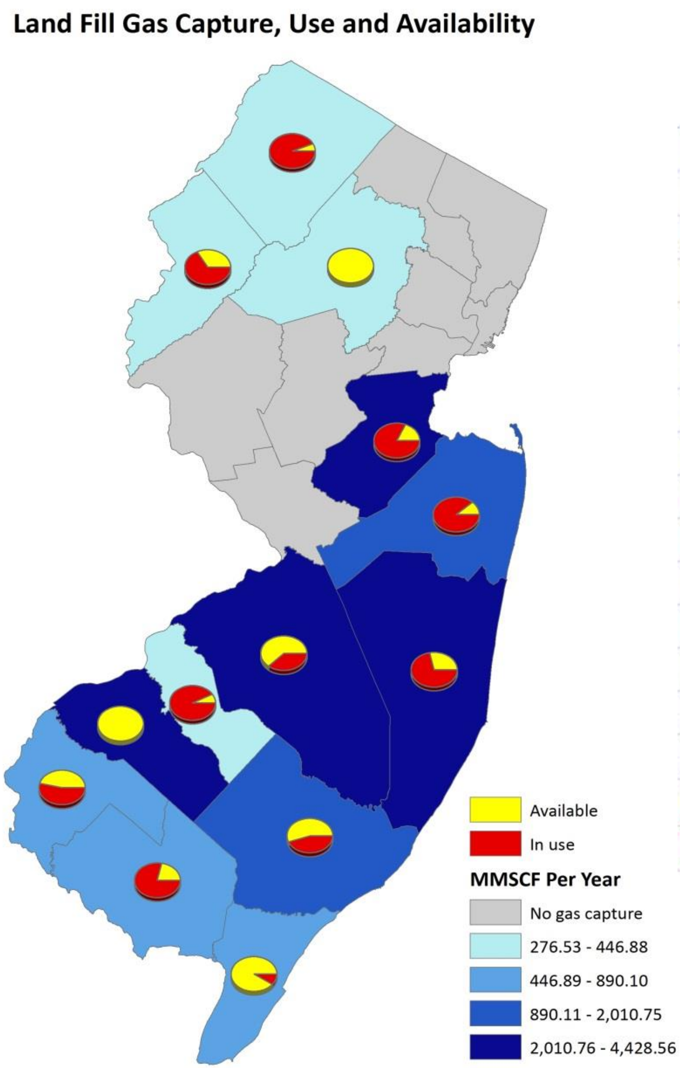


Total = 7.07 million dry tons/y[1]

Total = 5.10 million dry tons/y[2]

In the past, generating energy from solid waste typically involved incineration. Several new technologies described in Section III make the conversion possible without incineration.

1. Note that these are gross quantities, not taking into account differences in heat content per ton.
2 This total includes biogas and landfill gas quantities converted to dry tons.



Landfill Gas Totals by County in 2012 (mmscf/yr)			
County	Total Captured	Currently Used	Net Available
Atlantic	1,638.00	737.42	900.58
Bergen	1,194.16	0.00	1,194.16
Burlington	2,677.52	1,019.15	1,658.36
Camden	319.87	297.00	22.87
Cape May	803.06	70.64	732.41
Cumberland	890.10	699.90	190.20
Gloucester	2,709.59	0.00	2,709.59
Middlesex	4,428.56	3,642.69	785.87
Monmouth	2,010.75	1,788.50	222.25
Morris	446.88	0.00	446.88
Ocean	3,153.60	2,242.74	910.86
Salem	660.77	351.63	309.14
Sussex	306.94	289.18	17.76
Warren	276.53	182.89	93.63
Total	**21,516.31**	**11,321.74**	**10,194.57**

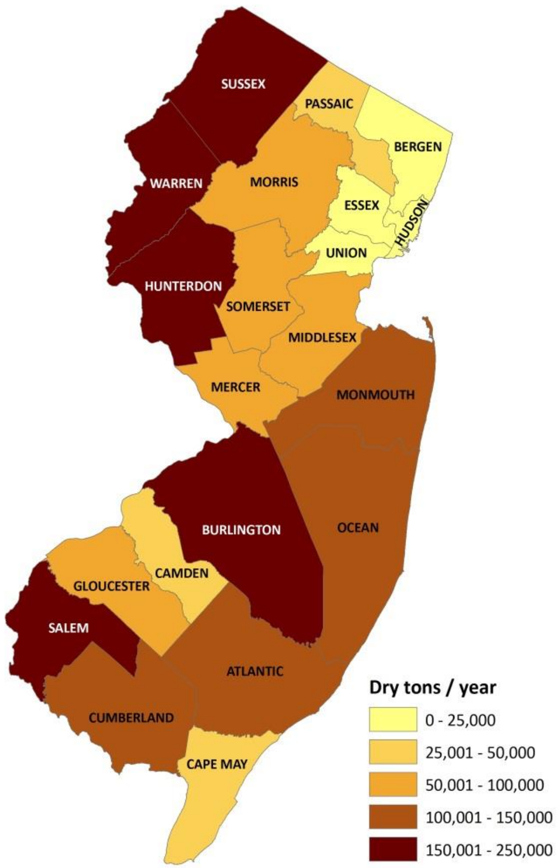
Biomass Contained in NJ's Incinerated Solid Waste

Current Gross Quantity (dry tons) 2010					
County	Solid Waste Based Biomass				
	Recycled	Landfilled	**Incinerated**	C&D non-recycled wood	**Total**
Atlantic	37,947	84,846	**1,524**	20,944	145,260
Bergen	166,837	195,159	**22,669**	86,593	471,258
Burlington	77,962	95,210	**17,209**	23,711	214,092
Camden	75,827	30,227	**99,732**	20,583	226,369
Cape May	22,539	32,505	**6**	21,897	76,947
Cumberland	34,772	40,639	**59**	6,815	82,286
Essex	112,229	36,171	**126,022**	19,283	293,705
Gloucester	76,846	9,064	**56,667**	10,686	153,263
Hudson	114,940	131,773	**334**	25,802	272,850
Hunterdon	16,169	17,525	**9,682**	8,298	51,674
Mercer	70,081	84,207	**43**	20,757	175,088
Middlesex	197,133	190,952	**6,669**	31,407	426,161
Monmouth	99,977	153,488	**123**	64,421	318,009
Morris	101,478	101,154	**4,539**	19,766	226,938
Ocean	91,931	139,858	**56**	88,561	320,405
Passaic	104,049	119,978	**26,905**	50,443	301,375
Salem	7,507	14,301	**41**	2,480	24,327
Somerset	46,273	71,276	**16,725**	33,212	167,487
Sussex	15,611	26,896	**1,063**	3,523	47,092
Union	43,600	10,202	**114,239**	22,938	190,978
Warren	11,293	5,335	**18,410**	874	35,912
New Jersey	1,524,999	1,590,766	**522,717**	582,996	4,221,478

Agriculture and forestry management are also important potential sources of biomass, and account for the majority of the remaining amount.

- Biomass from agricultural sources include both crops and crop residues. The use of agricultural crops for energy production would require the decision to convert the current food supply chain into energy production, which could have other major policy implications. Crop residues, on the other hand, are generally underutilized and undervalued, which should allow for an easier decision to use these resources.
- In the case of energy crops, New Jersey would also need to decide whether to maintain the current crop varieties, or introduce new crops that may be better suited to energy production (e.g.. poplar or switchgrass).

Agriculture and Forestry Biomass



There are several reasons for not practically recovering all of New Jersey's biomass:

1. ***Lack of collection and transport infrastructure for certain feedstocks***

   New Jersey's municipal solid waste and agricultural crops maintain a well established collection and delivery infrastructure. For agricultural and forestry residues, such a system may have to be created or revamped in order for owners of collection operations to consider and/or implement retrieval of aforementioned residues.

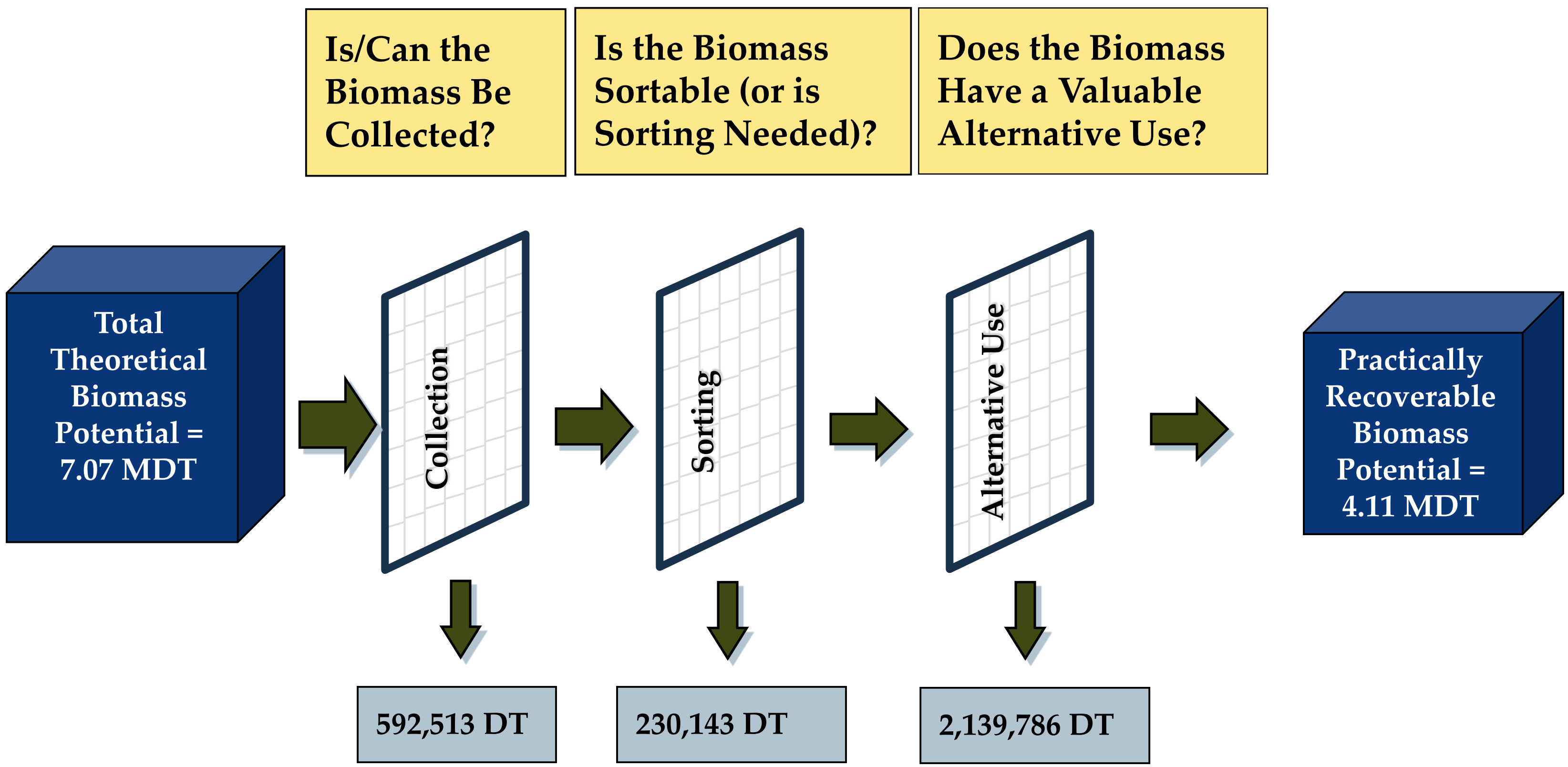
2. ***Co-mingling of significant quantities of biomass with other wastes***

   Further source separation practices will be needed if New Jersey is to take advantage of wastes that are now fully separated, such as food waste and C&D wood. This will require a change in behavior for businesses and residents which may be difficult to achieve.

3. ***Competition from existing uses***

   Much of New Jersey's urban waste biomass is currently recycled and used in alternative markets. These markets are well established, and may offer a higher value than (present) energy costs, especially given the technology costs for energy conversion.

The results of this process indicate that approximately 4.11 MDT (~58%) of New Jersey's biomass could ultimately be available to produce energy in the form of power, heat, or transportation fuels.



Note: This screening process is preliminary and would require considerably more analysis to reach any final conclusions. The screening analysis has been incorporated into the database, and provides flexible "scenario analysis" capabilities for the user.

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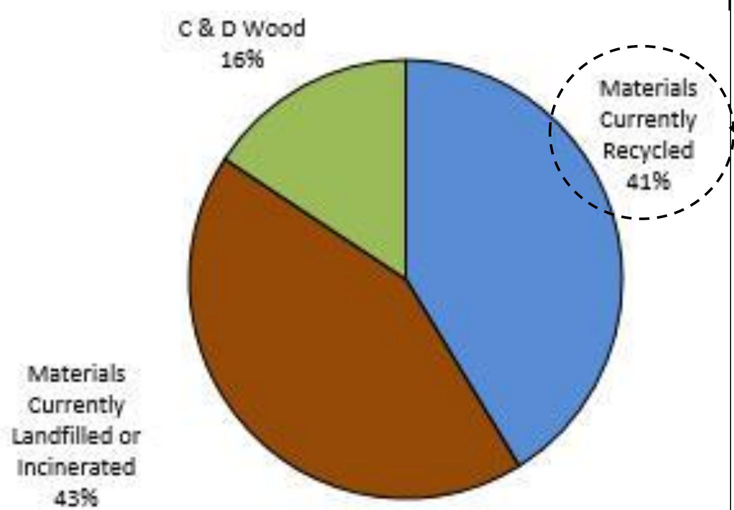
This chart provides one example of how the solid waste resource potential can be impacted when considering possible alternative uses.

Solid Waste Biomass Resource Composition (dry tons/y)



Total = 3.7 million dry tons/y[1]

Recycled Materials	2012 (dry tons)
Newspaper	269,912
Corrugated	736,576
Mixed Office Paper	174,899
Other Paper	147,229
Food Waste	66,877
Wood Scraps	129,507
TOTAL	1,524,999

Many recycled materials have an alternative market that may be more lucrative than energy production.

1. Includes amounts currently incinerated. (New chart does not include incinerated solid waste) Note that these are gross quantities, not taking into account differences in heat content per ton

Mapping out a strategy for effective biomass resource utilization is a valuable next step for New Jersey in understanding the actual potential.

Biomass Resource Utilization Strategy					
Biomass Locational Mapping	**Understand Quality Characteristics**	**Determine Infrastructure Requirements**	**Determine Most Appropriate Use**	**Develop Collection Plan**	**Develop Separation Plan**
Use GIS mapping to determine location of resources, including central nodes that might make good plant locations	Compile quality characteristics of proximal resources to determine compatibility with prospective facility	Evaluate collection, delivery, and handling infrastructure needed to process resources at each facility or node	For those resources that have an alternative use, decide whether the alternative use is preferred to energy production	For resources not currently collected, develop a viable collection plan	For resources not currently separated from the waste stream, develop separation plan

Bioenergy Calculator

- A unique **Bioenergy Calculator** and interactive biomass resource database were developed to aggregate all biomass and technology information.

- This database contains a number of important features: Detailed biomass resource data, by county, for more than **40 biomass resources**.

- Summary of energy generation data for **7 major bioenergy technologies** that takes into consideration advances in energy output and efficiency over time.

- The database was designed to analyze the biomass resource data and technology assessment data in an interactive fashion. The database is:
  - Structured by county and resource type.
  - Contains technology performance estimates to convert biomass quantities into energy (electricity and fuel) potential.

Statewide Biomass Totals

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FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	7,465	NA
	Rye	8,030	NA
	Corn for Grain	217,669	NA
	Wheat	42,086	NA
	Processing Residues (waste sugars)	0	NA
	Subtotal	***275,250***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultural crop residuals		
	Sweet Corn	5,257	66,166
	Rye	28,106	0
	Corn for Grain	132,135	1,766,931
	Corn for Silage	69,075	815,018
	Alfalfa Hay	84,725	0
	Other Hay	135,337	1,055,631
	Wheat	38,846	0
	Forestry Residues	916,426	7,148,123
	Processing Residues (lignocellulosic)	125,562	2,051,182
	Yard waste		
	Brush/Tree Parts	268,797	4,757,705
	Grass Clippings	41,284	644,026
	Leaves	253,055	3,947,657
	Stumps	25,855	457,641
	Subtotal	***2,124,461***	***22,710,079***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	211,384	2,029,282
	Waste paper, Landfilled	779,661	9,057,784
	Other Biomass, Landfilled	599,722	6,270,595
	C&D (Non-recycled wood)	917,995	10,399,042
	Recycled Materials		
	Food Waste	66,877	1,070,039
	Wood Scraps	129,507	1,146,134
	Corrugated	736,576	0
	Mixed Office Paper	174,899	0
	Newspaper	269,912	0
	Other Paper/Mag/JunkMail	147,229	2,138,055
	Subtotal	***4,033,760***	***32,110,931***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	78,859	0
	Oils - Used cooking oil "yellow"	32,882	493,225
	Oils - Grease trap waste "brown"	3,934	118,031
	Subtotal	***115,675***	***611,256***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	20,937	61,823
	Dairy Cows	51,657	457,599
	Equine	109,693	971,707
	Sheep	5,394	15,927
	Goats	2,818	8,321
	Swine	3,210	23,694
	Poultry (layers)	13,053	156,642
	Turkeys	861	12,707
	Wastewater treatment plant biosolids	127,170	1,526,044
	Subtotal (other wastes - solid)	***334,793***	***3,234,464***
	Waste methane sources	**MMSCF**	
	Wastewater treatment plant biogas	3,411	2,111,576
	Landfill Gas	10,195	5,158,454
	Subtotal (other wastes - gaseous)	***13,606***	***7,270,030***
	Subtotal (other wastes - all)	***852,403***	***10,504,494***
	TOTAL BIOMASS	**7,401,548**	

Bioenergy Calculator – Main Page

	Totals from Selected technology:				
Pick from Drop-Down Menu Below:	**2010**	**2015**	**2020**	**2025**	
Gasification-Stand Alone BIGCC	**5,196,222**	**5,327,560**	**5,493,585**	**5,654,998**	**MWh/yr**
Cellulosic Ethanol	**146,741,506**	**181,165,636**	**214,272,765**	**249,155,206**	**gallons/yr**

			Net Usable Quantity (Dry Tons)				Electricity Production Potential (MWh/Yr)			
FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)	2010	2015	2020	2025	2010	2015	2020	2025
Energy crops - starch/sugar based										
Sorghum	7,465	NA	0	0	0	0	-	-	-	-
Rye	8,030	NA	0	0	0	0	-	-	-	-
Corn for Grain	217,669	NA	0	0	0	0	-	-	-	-
Wheat	42,086	NA	0	0	0	0	-	-	-	-
Processing Residues (waste sugars)	0	NA	0	0	0	0	-	-	-	-
Subtotal	*275,250*	*0*	*0*	*0*	*0*	*0*	-		-	-
Energy crops - lignocellulosic	0	0	0	0	0	0	-	-	-	-
Agricultural crop residuals										
Sweet Corn	5,257	66,166	4,206	4,206	4,206	4,206	6,787	6,787	6,787	6,787
Rye	28,106	0	0	0	0	0	-	-	-	-
Corn for Grain	132,135	1,766,931	112,314	112,314	112,314	112,314	181,250	181,250	181,250	181,250
Corn for Silage	69,075	815,018	51,806	51,806	51,806	51,806	83,604	83,604	83,604	83,604
Alfalfa Hay	84,725	0	0	0	0	0	-	-	-	-
Other Hay	135,337	1,055,631	67,669	67,669	67,669	67,669	108,286	108,286	108,286	108,286
Wheat	38,846	0	0	0	0	0	-	-	-	-
Forestry Residues	916,426	7,148,123	458,213	458,213	458,213	458,213	733,248	733,248	733,248	733,248
Processing Residues (lignocellulosic)	125,562	2,051,182	125,562	125,562	125,562	125,562	210,409	210,409	210,409	210,409
Yard waste										
Brush/Tree Parts	268,797	4,757,705	268,797	273,977	281,093	287,250	488,041	497,446	510,367	521,546
Grass Clippings	41,284	644,026	41,284	41,857	42,649	43,398	66,064	66,982	68,249	69,447
Leaves	253,055	3,947,657	253,055	256,946	262,324	267,121	404,947	411,174	419,780	427,456
Stumps	25,855	457,641	25,855	26,485	27,427	28,209	46,944	48,088	49,798	51,218
Subtotal	*2,124,461*	*22,710,079*	*1,408,761*	*1,419,036*	*1,433,265*	*1,445,749*	*2,329,580*	*2,347,273*	*2,371,779*	*2,393,251*
Solid wastes - Landfilled										
Food waste, Landfilled	214,287	2,057,151	128,572	130,810	133,925	136,549	-	-	-	-
Waste paper, Landfilled	779,661	9,057,784	623,728	634,504	649,527	662,233	929,140	945,192	967,571	986,498
Other Biomass, Landfilled	599,722	6,270,595	431,800	439,260	449,660	458,456	643,232	654,345	669,838	682,940
C&D (Non-recycled wood)	582,996	6,604,177	373,117	398,544	429,127	460,234	677,451	723,616	779,145	835,624
Recycled Materials										
Food Waste	66,877	1,070,039	66,877	74,005	82,121	91,026	-	-	-	-
Wood Scraps	129,507	1,146,134	64,753	71,978	80,428	89,646	117,569	130,686	146,029	162,767
Corrugated	736,576	0	0	0	0	0	-	-	-	-
Mixed Office Paper	174,899	0	0	0	0	0	-	-	-	-
Newspaper	269,912	0	0	0	0	0	-	-	-	-
Other Paper/Mag/JunkMail	147,229	2,138,055	147,229	163,601	182,715	203,446	219,320	243,709	272,182	303,064
Subtotal	*3,701,664*	*28,343,935*	*1,836,077*	*1,912,702*	*2,007,504*	*2,101,590*	*2,586,712*	*2,697,548*	*2,834,766*	*2,970,892*

Bioenergy Calculator Demonstration
Net Usability Assumptions

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Feedstock Net Usability Assumptions				
Feedstocks	Practically Recoverable Percentage	Collectibility	Sortable or Sort N/A	Alt Use? (0=Yes)
Agricultural Crops - starch/sugar based				
Sorghum	0%	100%	100%	0%
Rye	0%	100%	100%	0%
Corn for Grain	0%	100%	100%	0%
Wheat	0%	100%	100%	0%
Food Processing Residues (waste sugars)	50%	100%	100%	50%
Energy crops - lignocellulosic	100%	100%	100%	100%
Agricultural crop residuals				
Sweet Corn	80%	80%	100%	100%
Rye	0%	90%	100%	0%
Corn for Grain	85%	85%	100%	100%
Sorghum	75%	75%	100%	100%
Alfalfa Hay	0%	100%	100%	0%
Other Hay	50%	100%	100%	50%
Wheat	0%	90%	100%	0%
Forestry Residues	50%	50%	100%	100%
Processing Residues (lignocellulosic)	100%	100%	100%	100%
Yard waste (collected)				
Brush/Tree Parts	100%	100%	100%	100%
Grass Clippings	100%	100%	100%	100%
Leaves	100%	100%	100%	100%
Stumps	100%	100%	100%	100%
Solid wastes - Landfilled				
Food waste, Landfilled	60%	100%	75%	80%
Waste paper, Landfilled	80%	100%	100%	80%
Other Biomass, Landfilled	72%	100%	90%	80%
C&D, Non-recycled wood	64%	100%	80%	80%
Recycled Products				
Food Waste	100%	100%	100%	100%
Wood Scraps	50%	100%	100%	50%
Corrugated	0%	100%	100%	0%
Mixed Office Paper	0%	100%	100%	0%
Newspaper	0%	100%	100%	0%
Other Paper/Mag/JunkMail	100%	100%	100%	100%
Oils - field crop or virgin				
Soybeans	100%	100%	100%	100%
Oils - Used cooking oil "yellow"	50%	100%	100%	50%
Oils - Grease trap waste "brown"	100%	100%	100%	100%
Agricultural livestock waste				
Beef Cattle	20%	20%	100%	100%
Dairy Cows	60%	60%	100%	100%
Equine	60%	60%	100%	100%
Sheep	20%	20%	100%	100%
Goats	20%	20%	100%	100%
Pigs	50%	50%	100%	100%
Poultry (layers)	100%	100%	100%	100%
Turkeys	100%	100%	100%	100%
Wastewater treatment plant biosolids	100%	100%	100%	100%
Wastewater treatment plant biogas	100%	100%	100%	100%
Landfill Gas	100%	100%	100%	100%

III. Technology Assessment

An early part of the project design was to identify the leading biomass-to-energy conversion technologies that should be evaluated.

Section III assesses existing and emerging biomass conversion technologies. Considerations for this analysis included:

- There are numerous *technically feasible* bioenergy conversion technologies. However, certain technologies that are not well developed yet and/or are likely to be applicable mainly to niche applications were generally excluded from detailed analysis.
- Although there are many biomass feedstocks that *could* be used with a particular conversion technology, in practice, certain feedstocks are better suited to certain conversion processes.
- Given the wide range of technologies within a particular "platform" (e.g., types of biomass gasification reactors), the analysis focuses on broad technology platforms with similar characteristics. Representative feedstock-conversion-end use pathways were selected for the economic analysis.
- The decision to screen out specific technologies *for the current analysis* does not mean that it will not find some application in New Jersey in the future.

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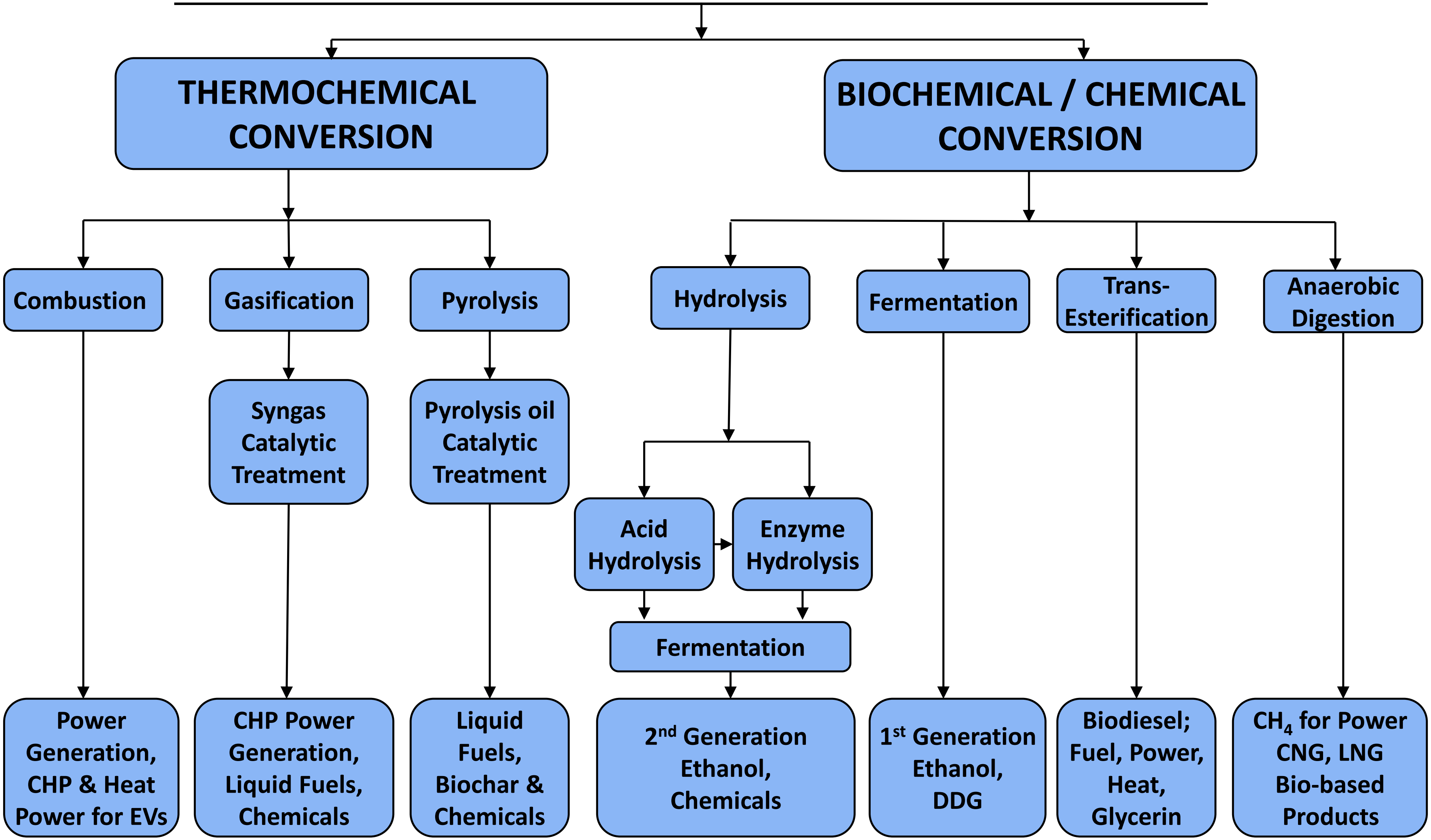
Technology Development and Commercialization Pathway

R&D	Demonstration: Initial System Prototypes	Demonstration: Refined Prototypes	Demonstration: Commercial Prototypes	Market Entry	Market Penetration	Market Maturity
• Research on component technologies • General assessment of market needs • Assess general magnitude of economics	• Integrating component technologies • Initial system prototype for debugging • Monitoring Policy & Market developments	• Ongoing development to reduce costs or for other needed improvements • Technology (systems) demonstrations • Some small-scale "commercial" demonstrations	• Commercial demonstration • Full size system in commercial operating environment • Communicate program results to early adopters/ selected niches	• Commercial orders • Early movers or niche segments • Product reputation is initially established • Business concept implemented • Market support usually needed to address high cost production	• Follow-up orders based on need and product reputation • Broad(er) market penetration • Infrastructure developed • Full-scale manufacturing	• Roll-out of new models, upgrades • Increased scale drives down costs and results in learning
10+ years	4 - 8 years			1 - 3 years	5-10 years	Ongoing

The time required to pass through any given stage can vary considerably. The values shown are representative of a technology that passes successfully from one stage to the next without setbacks.

BIOMASS-to-BIOENERGY & BIOPRODUCTS CONVERSION PATHWAYS



Technology Assessment

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Application	Thermochemical Conversion			Bio-Chemical/Chemical Conversion			
	Combustion	Gasification	Pyrolysis	Hydrolysis	Trans-Esterification	Fermentation	Anaerobic Digestion
Power	• Direct combustion • Small Scale CHP for Solid Biomass • Biomass co-firing with coal	• BIGCC • Power generation from gasification • small scale CHP			• Biodiesel for power generation		• Landfill Gas • Food waste AD • WWTP
CHP/ Heat	• CHP	• CHP			• Biodiesel for heat		• Biogas for heat
Transportation Fuels	• Clean Electricity for Electric Vehicles	• Biomass to drop in fuels	• Pyrolysis oils to drop in fuels.	• Enzyme Hydrolysis • Acid Hydrolysis to produce fuels	• Vegetable and waste oils to biodiesel	• Corn and sugars to ethanol	• RNG in the form of CNG & LNG
Bio-based Products		• Chemicals, bio-based products	• Chemicals, bio-based products • Biochar	• Chemicals, bio- based products	• Glycerin	• DDG as feed	• Bio-based fertilizer

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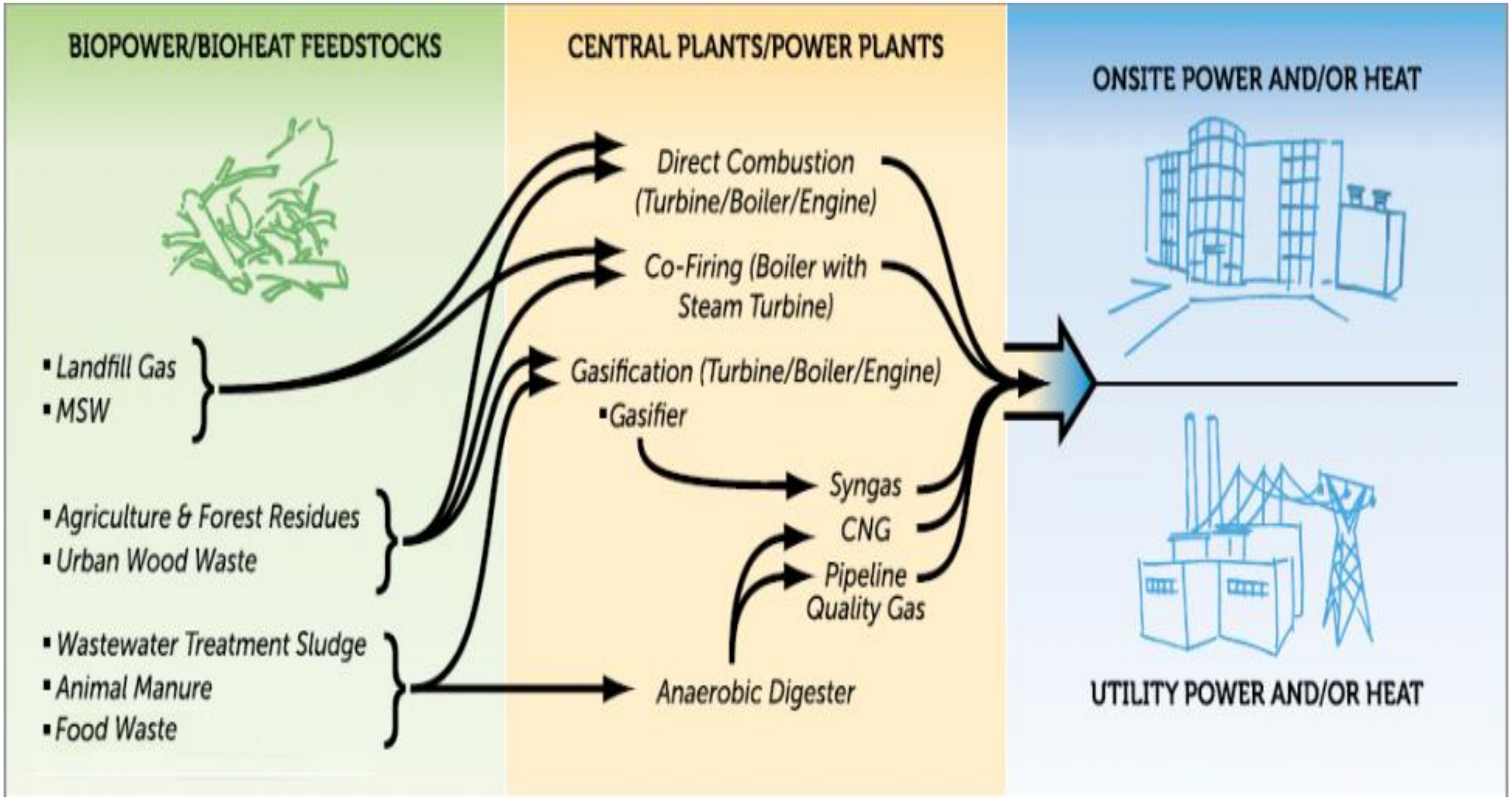
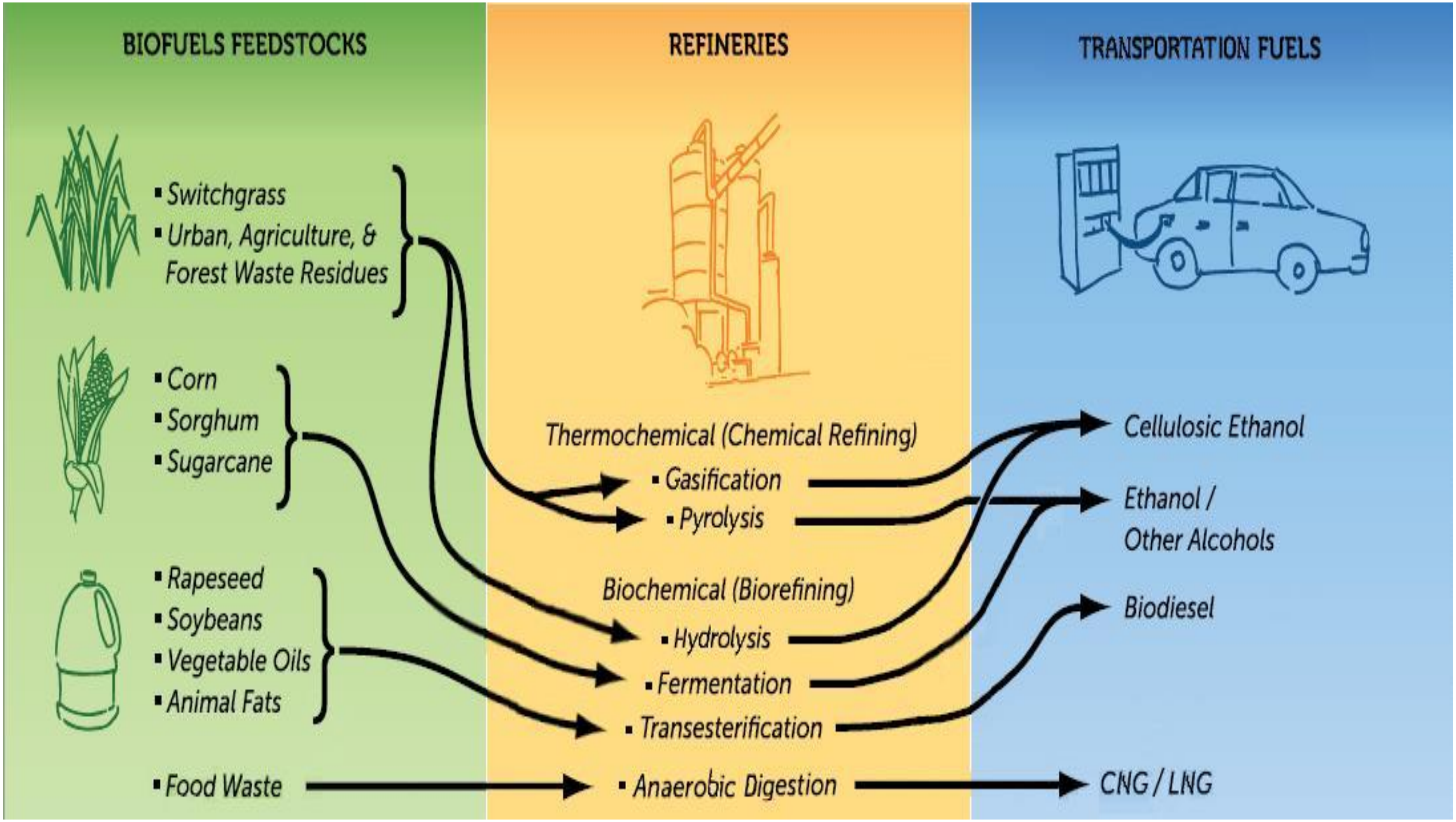
BIOPOWER & BIOHEAT PATHWAYS



State Bioenergy Primer
http://www.epa.gov/statelocalclimate/documents/pdf/bioenergy.pdf

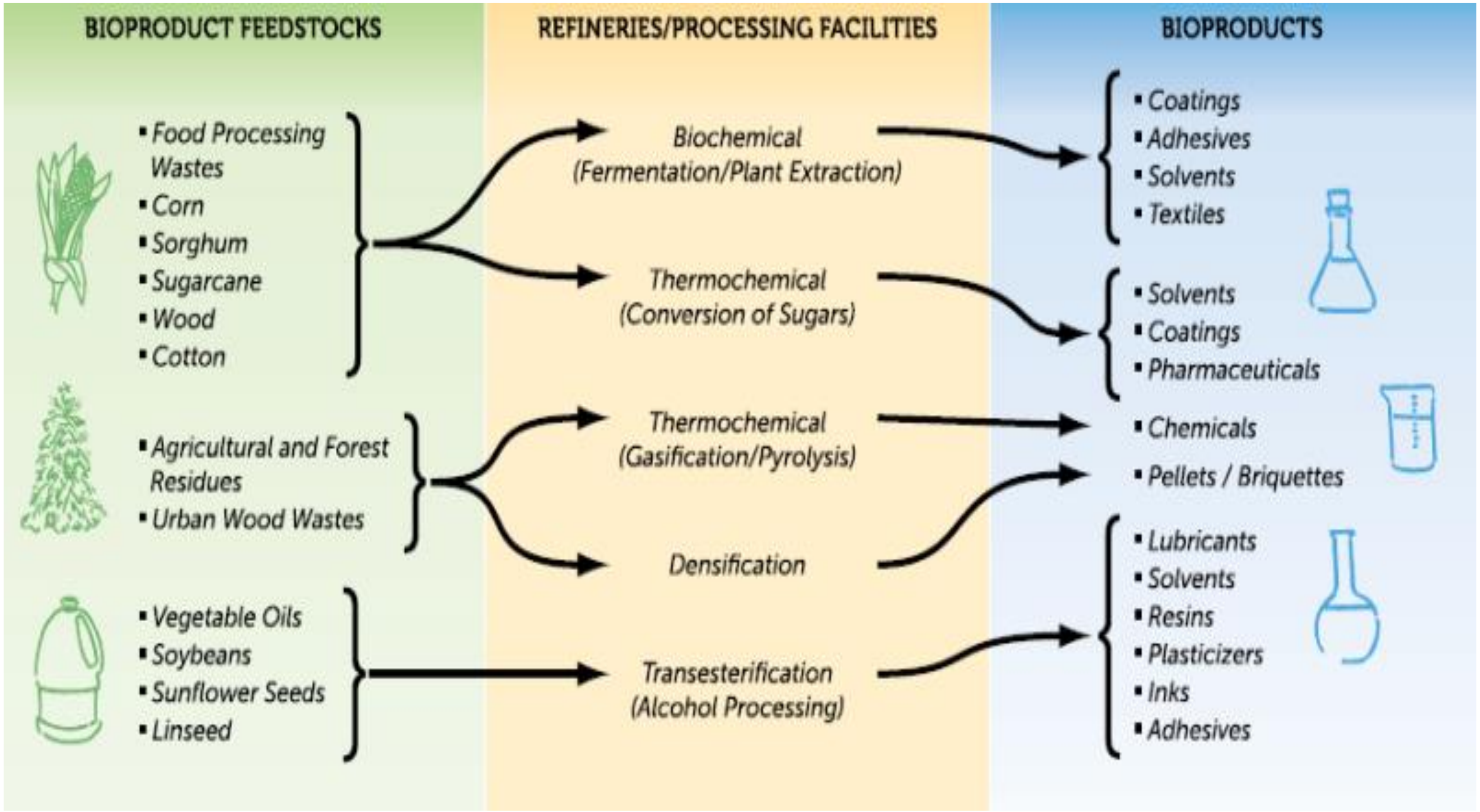
* State Bioenergy Primer

BIOFUELS PATHWAYS



State Bioenergy Primer
http://www.epa.gov/statelocalclimate/documents/pdf/bioenergy.pdf

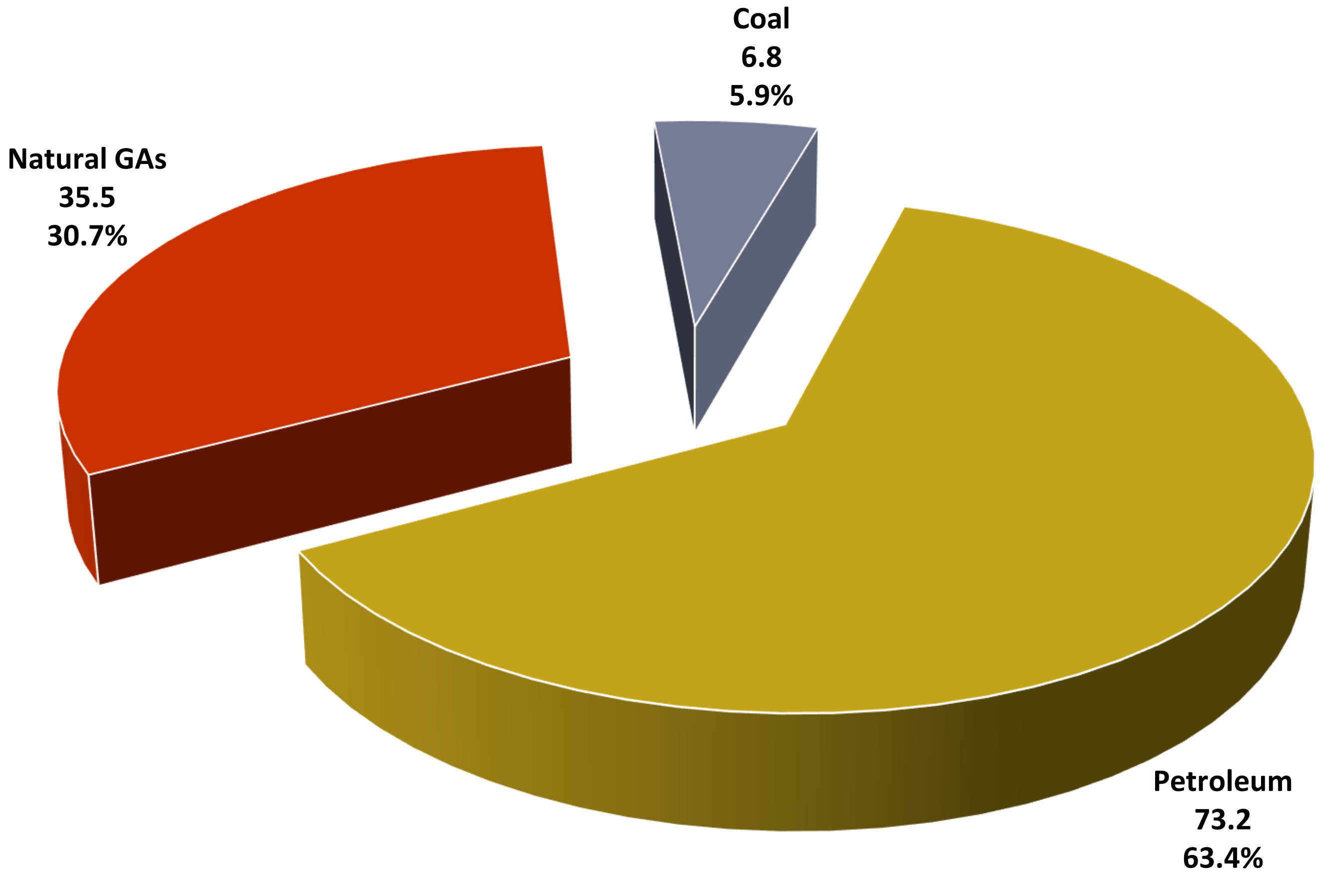
BIOPRODUCT FEEDSTOCKS



State Bioenergy Primer
http://www.epa.gov/statelocalclimate/documents/pdf/bioenergy.pdf

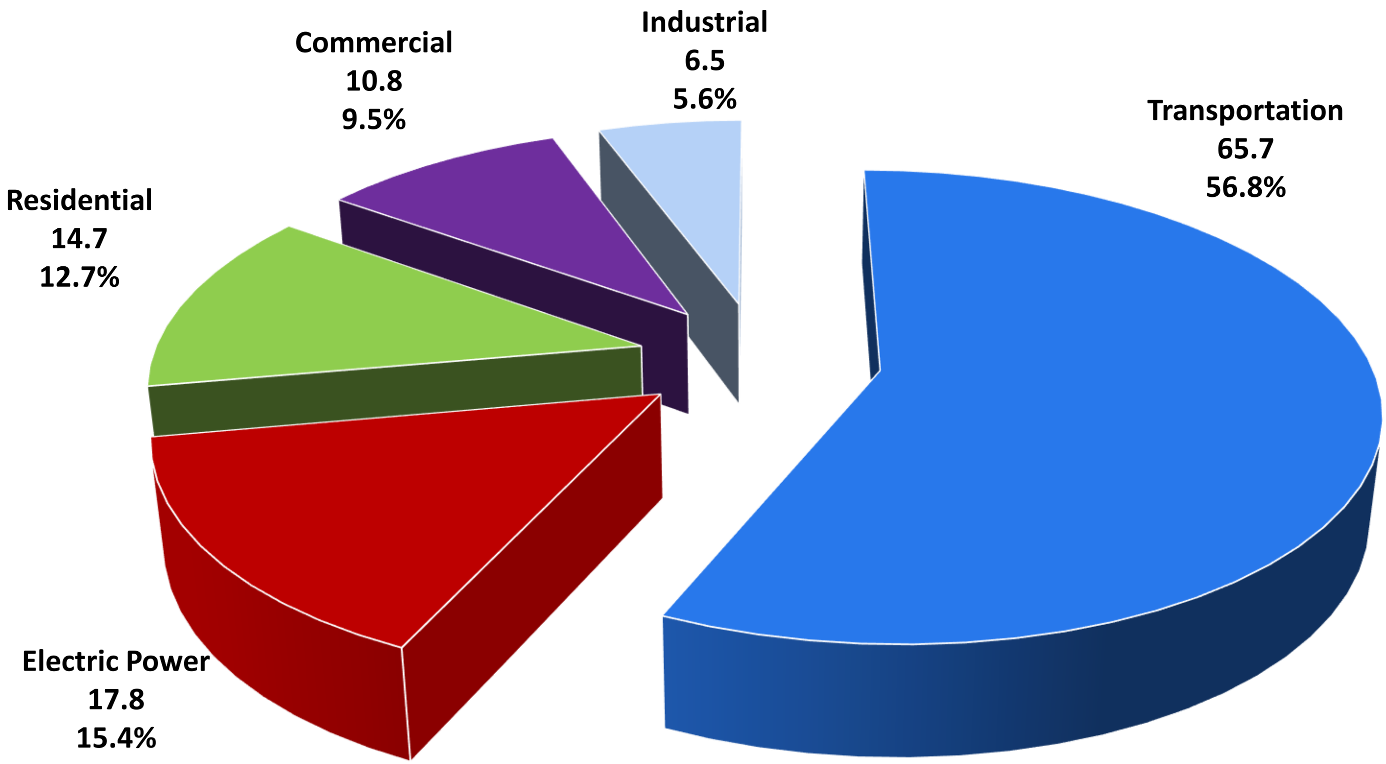
IV. GHG Reduction Scenarios

NJ Energy Related CO_2 Emissions by Fuel (million mtons/y, %)



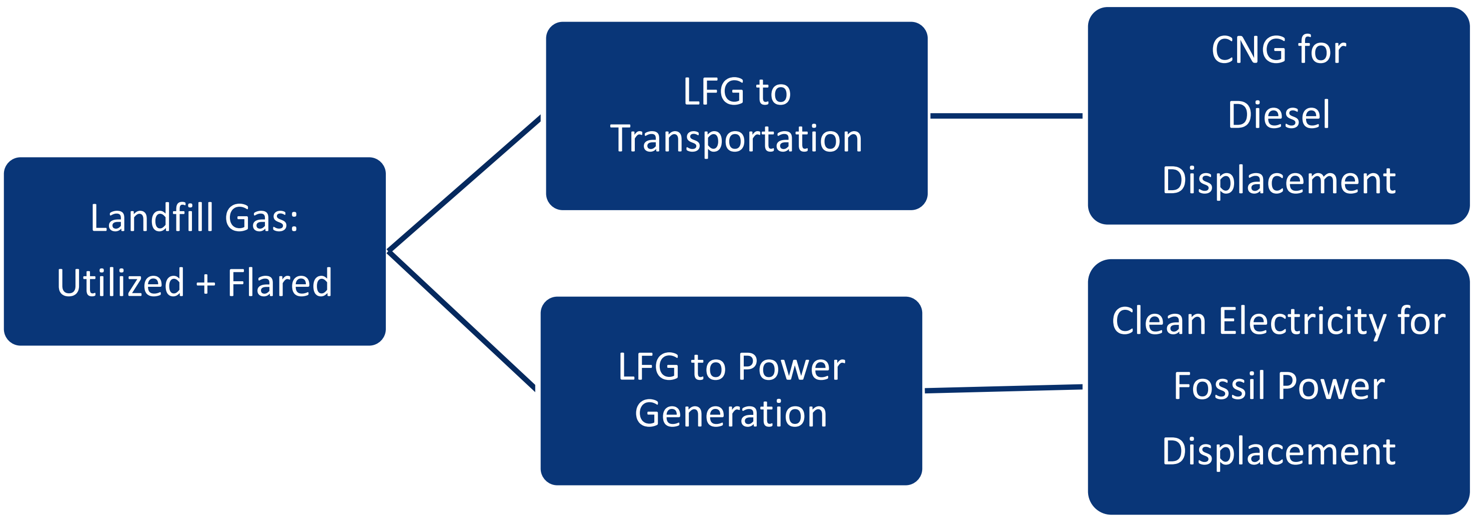
**http://www.eia.gov/environment/emissions/state/state_emissions.cfm*
*** 2012 Emissions*

NJ Energy Related CO_2 Emissions by Sector (million mtons/y, %)



**http://www.eia.gov/environment/emissions/state/state_emissions.cfm*
*** 2012 Emissions*

SCENARIO: Landfill Gas to Energy



Greenhouse Gas Reduction Potential: Landfill Gas to Power Generation

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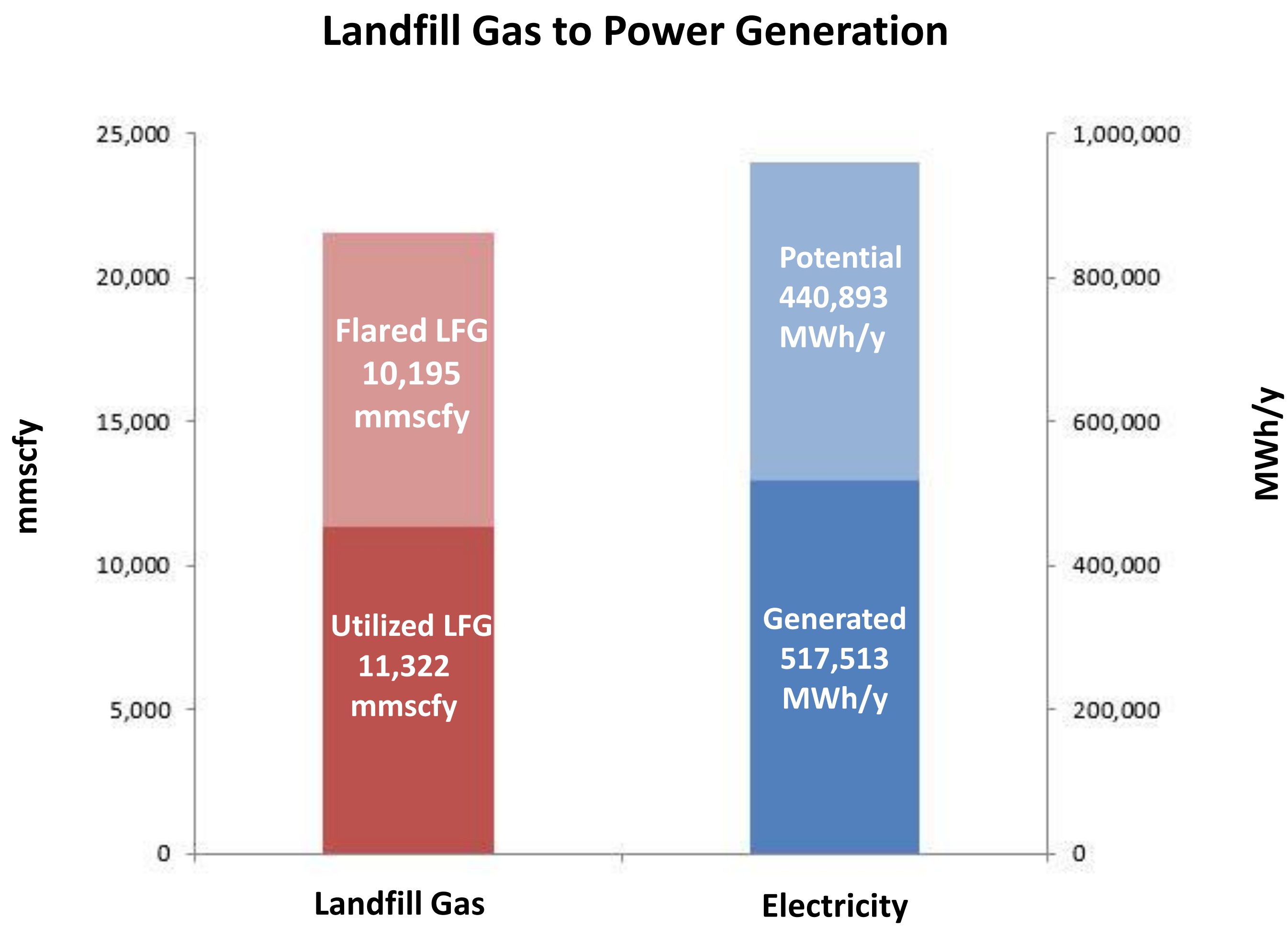

Greenhouse Gas Reduction Potential: Landfill Gas to Power Generation

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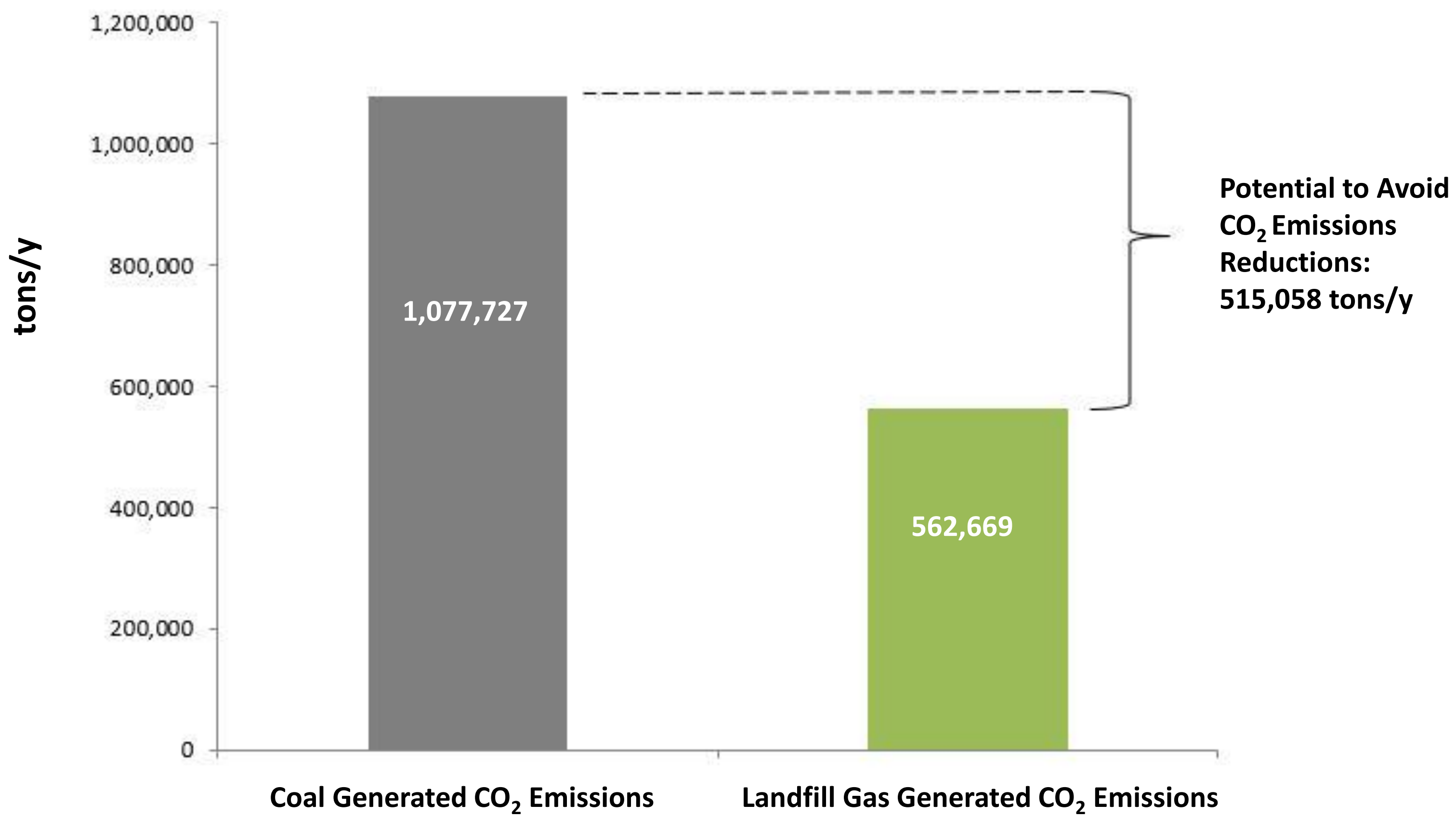
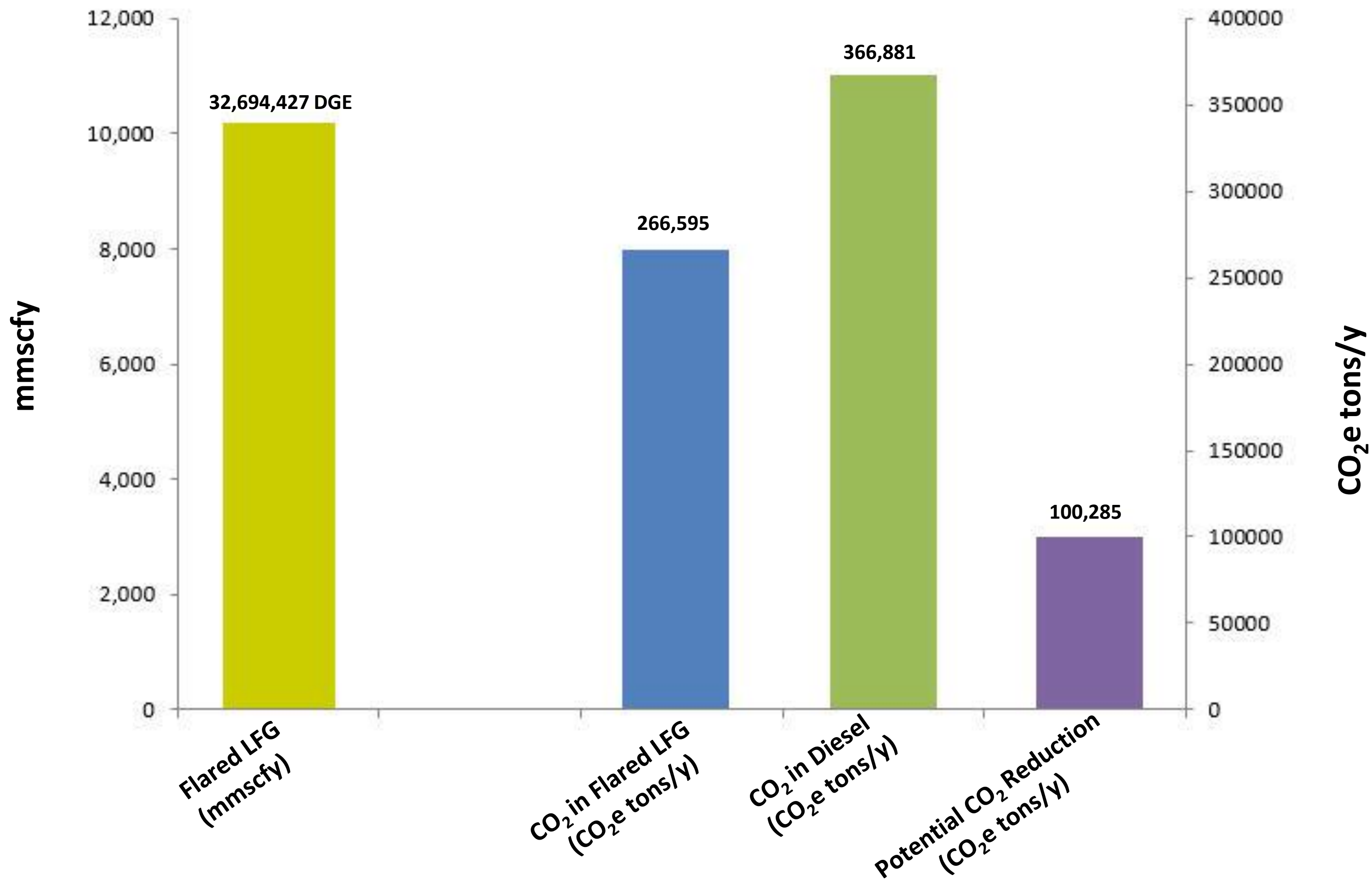
If the total LFG to electricity generation is achieved and assumed to displace coal generated power, New Jersey's net CO_2 reduction potential would be 515,058 tons per year.*



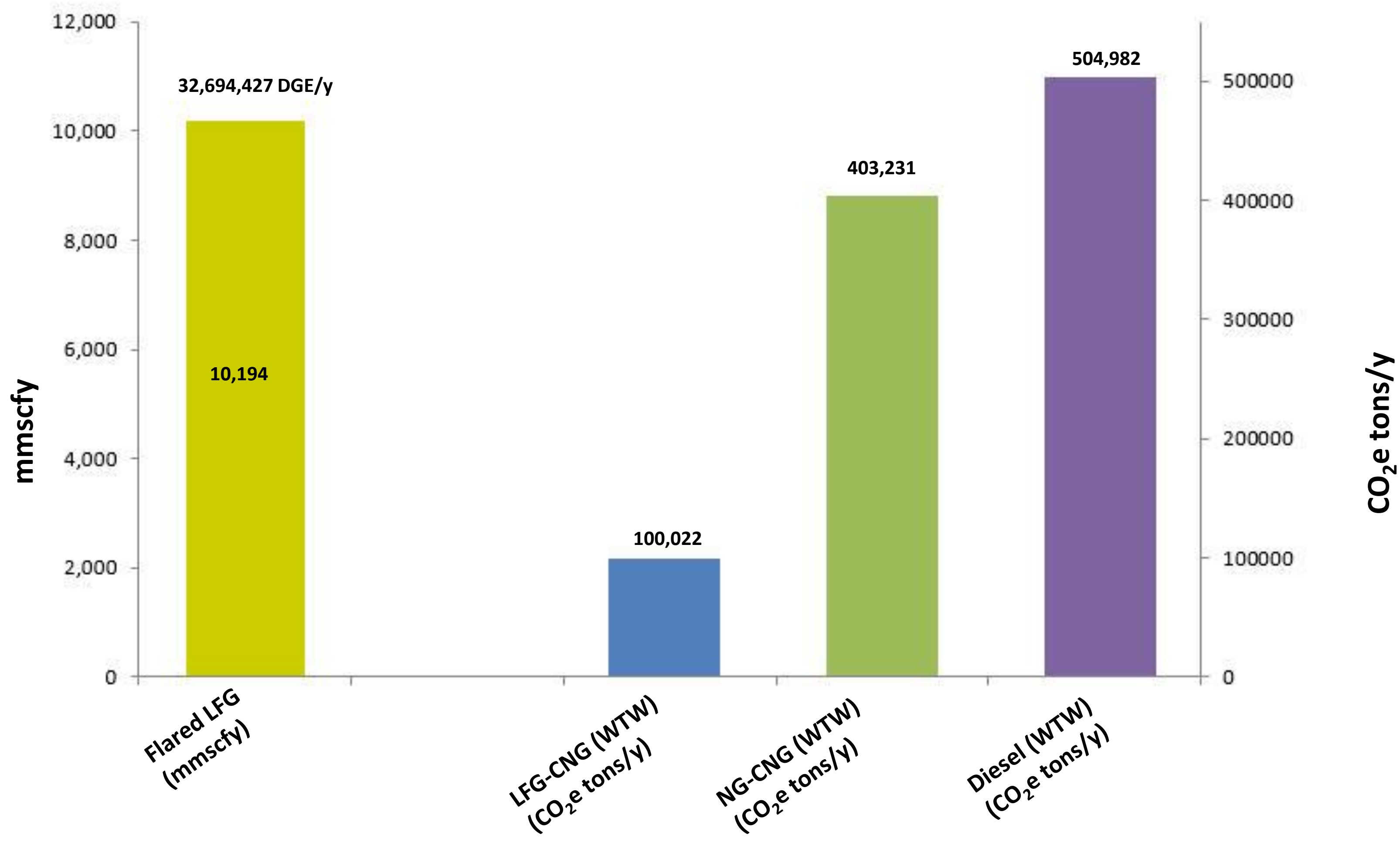
*The values in this chart are calculated based on a scenario that takes flaring as baseline.

LFG to CNG for Fossil Diesel Displacement

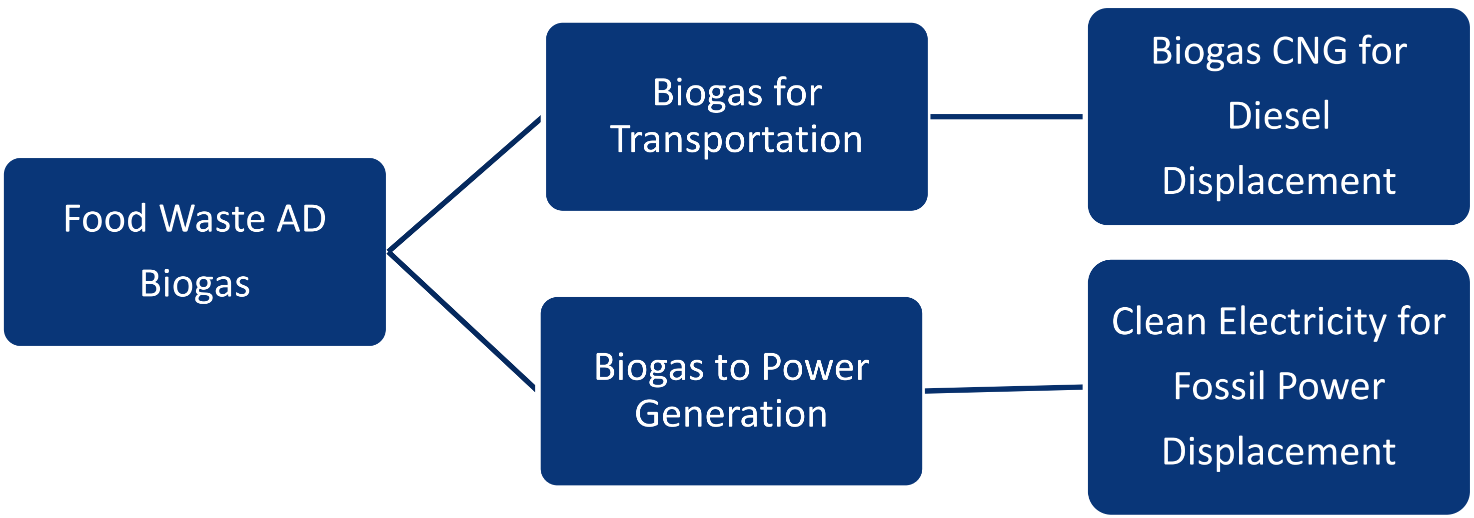


*The values in this chart are calculated based on a scenario that takes flaring as the baseline and does not include process emissions and byproduct credits.

LFG to CNG GREET Comparison



SCENARIO: Food Waste AD to Energy



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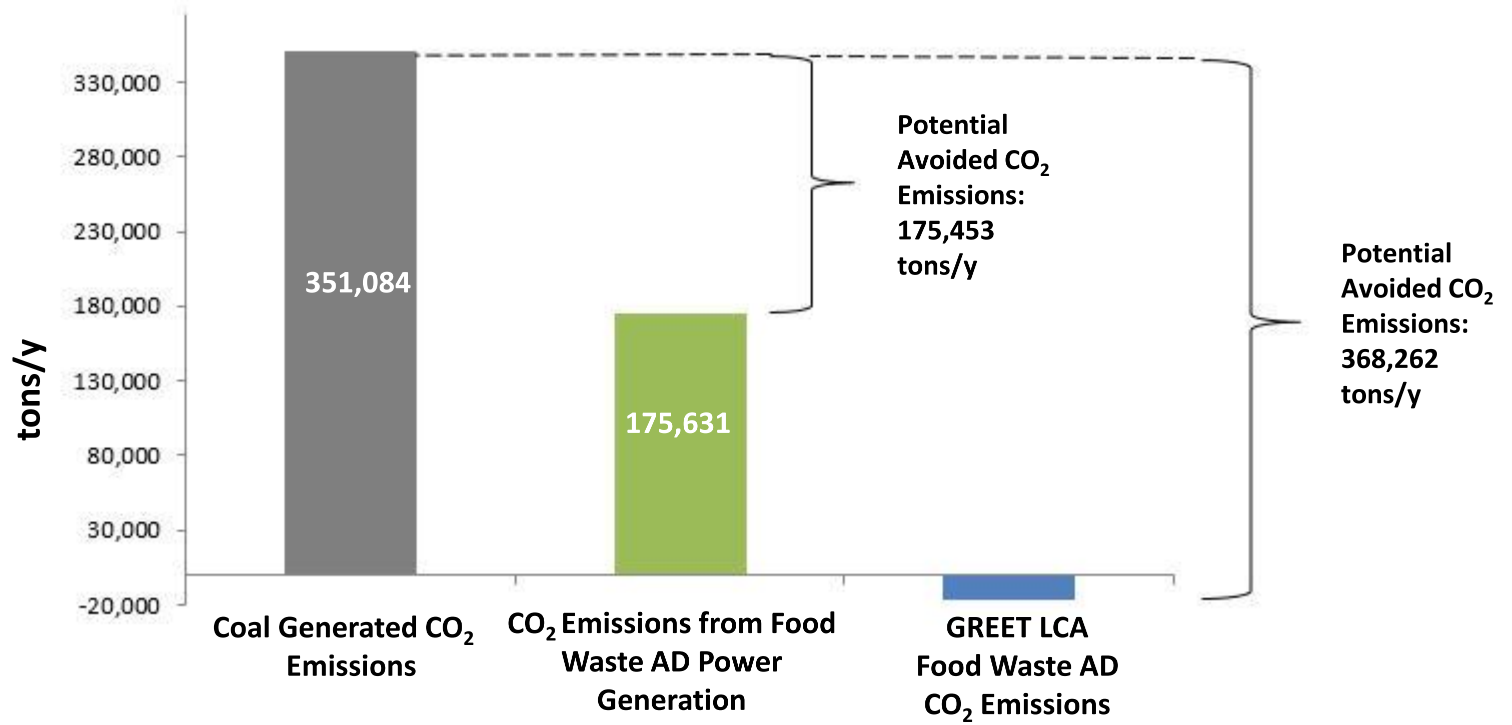
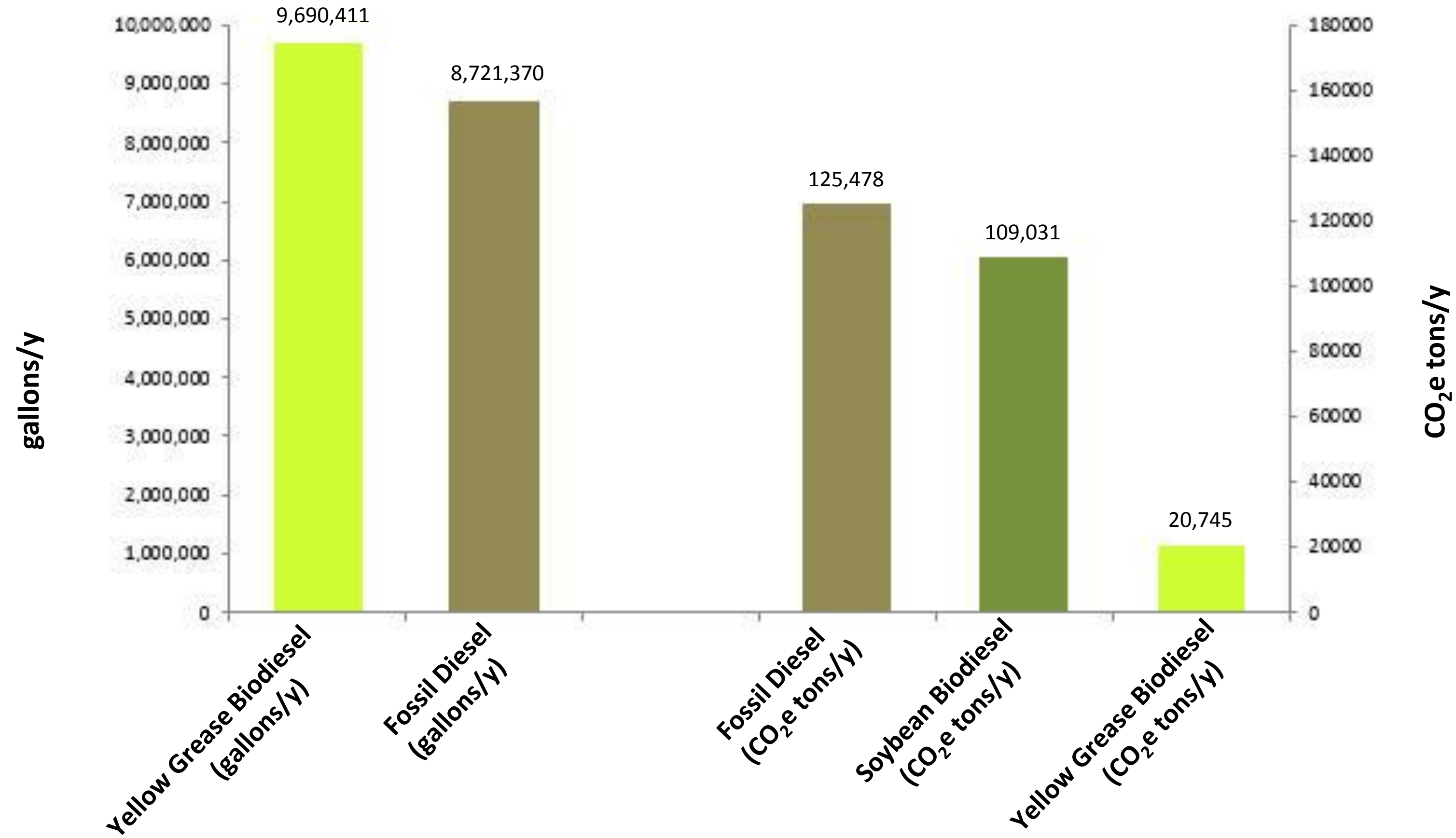
Food Waste AD Biogas for Power Generation Potential CO_2 Reductions Comparison



Yellow Grease Biodiesel to Displace Fossil Diesel



**Carbon Intensity Lookup Table, www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf (accessed 10/10/13)*
Well-to-Wheels Analysis of LFG Gas-Based Pathways. ANL/ESD/10-3

Greenhouse Gas Reduction Potential: Forestry Waste to 2nd Generation Ethanol

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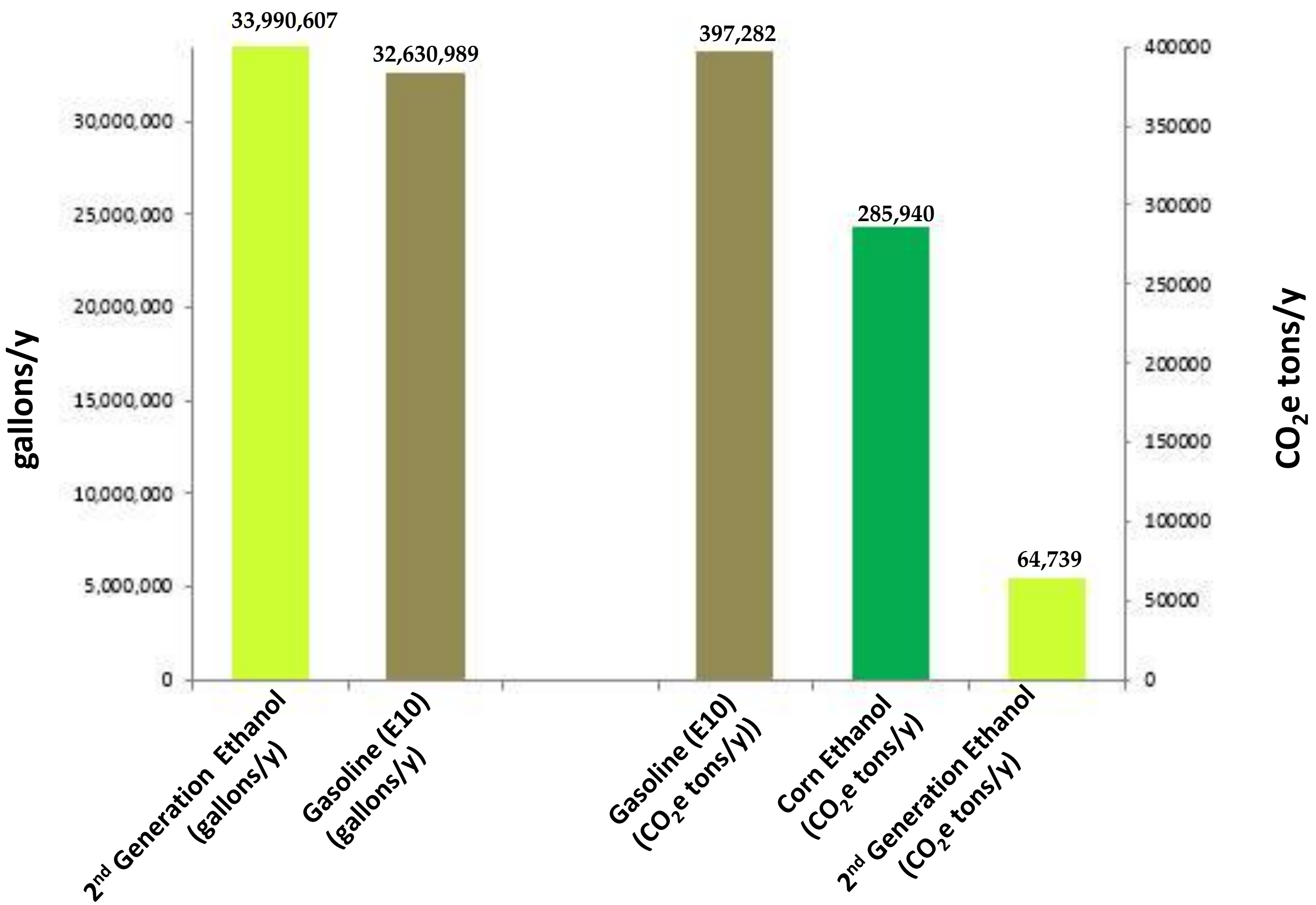
2nd Generation Ethanol to Displace Fossil Gasoline



**Carbon Intensity Lookup Table, www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf (accessed 10/10/13)*
**Well-to-Wheels Analysis of LFG Gas-Based Pathways. ANL/ESD/10-3*

ELECTRICITY

- New Jersey averaged the sixth highest electricity prices in the Nation in 2011.*
- New Jersey's Renewable Portfolio Standard requires that 22.5 percent of electricity sold in the state come from renewable energy sources by 2021, with 17.88 percent coming from Class I and 2.5 percent coming from Class II renewable energy**.
- Class I Renewable Energy definitions include sustainable biomass, biogas, landfill gas, biogas from food waste anaerobic digestion and waste water treatment facilities.
- Average site energy consumption (127 million Btu per year) in New Jersey homes and average household energy expenditures ($3,065 per year) are among the highest in the country, according to EIA's Residential Energy Consumption Survey.
- New Jersey's 2011 State Energy Master Plan*** identified "Biomass and Waste-to-Energy" as one of the energy generation resources.
- This section highlights possible capital costs if an emerging technology is going to be developed.

* *http://www.eia.gov/state/?sid=NJ*
** *N.J.A.C. 14:8-2.5 and 2.6*
****New Jersey State Energy Master Plan, 2011*

TRANSPORTATION

- Biofuels industry has two critical milestones in its development:
  - Consumers and vehicle manufacturers must adopt new environmentally friendly fuels. Biofuels consumption has to displace the fossil fuels.
  - Advanced biofuel manufacturers must demonstrate technical and commercial capability to meet Renewable Fuel Standard II requirements.
- Approximately 99% of all biofuel consumption in the US is in the form of 1st generation ethanol and biodiesel.
- For the past few years the conventional ethanol demand leveled due to saturation of the gasoline market with fuel containing 10% ethanol.
- In 2011 the USEPA approved the use of E15 (15 % ethanol blend) gasoline in all cars and light trucks made since 2011. However, concerns from consumers and vehicle manufacturers limit uptake. The use of E85 gasoline faces similar challenges since very few vehicles can handle the blend.
- There is a potential of advanced ethanol from energy crops, agricultural waste, MSW and algae. Progress has been slow but 15bn gallons cap for 2015 is encouraging.
- The market price of advanced ethanol is difficult to predict. Coupling fuel production with bio-products will provide wider opportunities to advanced biofuels.
- MSW, food waste, used oil and fats prove that they are becoming attractive feedstocks.
- Animal fats are attractive feedstocks for biodiesel because their cost is lower than vegetable oil.

** Waste to Biofuels Market Analysis 2013, Renewable Waste Intelligence, December 2012.*

BIO-BASED PRODUCTS & BIO-CHEMICALS

- Global demand is growing rapidly.
- Interest levels for low-carbon products are promising.
- Flexibility to produce bio-chemicals and bio-products secures operational continuity if market conditions become unattractive for advanced biofuels production.
- USDA Bio Preferred program and new voluntary labels of "USDA Certified BioBased Product" encourage demand for eco-friendly products.
- The availability and cost of feedstocks play an important role in development.

** Waste to Biofuels Market Analysis 2013, Renewable Waste Intelligence, December 2012.*

VI. Policy Recommendations/Next Steps

HOW CAN ADVANCED BIOFUELS GOALS (RFS) BE ACHIEVED?

- Improve Immature Technology - Most applications are not ready for commercialization, inadequate scale-up, w/o piloting
- Secure Feedstock - Energy crops, waste biomass
- **Avoid Overpromising!**
- **Set Realistic Targets!**
- Encourage Investment
- Assure Impatient Venture Capital Firms (Bioenergy vs. IT)
- Provide RDD&D Funding ($$$$)
- Help Biofuels to coexist with Low Natural Gas Prices
- Provide Long Term Policy (at several levels)

Policy Recommendations/Next Steps: Summary

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Capturing New Jersey's Biomass Energy Potential – Possible Policy Considerations:				
Develop Policies to Provide Better Access to Biomass Resources	**Make NJ a Leader in Support of New Technologies**	**Integrate with Existing NJ Petrochemical/ Refining Infrastructure**	**Capitalize on Existing Policies and Practices**	**Address Regulatory Roadblocks and Inconsistencies**
• Create incentives to develop biomass "nodes" as possible plant sites, and to increase waste diversion practices • Establish Bioenergy Enterprise Zones • Create incentives to support development of feedstock infrastructure • Create educational programming to encourage more rigorous recycling efforts	• Establish/appoint a state agency with primary responsibility for developing bioenergy industry • Create Bioenergy Innovation Fund to support ongoing R&D • Promote NJ as premier location for biomass technology companies • Leverage expertise in academia & pharma/ biotech industries	• Further evaluate technologies (e.g., FT, biodiesel) that may benefit from proximity to petrochemical infrastructure • Engage industry experts in efforts to develop workable solutions	• Integrate new efforts (i.e. biofuels) with existing policies (e.g. RPS, Clean Energy Program, & MSW recycling reqs.) • Should not undermine the viability of RPS projects such as waste incineration • Analyze highest and best use of feedstocks by measuring the value of tradeoffs of alternative uses	• Biomass feedstocks and end products may be subject to different regulatory oversight; need to identify and address incongruous policies and regulations • Streamline regulatory process

Recommendations for Accelerating Bioenergy Production

Securing Feedstocks:

- Supportive, consistent policies which will create positive market signals and certainty to grow energy crops.
- Promote biomass that does not follow food-to-fuels pathways.
- Improve yield through research by scientists, engineers, agronomists and other experts (e.g. algae development, energy crops, double cropping energy crops with food crops).
- Inclusion of organic waste as feedstock.
- Efficient handling and preparation of feedstocks.
- Life Cycle Analysis to determine true environmental benefits.
- Reduce cost of feedstocks (low cost waste can help!).

Recommendations for Accelerating Bioenergy Production

Technology Development:

- Supportive, consistent policies to create positive market signals and certainty
- Secure feedstock supply - long term contracts eliminate/reduce risk
- Scientists, engineers and other experts - integrate science & engineering teams with demonstration plant and industrial partners at an early stage
- Test-beds for scale-up, pilot testing and verification
- Life Cycle Analysis to determine true environmental benefits
- Funding for RD&D and investment for commercialization
- Process flexibility to accommodate varying inbound biomass composition and maximize revenue potential
- Provide process, economic and dynamic modeling from plant operating data
- Transparency (at some level)

For more information, a detailed report and the bioenergy calculator can be found at:

http://ecocomplex.rutgers.edu/BiomassEnergyPotential.html

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