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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.

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Glossary of Acronyms Used

AD	Anaerobic Digestion
BIGCC	Biomass Integrated Gasification Combined Cycle
BTL	Biomass to Liquids
BTU	British Thermal Unit
C&D	Construction & Demolition
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
DDG	Distiller Dry Grain
DGE	Diesel Gallon Equivalent
FT	Fischer- Tropsch
GHG	Greenhouse Gas
GREET	The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
GGE	Gasoline Gallon Equivalent
HDV	Heavy Duty Vehicle
HHV	Higher Heating Value
ICE	Internal Combustion Engine
iLUC	Indirect Land Use Change
kW(h)	kilowatt (hour)
LFG	Landfill Gas
LDV	Light Duty Vehicle
LCOE	Levelized Cost of Energy (used for power)
LNG	Liquid Natural Gas
M	Million
MDT	Million Dry Ton(s)
MeTHF	Methyltetrahydrofuran
MGPY	Million Gallon per Year
MMBTU	Million British Thermal Units
MSW	Municipal Solid Waste
MW(h)	Megawatt (hour)
NJAES	New Jersey Agricultural Experiment Station
REC	Renewable Energy Certificate
RNG	Renewable Natural Gas
RPS	Renewable Portfolio Standard
MMSCF	Million Standard Cubic Foot
TPD	Ton Per Day
WWTP	Wastewater Treatment Plant

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I. Executive Summary

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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

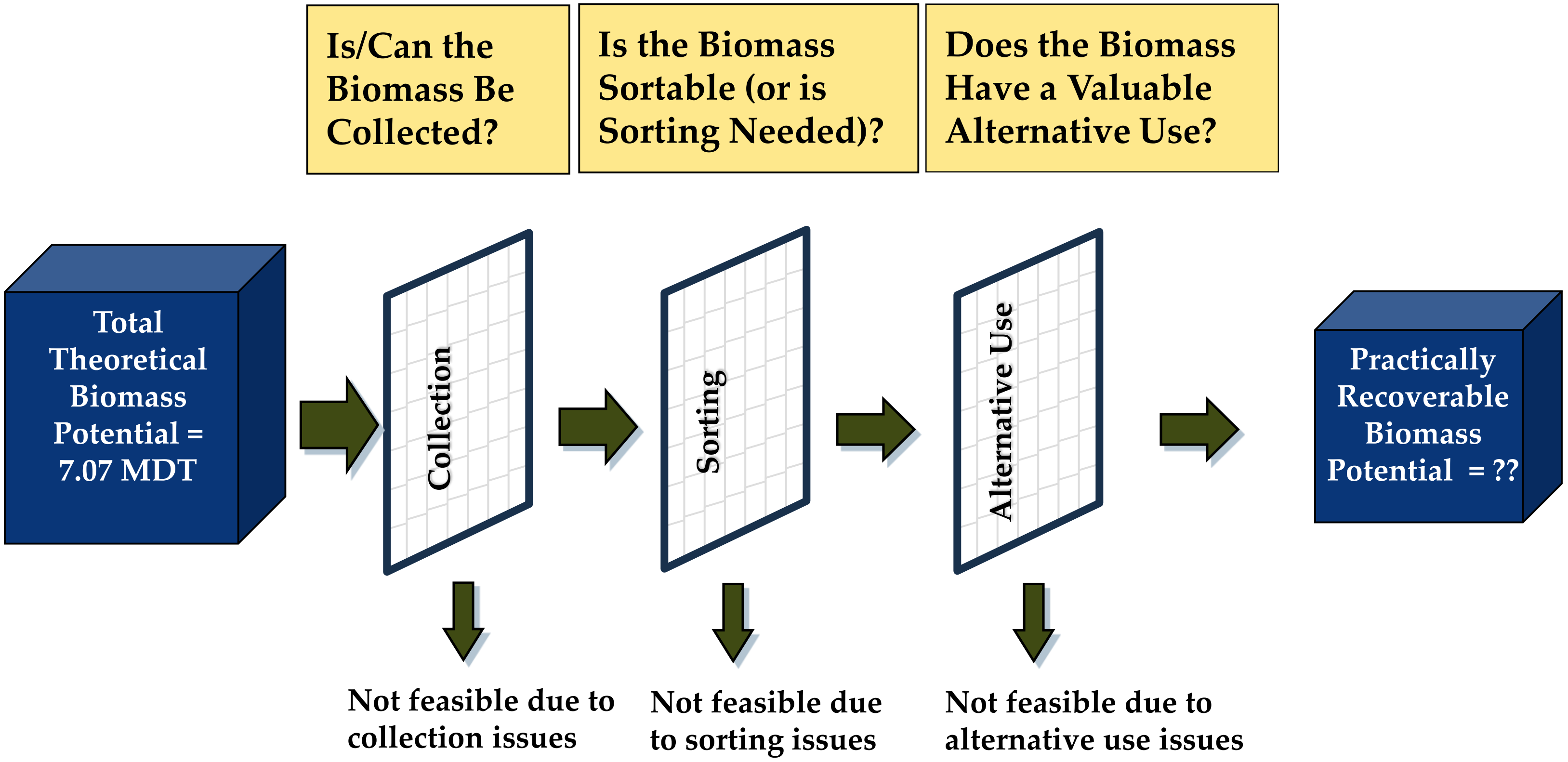
Executive Summary: Biomass Resource Categories

A range of biomass resources were examined; these can be divided into 5 categories based on their physical characteristics.

Feedstock Type	Definitions	Resources
Sugars/Starches	Traditional agricultural crops suitable for fermentation using 1st generation technologies Some food processing residues are sugar and starch materials	•Agricultural crops (sugars/starches) •Food processing residues (w/residual sugars)
Lignocellulosic Biomass	Clean woody and herbaceous materials from a variety of sources Includes clean urban biomass that is generally collected separately from the municipal waste stream (wood from the urban forest, yard waste, used pallets)	•Agricultural residues •Cellulosic energy crops •Food processing residues •Forest residues, mill residues •Urban wood wastes •Yard wastes
Fat and Oils	Traditional edible oil crops and waste oils suitable for conversion to biodiesel	•Agricultural crops (beans/oils) •Waste oils/fats/grease
Solid Wastes	Primarily lignocellulosic biomass, but that may be contaminated (e.g., C&D wood) or co-mingled with other biomass types	•Municipal solid waste (biomass portion) •C&D wood •Food wastes •Non-recycled paper •Recycled materials
Other Wastes	Other biomass wastes that are generally separate from the solid waste stream Includes biogas and landfill gas	•Animal waste (farm) •Wastewater treatment biogas and biosolids •Landfill gas

Executive Summary: Practicality of Biomass Resource Recovery

A screening process was developed to estimate how much of New Jersey's theoretically available biomass might be recoverable for bioenergy production.



Is/Can the Biomass Be Collected?

Is the Biomass Sortable (or is Sorting Needed)?

Does the Biomass Have a Valuable Alternative Use?

Total Theoretical Biomass Potential = 7.07 MDT

Collection

Sorting

Alternative Use

Practically Recoverable Biomass Potential = ??

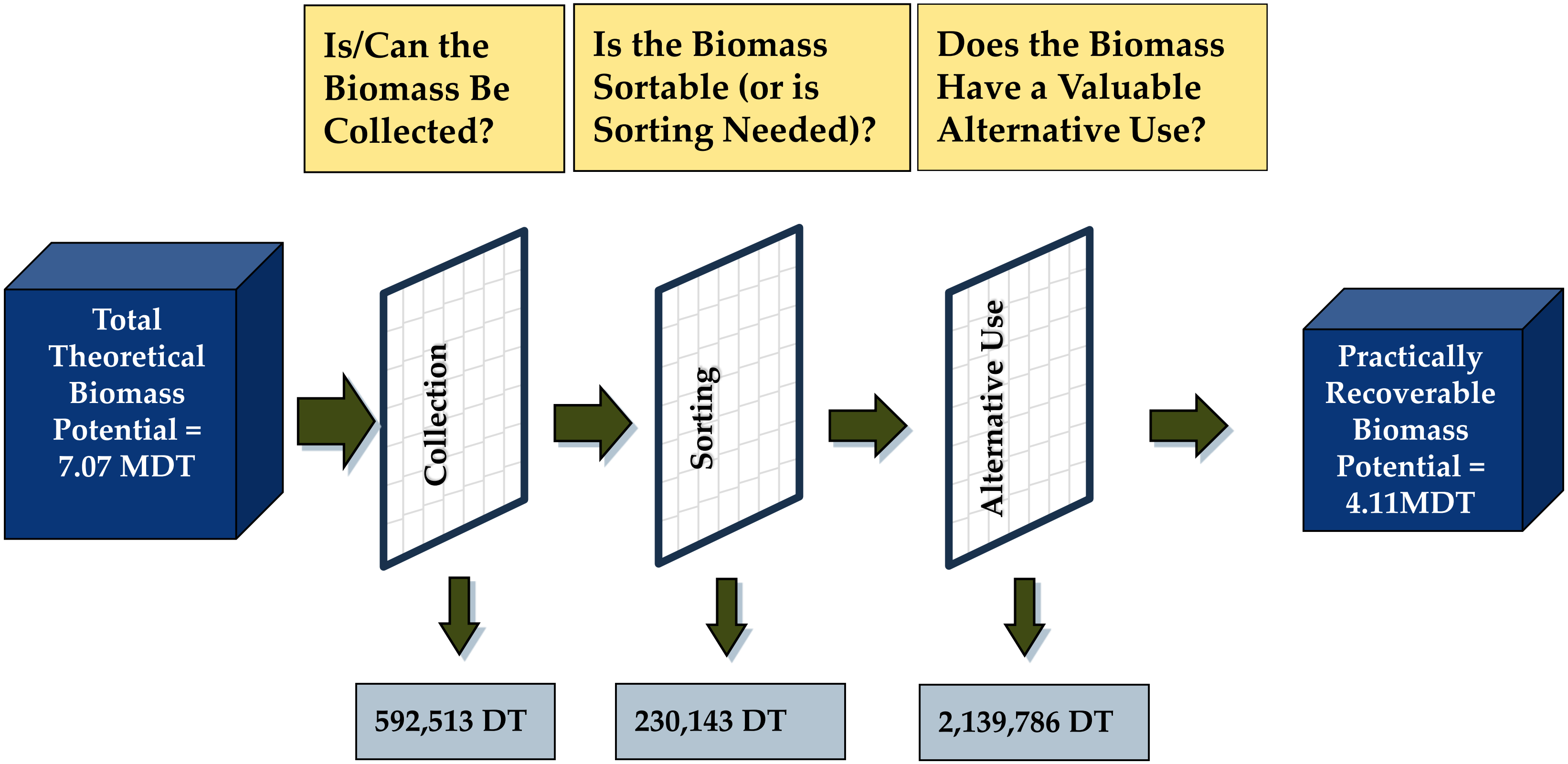
Not feasible due to collection issues

Not feasible due to sorting issues

Not feasible due to alternative use issues

Executive Summary: Practically Recoverable Biomass

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.



Is/Can the Biomass Be Collected?

Is the Biomass Sortable (or is Sorting Needed)?

Does the Biomass Have a Valuable Alternative Use?

Total Theoretical Biomass Potential = 7.07 MDT

Collection

Sorting

Alternative Use

Practically Recoverable Biomass Potential = 4.11MDT

592,513 DT

230,143 DT

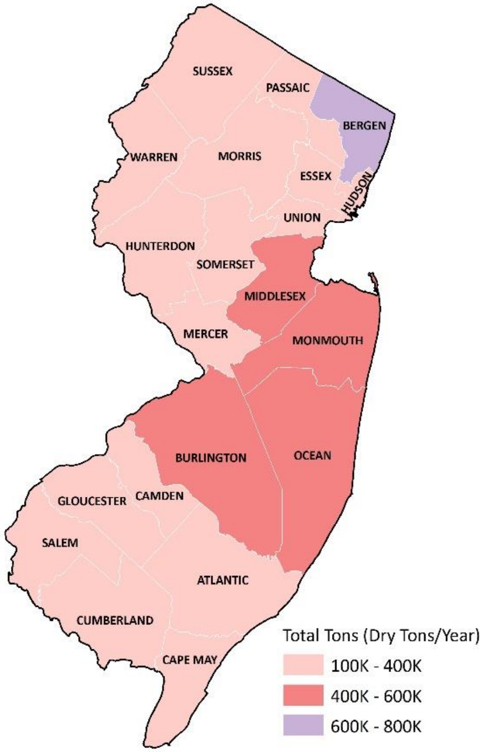
2,139,786 DT

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.

Executive Summary: Biomass Geographic Distribution

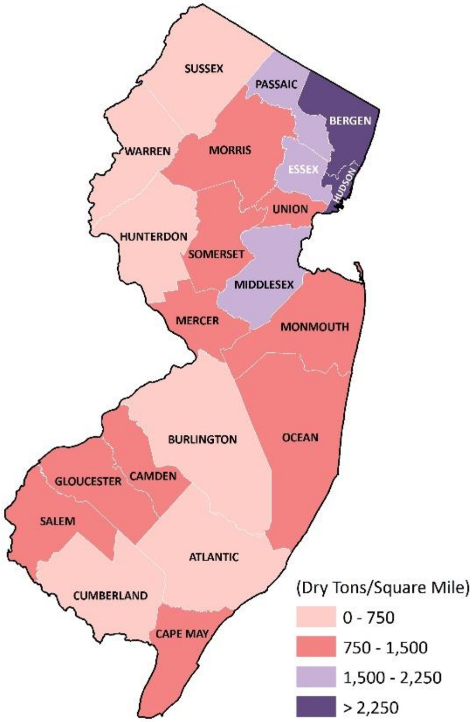
Biomass is primarily concentrated in the counties of central and northeastern New Jersey.

County Totals



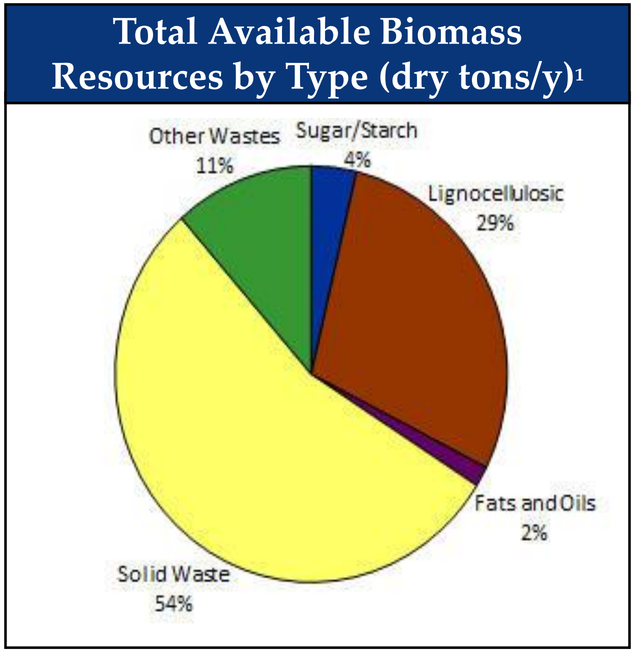
The energy contained in each ton of biomass is lower than for conventional fuels; thus, transportation distances between a resource and an energy conversion facility can be a key factor in determining the economics of a bioenergy project.

Biomass/Sq. mile



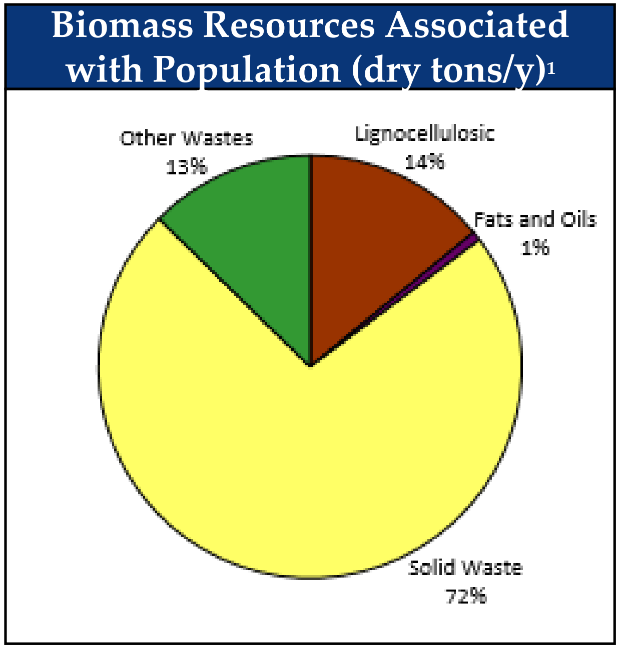
Executive Summary: Biomass Distribution by Type

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


Total Available Biomass Resources by Type (dry tons/y)[1]

Total = 7.07 million dry tons/y[1]

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


Biomass Resources Associated with Population (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.

Executive Summary: County Population Growth » *2010-2025*

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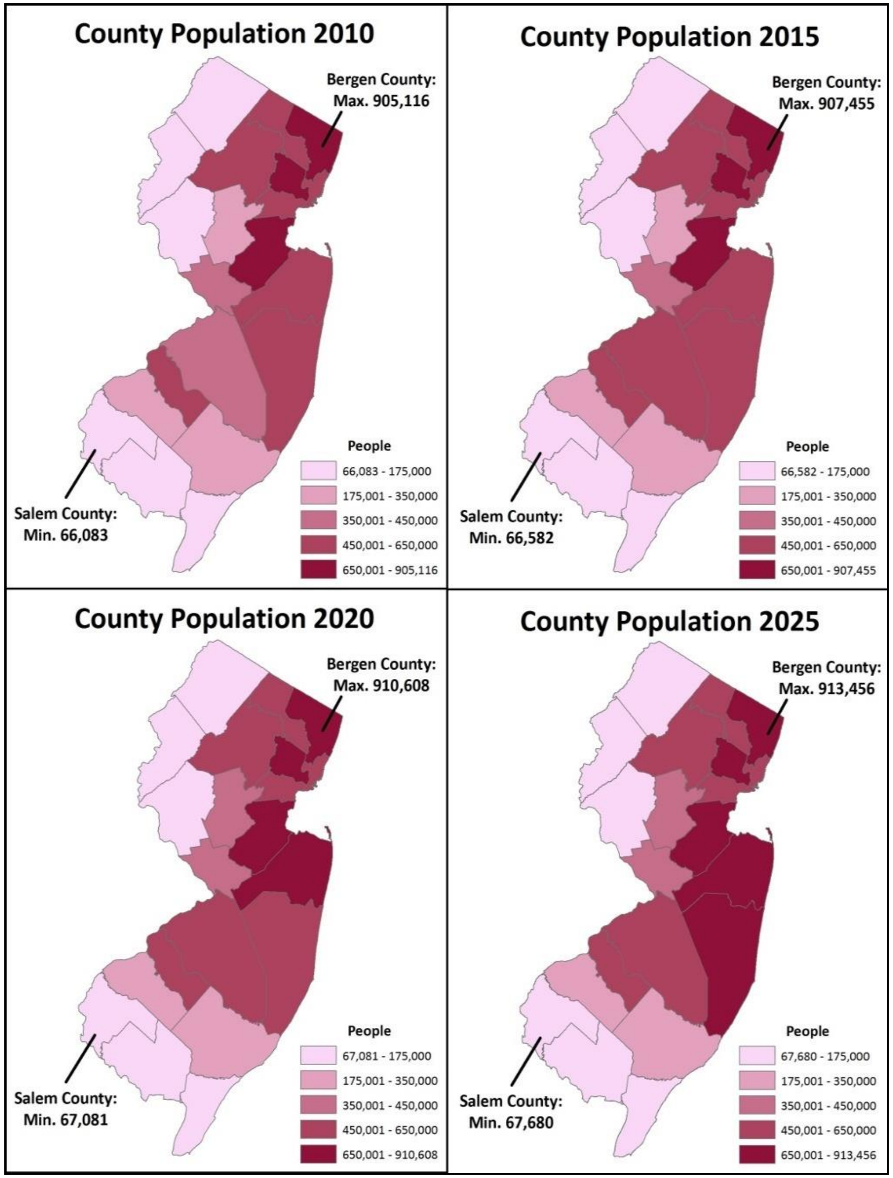
New Jersey Population Projections by County

Between 2010 and 2025, New Jersey's population is expected to grow by about 5.77%, adding approximately 500,000 more people.



Executive Summary: Municipal Solid Waste » *2010-2025*

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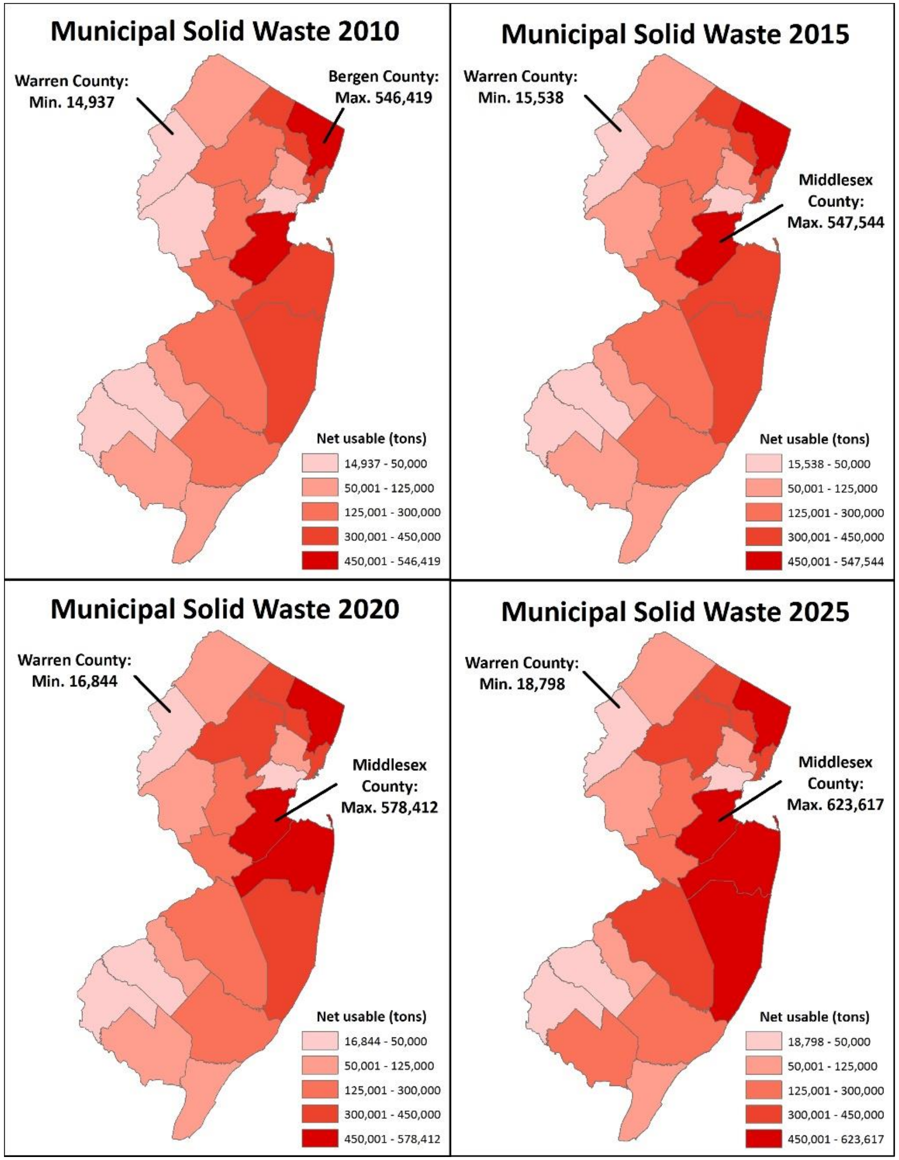
Municipal Solid Waste Projections by County

With increases in population comes increases in the amount of solid waste generated in the state. MSW is expected to increase by 12.76% by 2025.



Executive Summary: Bioenergy Technology Options

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.

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.

The biomass supply data described in Section II was integrated with the conversion technology data developed in Section III to estimate the energy potential of New Jersey’s biomass resources.

- “Typical” moisture and energy content and/or yield assumptions for each resource to calculate total estimated energy potential was developed.
- Estimated energy potential included energy produced using current or near-term technologies appropriate for each resource .
- This was a *high-level* examination of potential energy from biomass, such that the quantitative estimates described in this presentation should be considered indicative only. In particular, the results of the screening analysis to estimate recoverable potential should be considered preliminary.

Executive Summary : Bioenergy Potential

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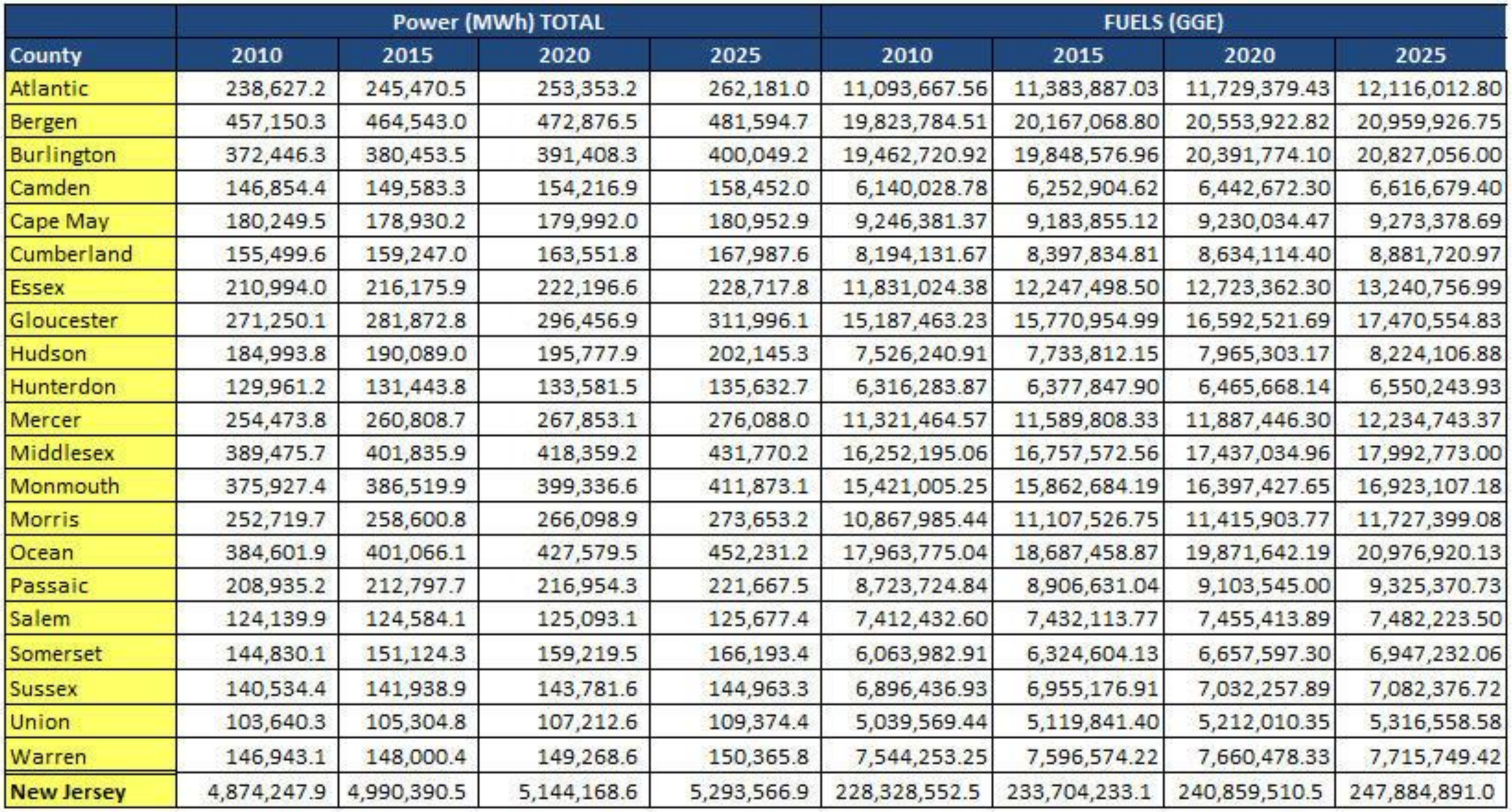
Bioenergy Potential by County

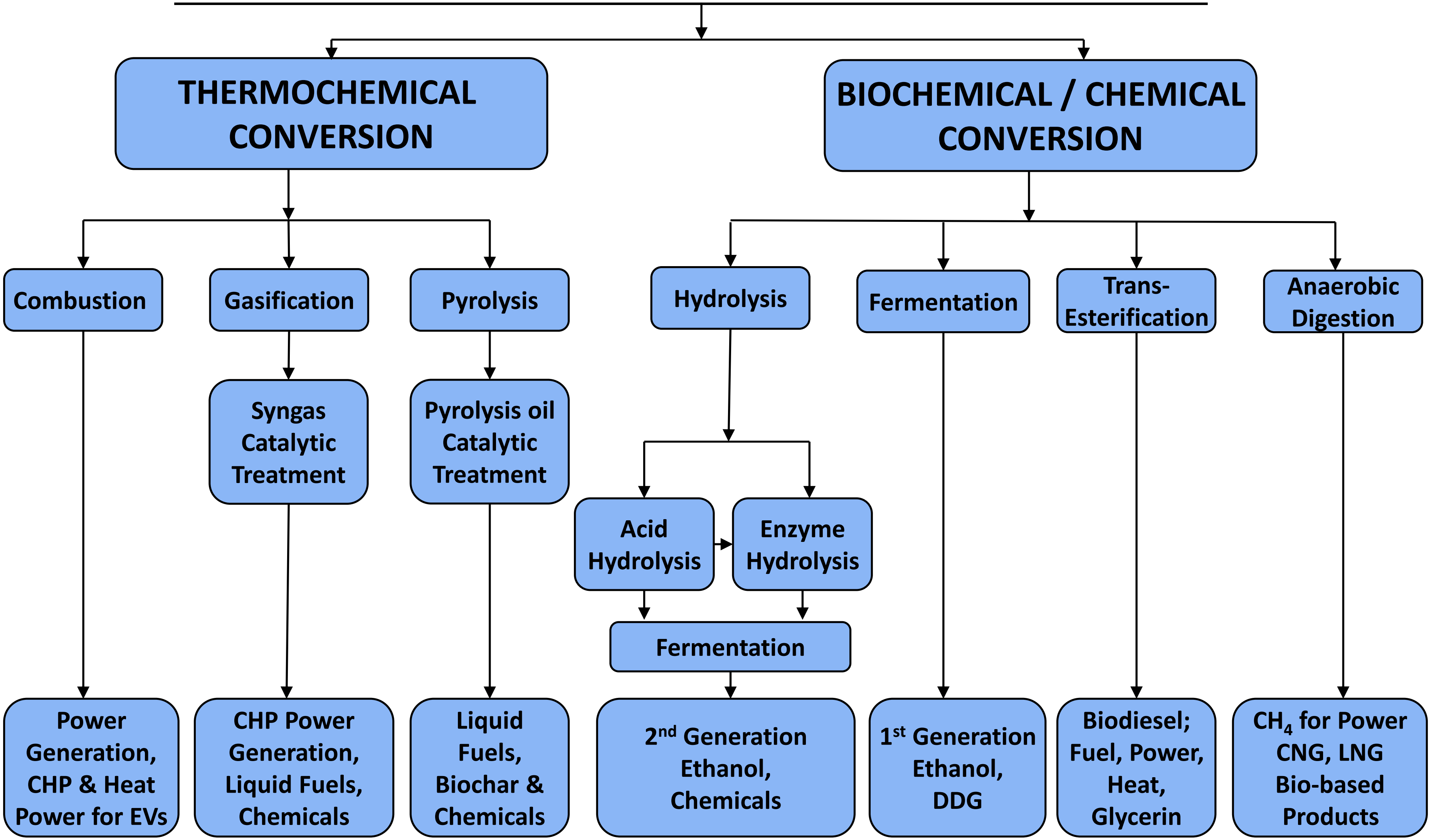


	Power (MWh) TOTAL				FUELS (GGE)			
County	2010	2015	2020	2025	2010	2015	2020	2025
Atlantic	238,627.2	245,470.5	253,353.2	262,181.0	11,093,667.56	11,383,887.03	11,729,379.43	12,116,012.80
Bergen	457,150.3	464,543.0	472,876.5	481,594.7	19,823,784.51	20,167,068.80	20,553,922.82	20,959,926.75
Burlington	372,446.3	380,453.5	391,408.3	400,049.2	19,462,720.92	19,848,576.96	20,391,774.10	20,827,056.00
Camden	146,854.4	149,583.3	154,216.9	158,452.0	6,140,028.78	6,252,904.62	6,442,672.30	6,616,679.40
Cape May	180,249.5	178,930.2	179,992.0	180,952.9	9,246,381.37	9,183,855.12	9,230,034.47	9,273,378.69
Cumberland	155,499.6	159,247.0	163,551.8	167,987.6	8,194,131.67	8,397,834.81	8,634,114.40	8,881,720.97
Essex	210,994.0	216,175.9	222,196.6	228,717.8	11,831,024.38	12,247,498.50	12,723,362.30	13,240,756.99
Gloucester	271,250.1	281,872.8	296,456.9	311,996.1	15,187,463.23	15,770,954.99	16,592,521.69	17,470,554.83
Hudson	184,993.8	190,089.0	195,777.9	202,145.3	7,526,240.91	7,733,812.15	7,965,303.17	8,224,106.88
Hunterdon	129,961.2	131,443.8	133,581.5	135,632.7	6,316,283.87	6,377,847.90	6,465,668.14	6,550,243.93
Mercer	254,473.8	260,808.7	267,853.1	276,088.0	11,321,464.57	11,589,808.33	11,887,446.30	12,234,743.37
Middlesex	389,475.7	401,835.9	418,359.2	431,770.2	16,252,195.06	16,757,572.56	17,437,034.96	17,992,773.00
Monmouth	375,927.4	386,519.9	399,336.6	411,873.1	15,421,005.25	15,862,684.19	16,397,427.65	16,923,107.18
Morris	252,719.7	258,600.8	266,098.9	273,653.2	10,867,985.44	11,107,526.75	11,415,903.77	11,727,399.08
Ocean	384,601.9	401,066.1	427,579.5	452,231.2	17,963,775.04	18,687,458.87	19,871,642.19	20,976,920.13
Passaic	208,935.2	212,797.7	216,954.3	221,667.5	8,723,724.84	8,906,631.04	9,103,545.00	9,325,370.73
Salem	124,139.9	124,584.1	125,093.1	125,677.4	7,412,432.60	7,432,113.77	7,455,413.89	7,482,223.50
Somerset	144,830.1	151,124.3	159,219.5	166,193.4	6,063,982.91	6,324,604.13	6,657,597.30	6,947,232.06
Sussex	140,534.4	141,938.9	143,781.6	144,963.3	6,896,436.93	6,955,176.91	7,032,257.89	7,082,376.72
Union	103,640.3	105,304.8	107,212.6	109,374.4	5,039,569.44	5,119,841.40	5,212,010.35	5,316,558.58
Warren	146,943.1	148,000.4	149,268.6	150,365.8	7,544,253.25	7,596,574.22	7,660,478.33	7,715,749.42
New Jersey	4,874,247.9	4,990,390.5	5,144,168.6	5,293,566.9	228,328,552.5	233,704,233.1	240,859,510.5	247,884,891.0

Technologies Used

Power	Fuels
Direct Combustion-Stand Alone for Solid Biomass	Transesterification
Direct Combustion-ADG/Landfill Gas	Dilute Acid Hydrolysis
	AD/Landfill Gas to Transportation Fuel

BIOMASS-to-BIOENERGY & BIOPRODUCTS CONVERSION PATHWAYS



THERMOCHEMICAL CONVERSION

- Combustion
  - Power Generation, CHP & Heat Power for EVs
- Gasification
  - Syngas Catalytic Treatment
    - CHP Power Generation, Liquid Fuels, Chemicals
- Pyrolysis
  - Pyrolysis oil Catalytic Treatment
    - Liquid Fuels, Biochar & Chemicals

BIOCHEMICAL / CHEMICAL CONVERSION

- Hydrolysis
  - Acid Hydrolysis
  - Enzyme Hydrolysis
    - Fermentation
      - 2nd Generation Ethanol, Chemicals
- Fermentation
  - 1st Generation Ethanol, DDG
- Trans-Esterification
  - Biodiesel; Fuel, Power, Heat, Glycerin
- Anaerobic Digestion
  - CH$_4$ for Power CNG, LNG Bio-based Products

Executive Summary: Greenhouse Gas Reduction Potential

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).

Executive Summary: Recommendations

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)

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!).

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II. Biomass Supply Analysis

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Biomass Supply Analysis: Overview

The purpose of this recent comprehensive supply analysis was to update New Jersey's biomass data*, that could potentially be available to produce energy and contribute to New Jersey's renewable energy generation profile.**

- Biomass is a broad definition for biologically-derived renewable materials that can be used to produce heat, electric power, transportation fuels and biobased intermediaries, products and chemicals.
- Recently, NJAES/ EcoComplex conducted a research and collected public data on biomass resources for each New Jersey's county to update estimated available biomass quantities in dry tons/y.
- A Bioenergy Calculator and interactive biomass resource database were also updated to analyze and aggregate the data collected by NJAES/EcoComplex.
- A screening process within the database was also updated to determine how much of the total biomass created was "practically" recoverable.
- The quantitative results are estimates only; capturing even the practically recoverable biomass estimate of 4.11 MDT will require an intense examination of public policies, economic incentives, and regulatory practices.

* Industrial biomass waste was not included

** New Jersey Biomass Energy Assessment, NJAES, 2007

Biomass Supply Analysis: Resource Categories

A range of biomass resources were examined; these can be divided into 5 categories based on their physical characteristics.

Feedstock Type	Definitions	Resources
Sugars/Starches	Traditional agricultural crops suitable for fermentation using 1st generation technologies Some food processing residues are sugar and starch materials	•Agricultural crops (sugars/starches) •Food processing residues (w/residual sugars)
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Fats and Oils	Traditional edible oil crops and waste oils suitable for conversion to biodiesel	•Agricultural crops (beans/oils) •Waste oils/fats/grease
Solid Wastes	Primarily lignocellulosic biomass, but that may be contaminated (e.g., C&D wood) or co-mingled with other biomass types	•Municipal solid waste (biomass portion) •C&D wood •Food wastes •Non-recycled paper •Recycled materials
Other Wastes	Other biomass wastes that are generally separate from the solid waste stream Includes biogas and landfill gas	•Animal waste (farm) •Wastewater treatment biogas and biosolids •Landfill gas

Major Findings

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[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

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.

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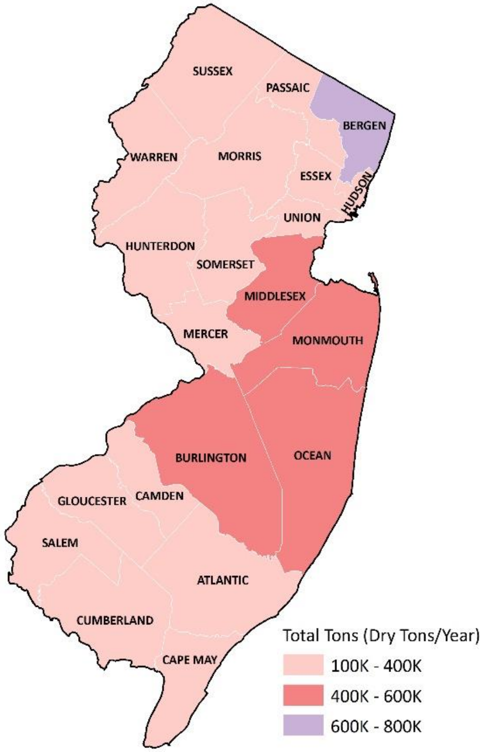
Biomass Supply Analysis: Biomass Geographic Distribution

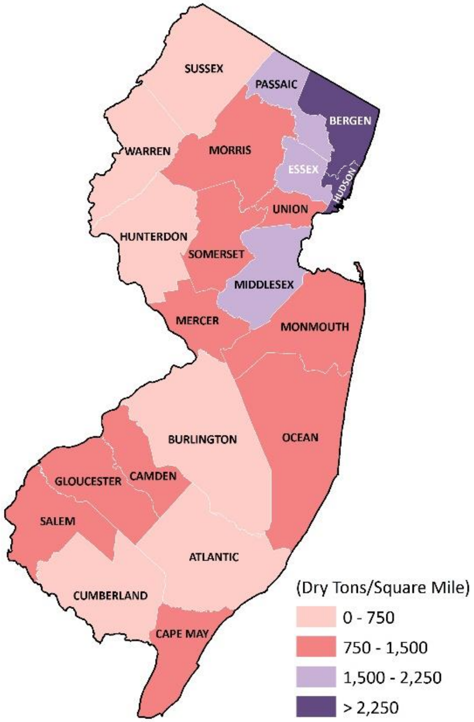
Biomass is primarily concentrated in the counties of central and northeastern New Jersey.

County Totals



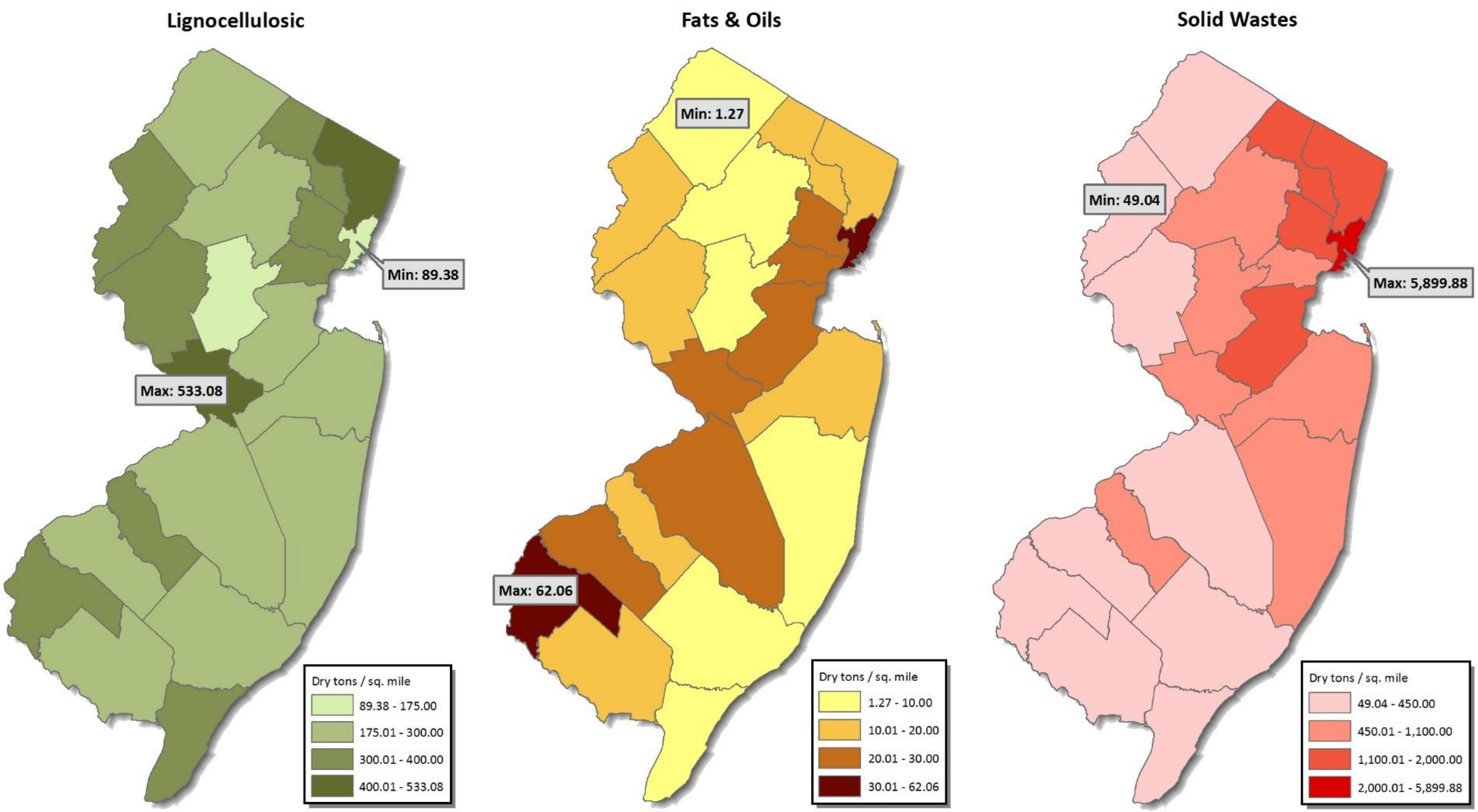
The energy contained in each ton of biomass is lower than for conventional fuels; thus, transportation distances between a resource and an energy conversion facility can be a key factor in determining the economics of a bioenergy project.

Biomass/Sq. mile



Biomass Supply Analysis: Geographic Distribution by Feedstock

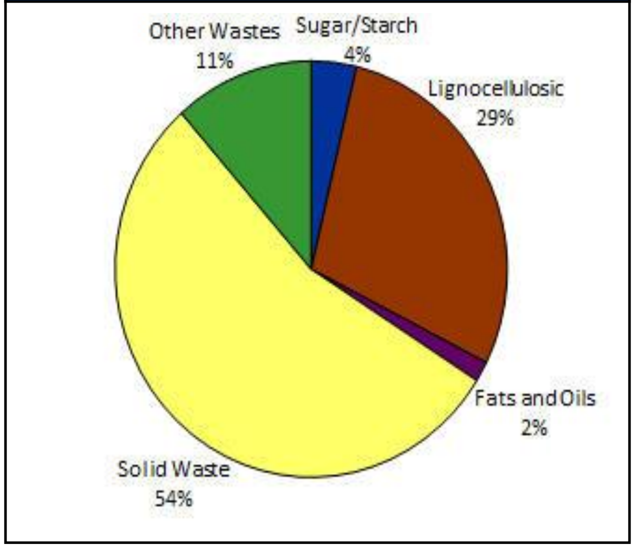
Biomass Resources by Feedstock Category 2010



Biomass Supply Analysis: Biomass Distribution by Type

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.

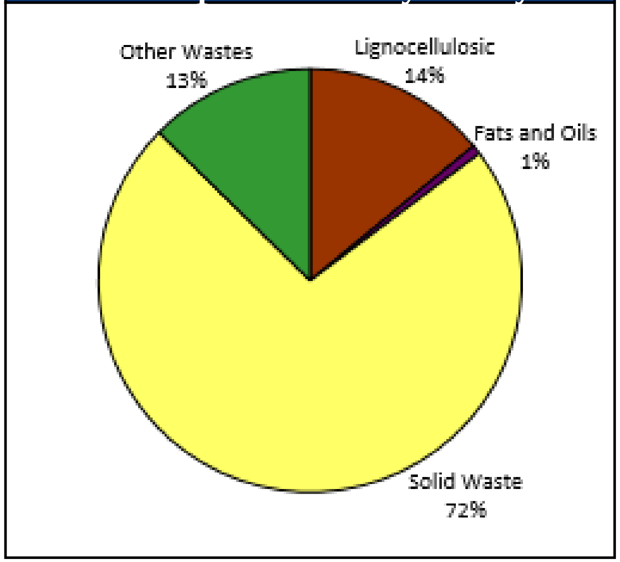
Total Available Biomass Resources by Type (dry tons/y)[1]



Total = 7.07 million dry tons/y[1]

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

Biomass Resources Associated with Population (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.

Biomass Supply Analysis: County Population Growth» *2010-2025*

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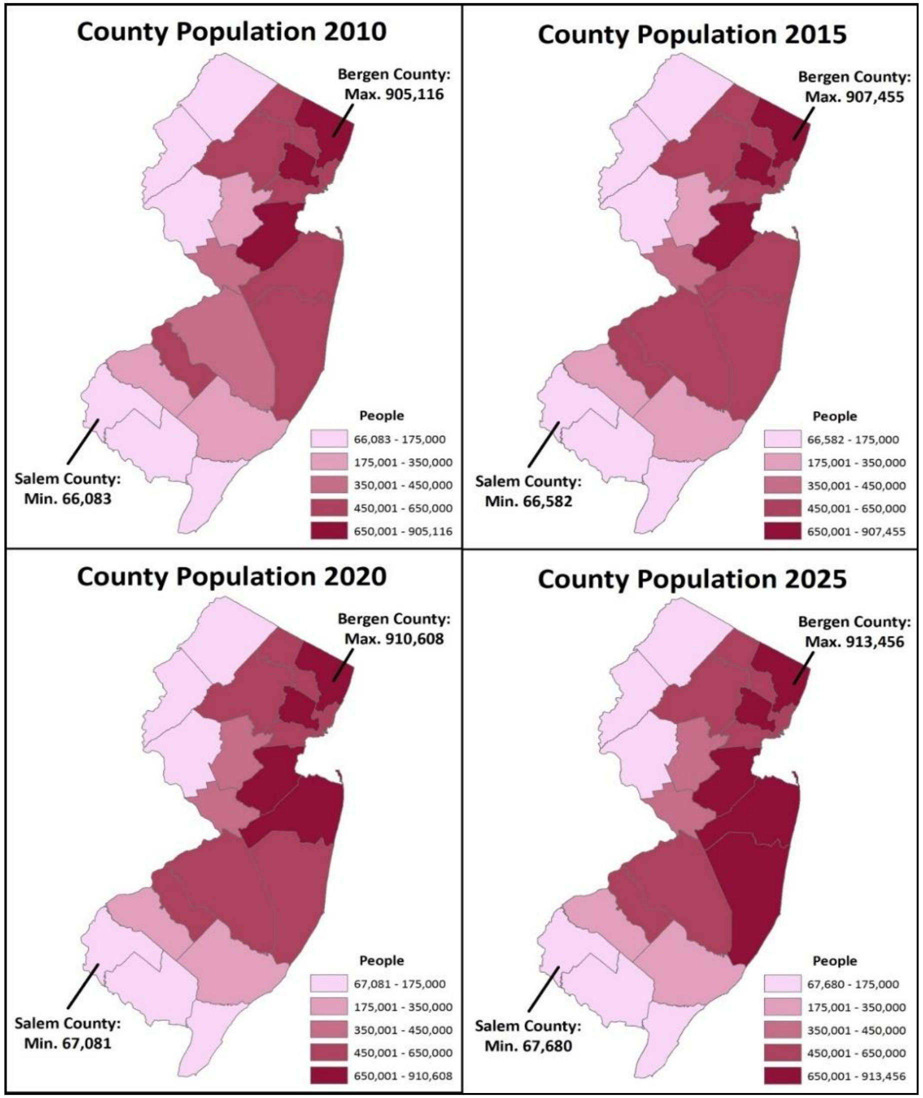
New Jersey Population Projections by County

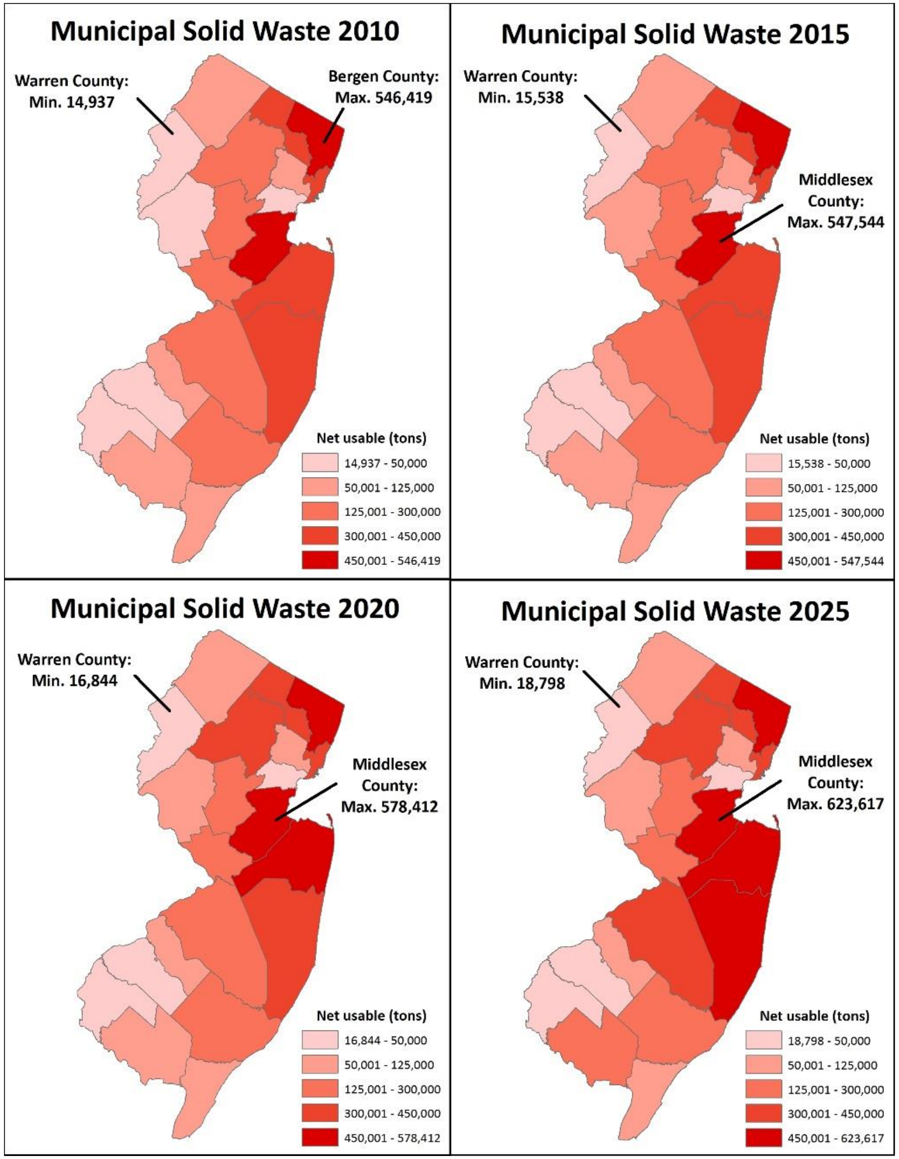
Between 2010 and 2025, New Jersey’s population is expected to grow by 5.77% adding approximately 500,000 more people.



Biomass Supply Analysis: Municipal Solid Waste» *2010-2025*

Municipal Solid Waste Projections by County

With increases in population comes increases in the amount of solid waste generated in the state. MSW is expected to increase by 12.76% by 2025.



Municipal Solid Waste 2010

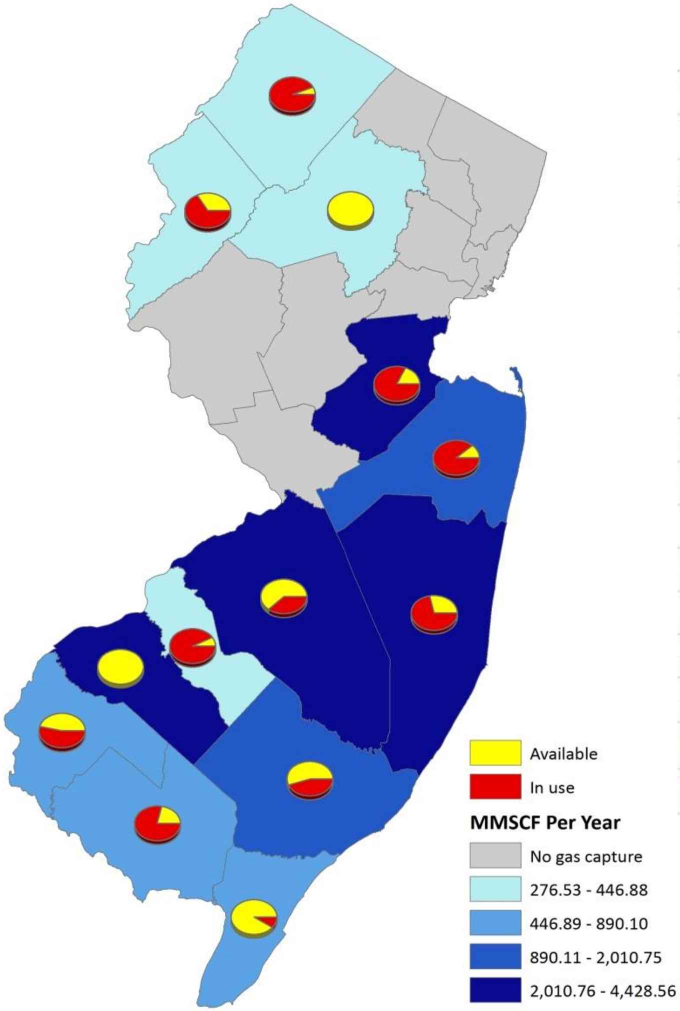
Municipal Solid Waste 2015

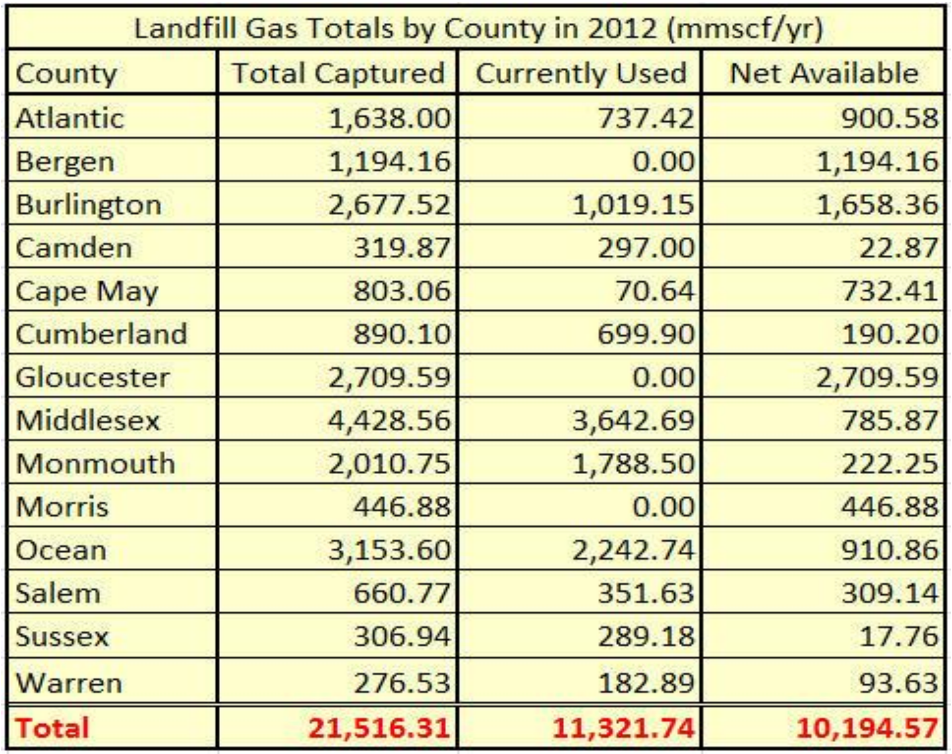
Municipal Solid Waste 2020

Municipal Solid Waste 2025

Biomass Supply Analysis: Landfill Gas Generation and Use» *2012*

Land Fill Gas Capture, Use and Availability





Landfill Gas Totals by County in 2012 (mmscf/yr)

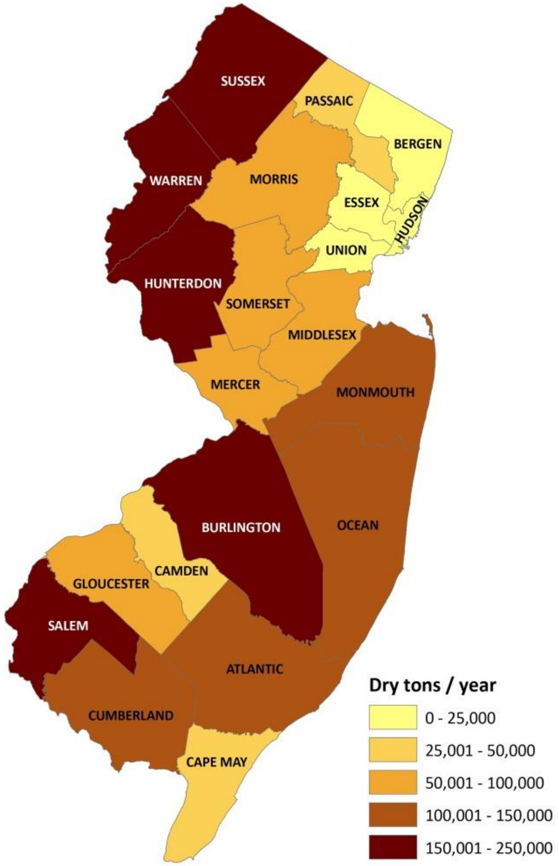
County	Total Captured	Currently Used	Net Available
Atlantic	1,638.00	737.42	900.58
Bergen	1,194.16	0.00	1,194.16
Burlington	2,677.52	1,019.15	1,658.36
Camden	319.87	297.00	22.87
Cape May	803.06	70.64	732.41
Cumberland	890.10	699.90	190.20
Gloucester	2,709.59	0.00	2,709.59
Middlesex	4,428.56	3,642.69	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 Supply Analysis: Agricultural Potential

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



Biomass Supply Analysis: Overview

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.

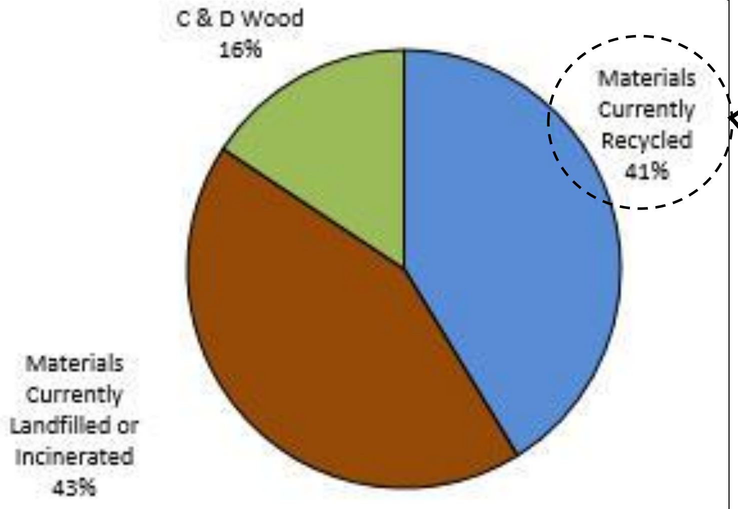
3. ***Competition from existing uses***

   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.

Biomass Supply Analysis: Practicality of Resource Recovery

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.

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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

Biomass Supply Analysis: Practicality of Biomass Resource Recovery

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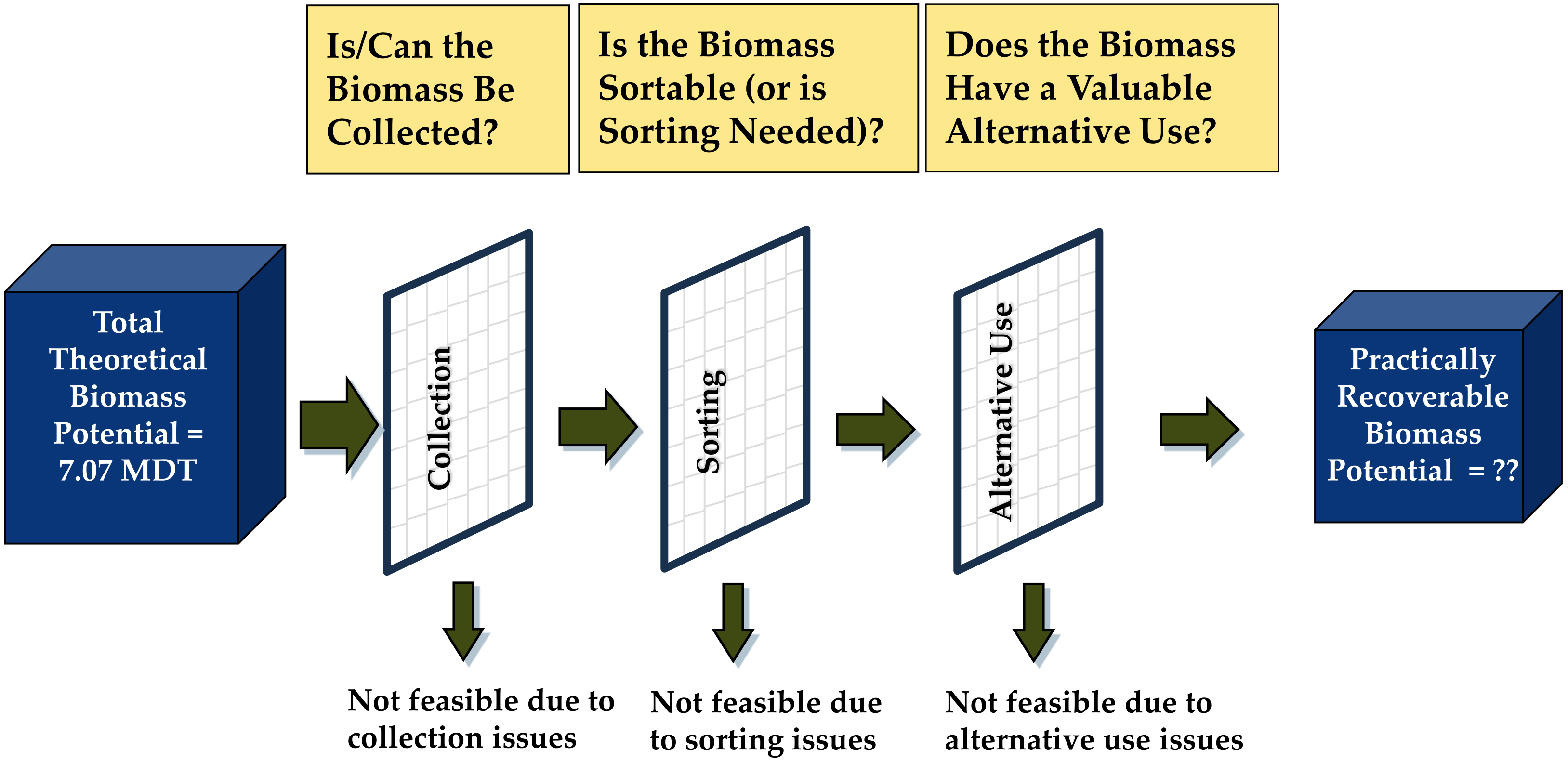
A screening process was developed to estimate how much of New Jersey's theoretically available biomass might be recoverable for bioenergy production.



Is/Can the Biomass Be Collected?

Is the Biomass Sortable (or is Sorting Needed)?

Does the Biomass Have a Valuable Alternative Use?

Total Theoretical Biomass Potential = 7.07 MDT

Collection

Sorting

Alternative Use

Practically Recoverable Biomass Potential = ??

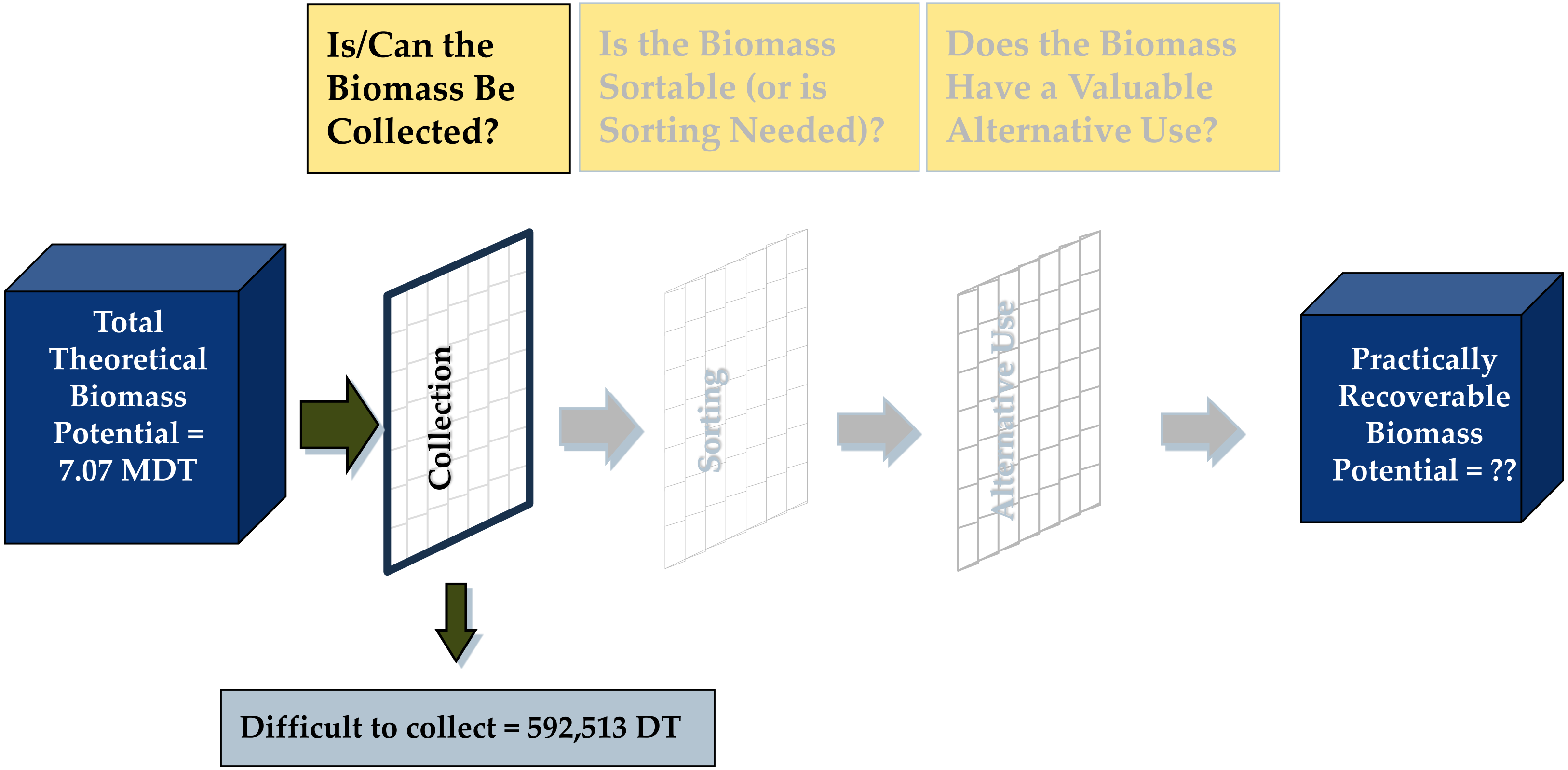
Not feasible due to collection issues

Not feasible due to sorting issues

Not feasible due to alternative use issues

Biomass Supply Analysis: Practicality of Resource Recovery

If a resource is either currently collected, easy to collect, or produced onsite such as landfill gas, it passed the collection screen.



Is/Can the Biomass Be Collected?

Is the Biomass Sortable (or is Sorting Needed)?

Does the Biomass Have a Valuable Alternative Use?

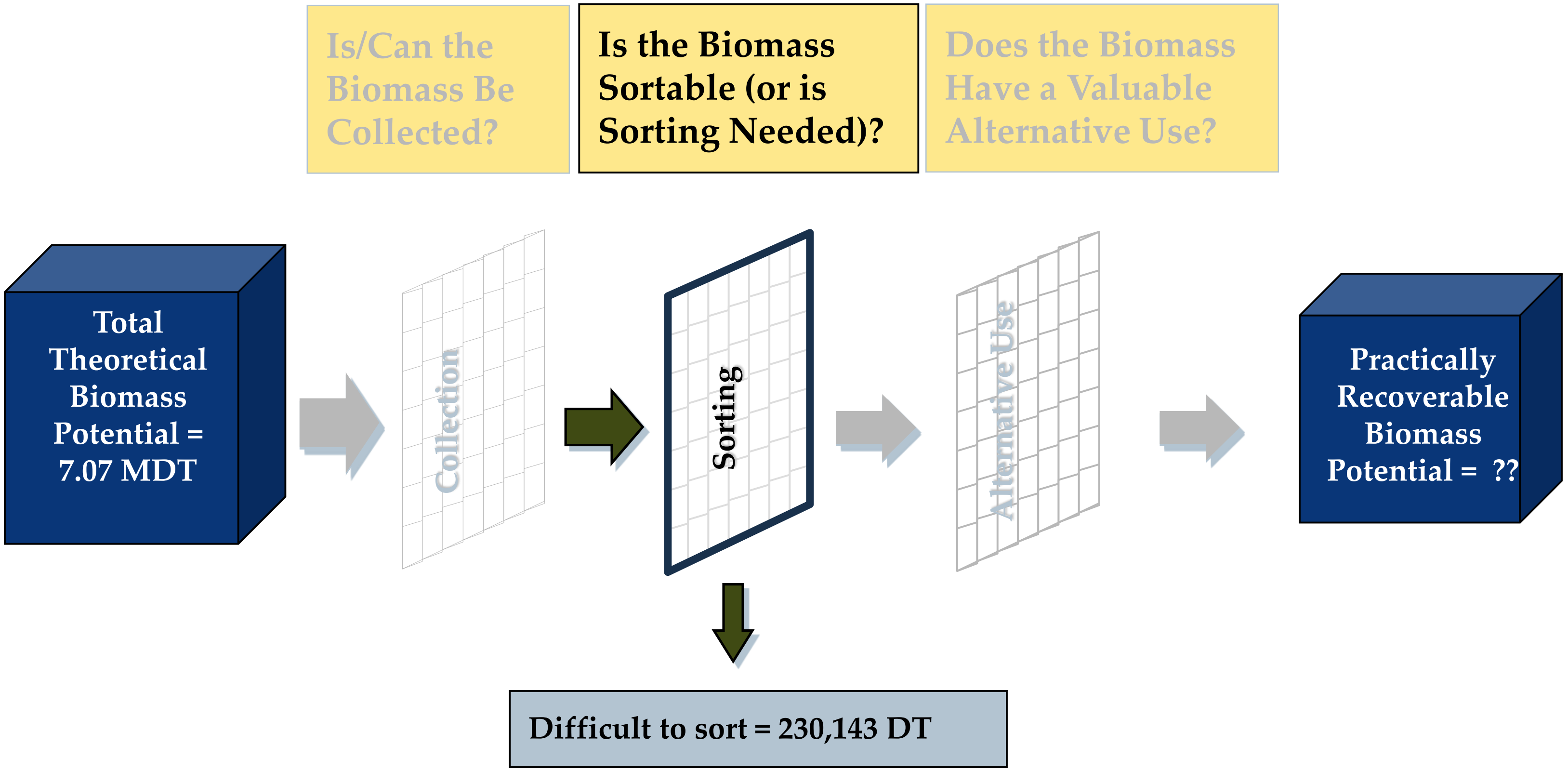
Total Theoretical Biomass Potential = 7.07 MDT

Practically Recoverable Biomass Potential = ??

Difficult to collect = 592,513 DT

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.

The Sorting Screen filtered out the resources that were difficult to sort.



Is/Can the Biomass Be Collected?

Is the Biomass Sortable (or is Sorting Needed)?

Does the Biomass Have a Valuable Alternative Use?

Total Theoretical Biomass Potential = 7.07 MDT

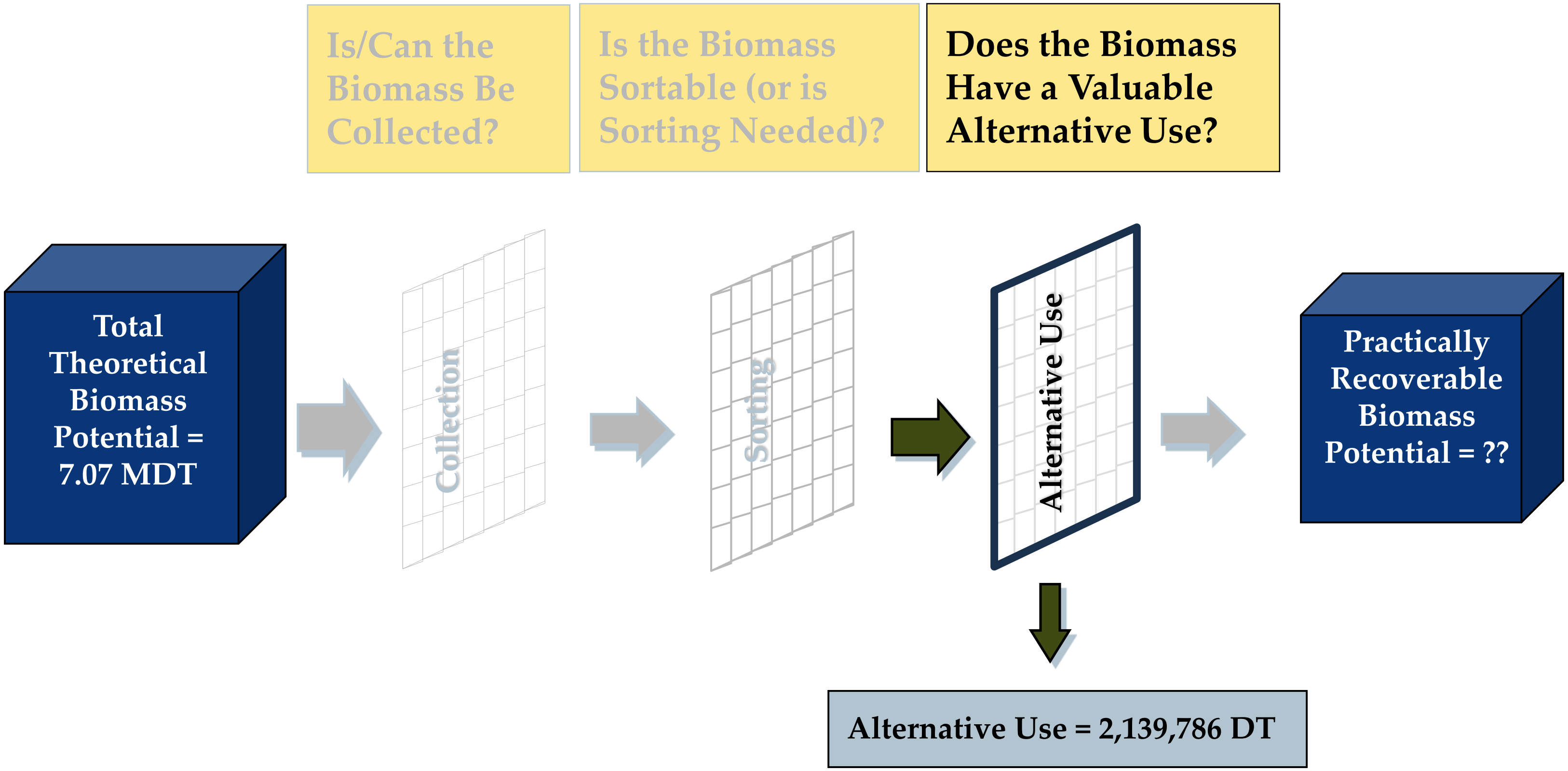
Practically Recoverable Biomass Potential = ??

Difficult to sort = 230,143 DT

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.

Biomass Supply Analysis: Practicality of Resource Recovery

The Alternative Use screen filtered out the resources with a current alternative use and would likely not be converted to energy.



Is/Can the Biomass Be Collected?

Is the Biomass Sortable (or is Sorting Needed)?

Does the Biomass Have a Valuable Alternative Use?

Total Theoretical Biomass Potential = 7.07 MDT

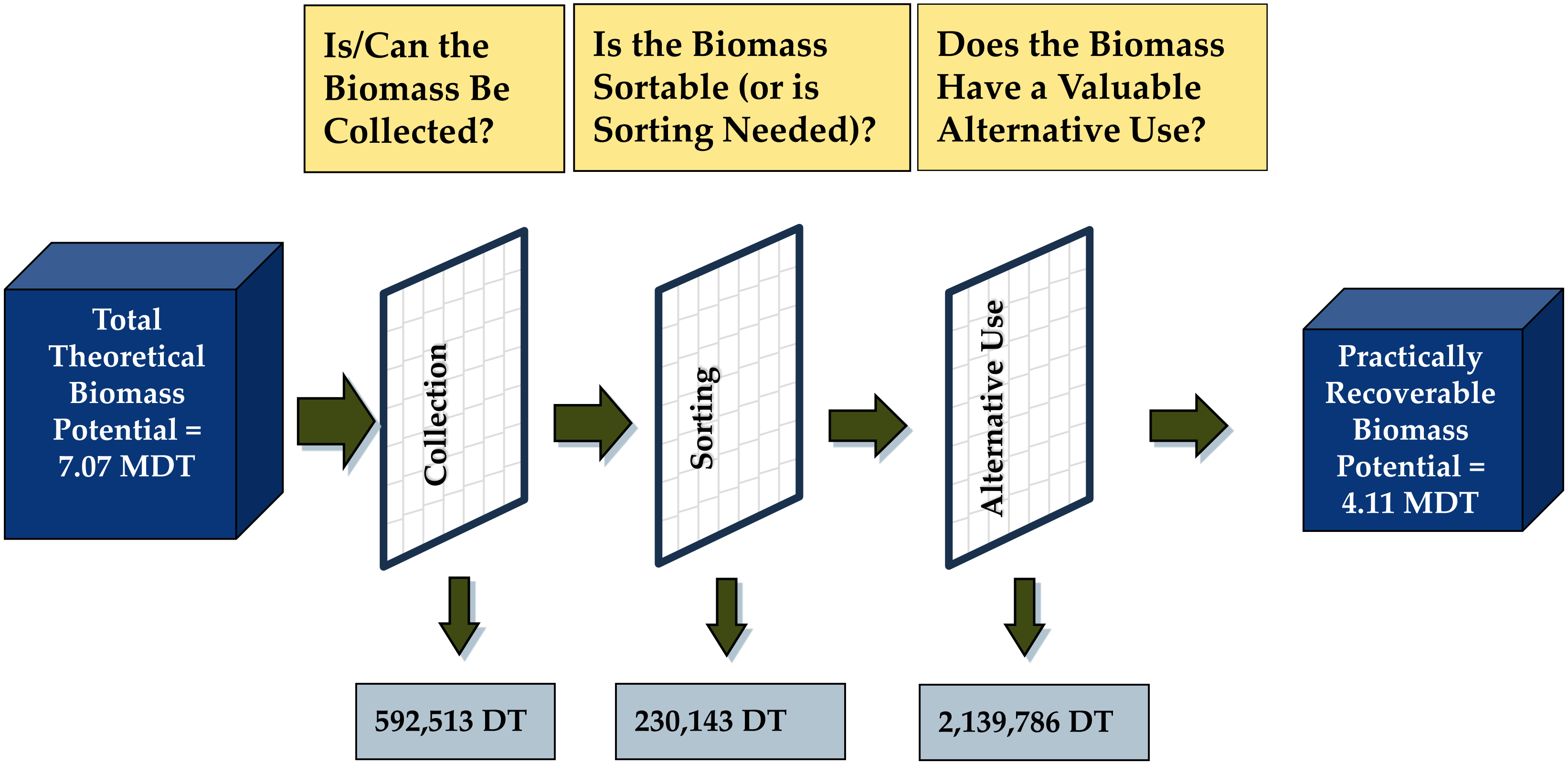
Practically Recoverable Biomass Potential = ??

Alternative Use = 2,139,786 DT

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.

Biomass Supply Analysis: Practically Recoverable Biomass

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.

Biomass Supply Analysis: Potential Pathway

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

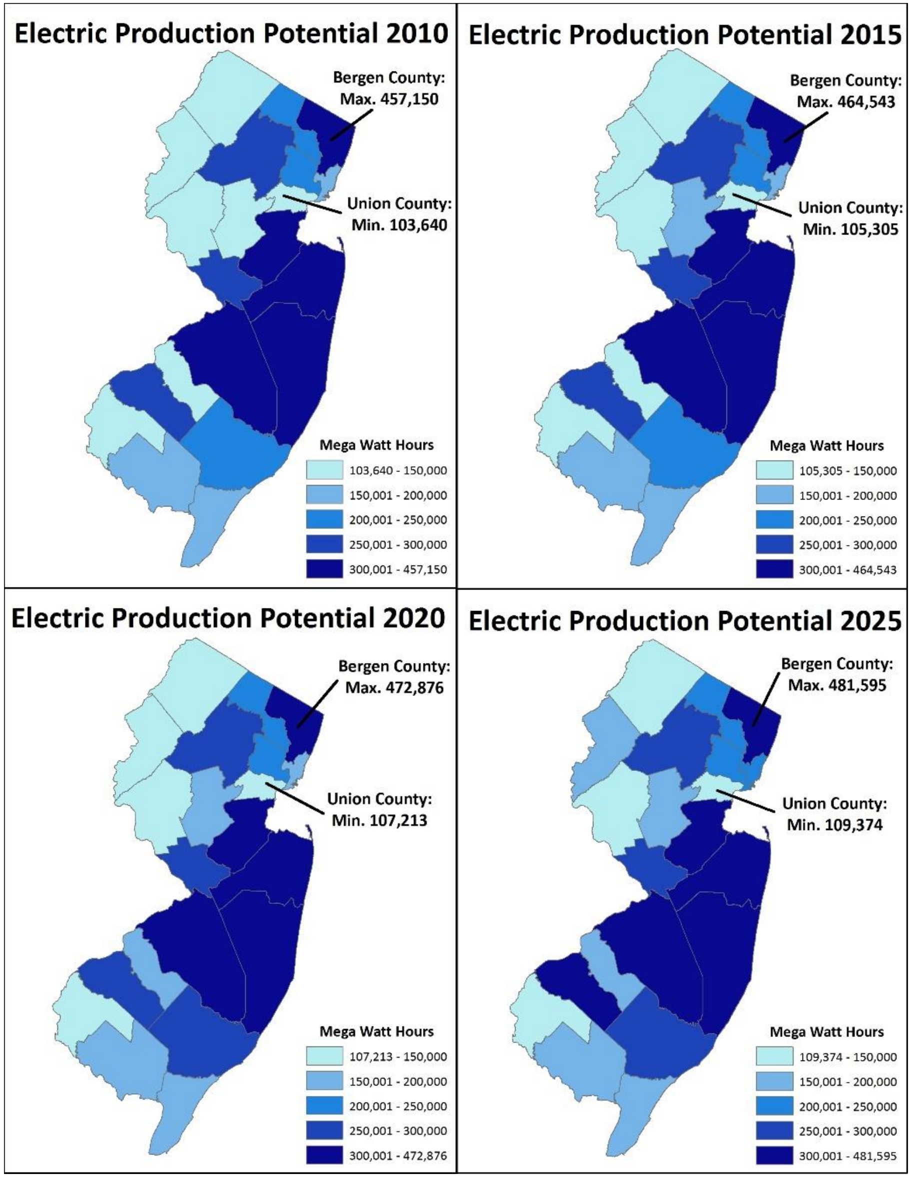
Biomass Resource Utilization Strategy

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

Biomass Supply Analysis: Power Generation Potential»
2010-2025

Biopower Production Projections

Total biopower potential is estimated to increase from 654 MW in 2010 to 710 MW by 2025, a ~8.6% increase.



Biomass Supply Analysis: Biofuels Generation Potential» *2010-2025*

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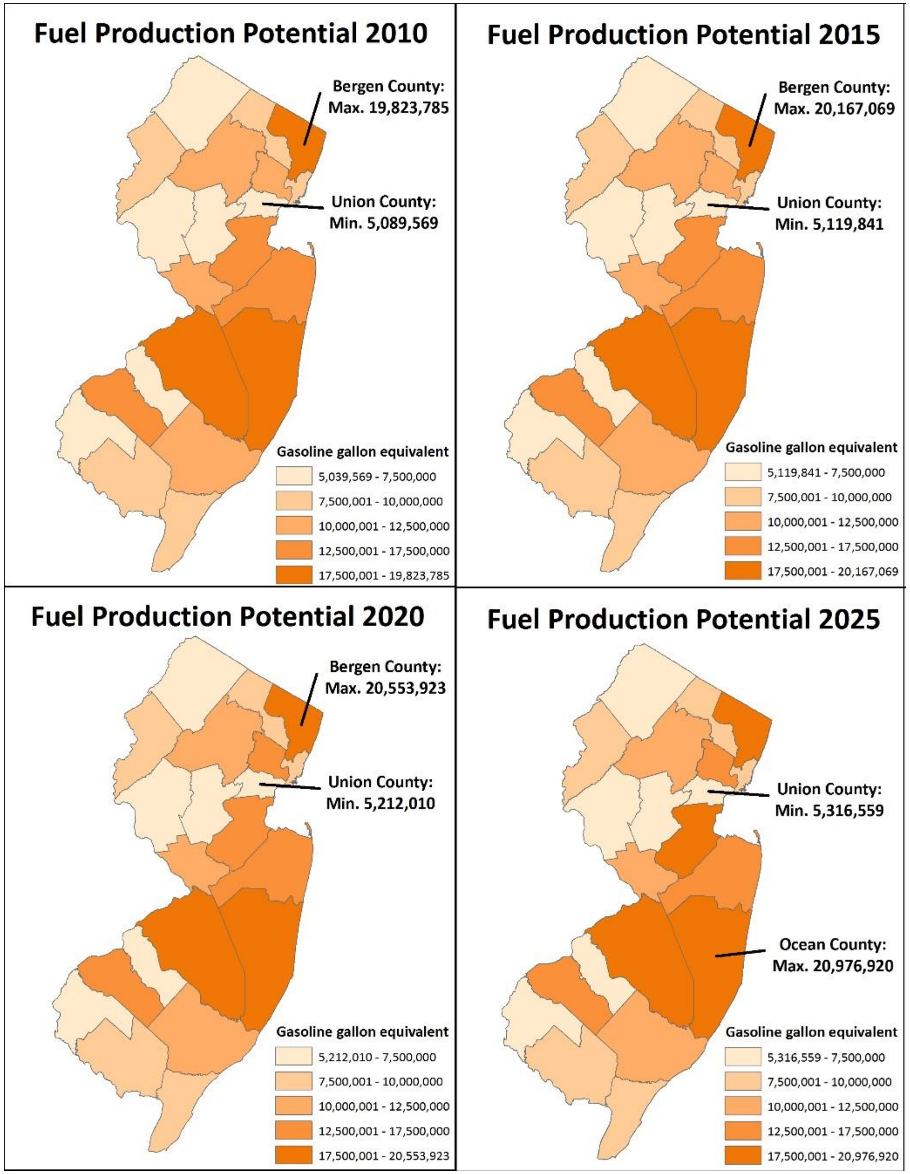
Experiment Station

Biofuel Production Projections

Total biofuel potential is estimated to increase from 228M GGE in 2010 to 272M GGE by 2025, an ~16% increase.



Fuel Production Potential 2010

Fuel Production Potential 2015

Fuel Production Potential 2020

Fuel Production Potential 2025

In the biofuels analyses, differences in volumetric energy densities among biofuels were normalized to gallons of gasoline equivalent (GGE).

Liquid Fuels	HHV (Btu/gal)	GGE for 1 gallon of biofuel
Conventional Gasoline	124,340	-
Ethanol	84,530	0.68
Biodiesel	128,763	1.04
Fischer Tropsch Diesel	130,030	1.05
MeTHF	111,750	0.90

HHV – High Heating Value

MeTHF - methyltetrahydrofuran, an ether produced by hydrogenation of levulinic acid.

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

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III. Technology Assessment

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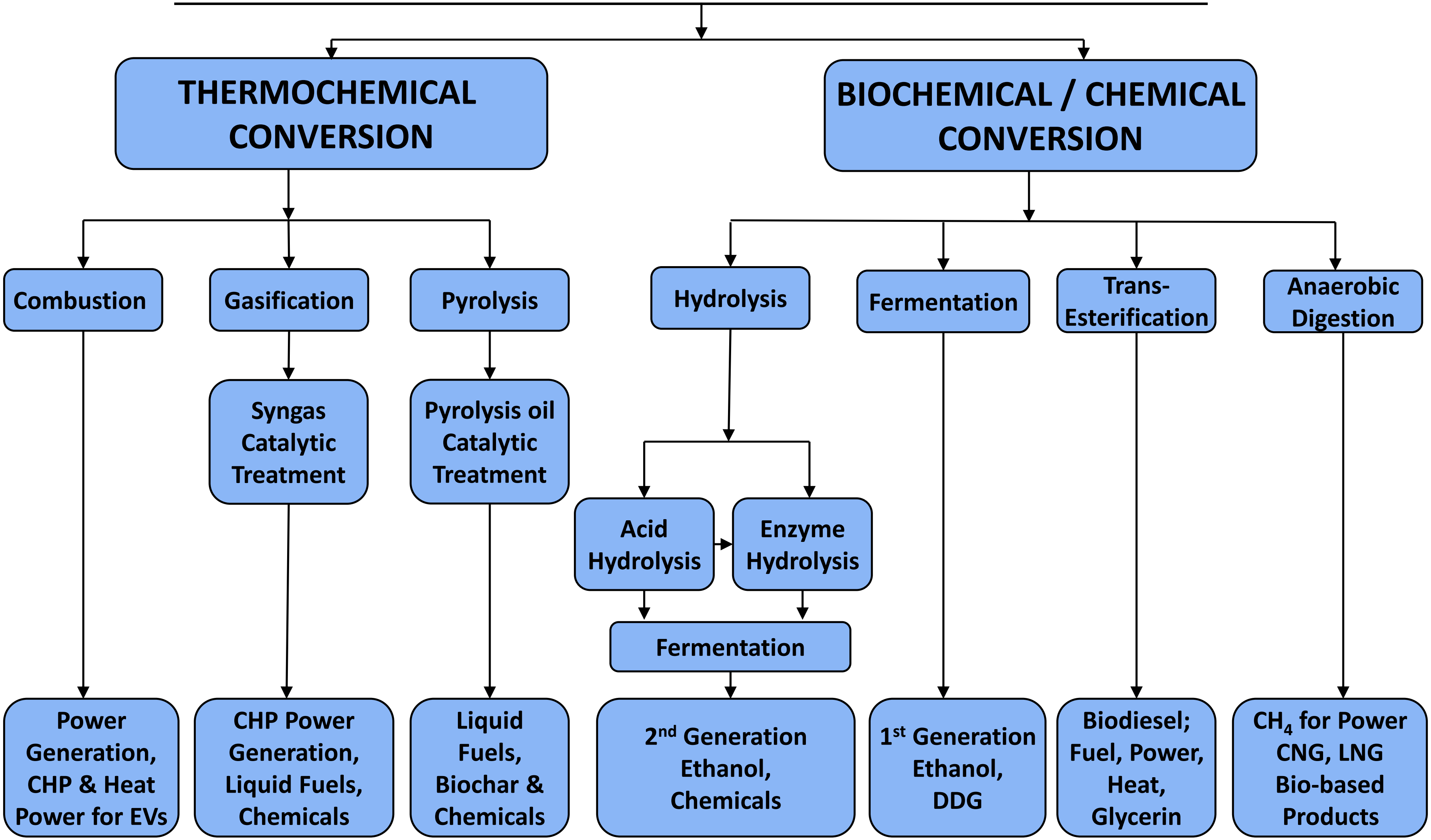
Technology Development and Commercialization Pathway

R&D	Demonstration			Market Entry	Market Penetration	Market Maturity
	Initial System Prototypes	Refined Prototypes	Commercial Prototypes			
• 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



THERMOCHEMICAL CONVERSION

BIOCHEMICAL / CHEMICAL CONVERSION

Combustion

Gasification

Pyrolysis

Hydrolysis

Fermentation

Trans-Esterification

Anaerobic Digestion

Syngas Catalytic Treatment

Pyrolysis oil Catalytic Treatment

Acid Hydrolysis

Enzyme Hydrolysis

Fermentation

Power Generation, CHP & Heat Power for EVs

CHP Power Generation, Liquid Fuels, Chemicals

Liquid Fuels, Biochar & Chemicals

2nd Generation Ethanol, Chemicals

1st Generation Ethanol, DDG

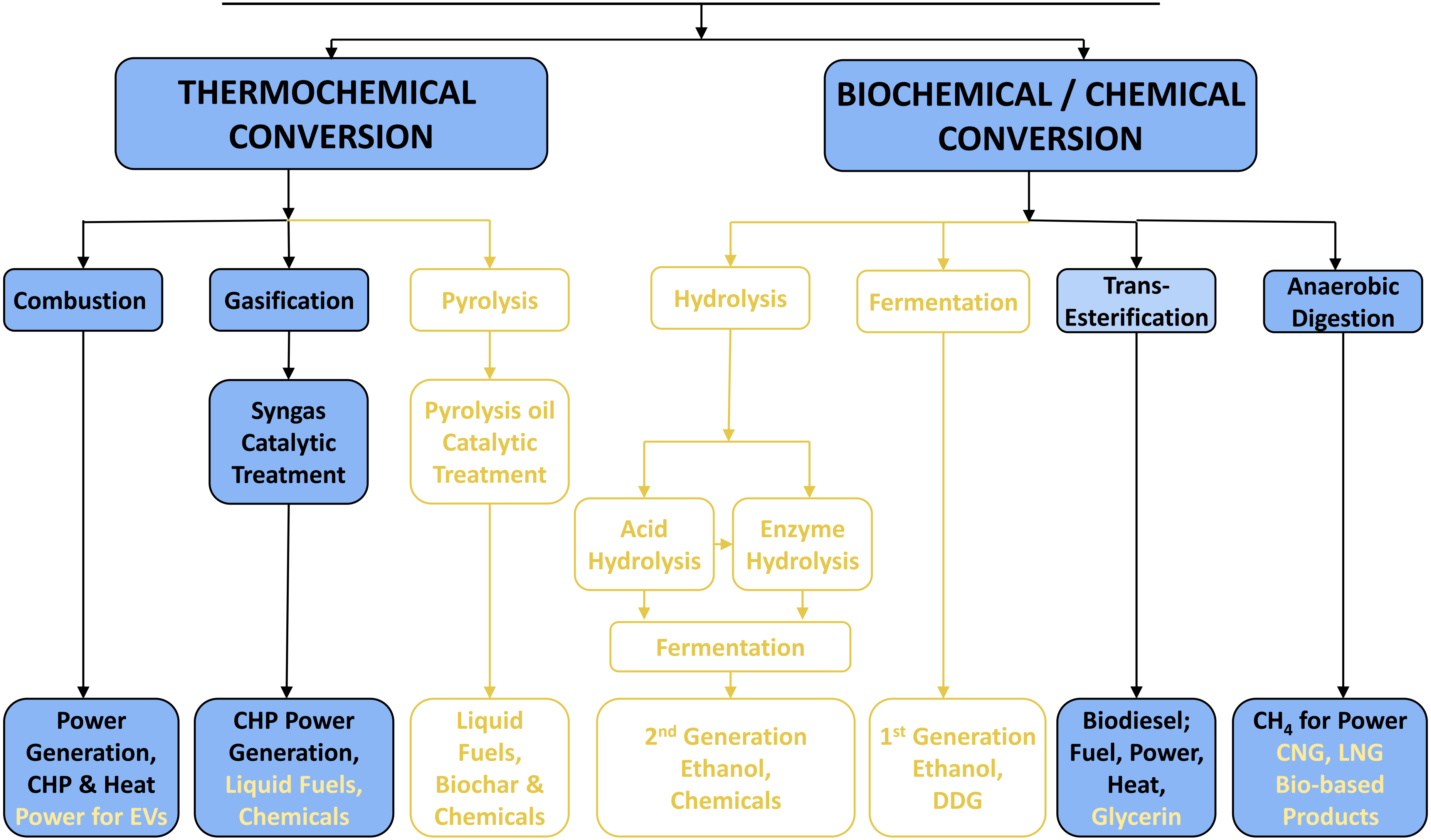
Biodiesel; Fuel, Power, Heat, Glycerin

CH_4 for Power CNG, LNG Bio-based Products

Technology Assessment

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

BIOMASS-to-BIOPOWER & BIOHEAT CONVERSION PATHWAYS



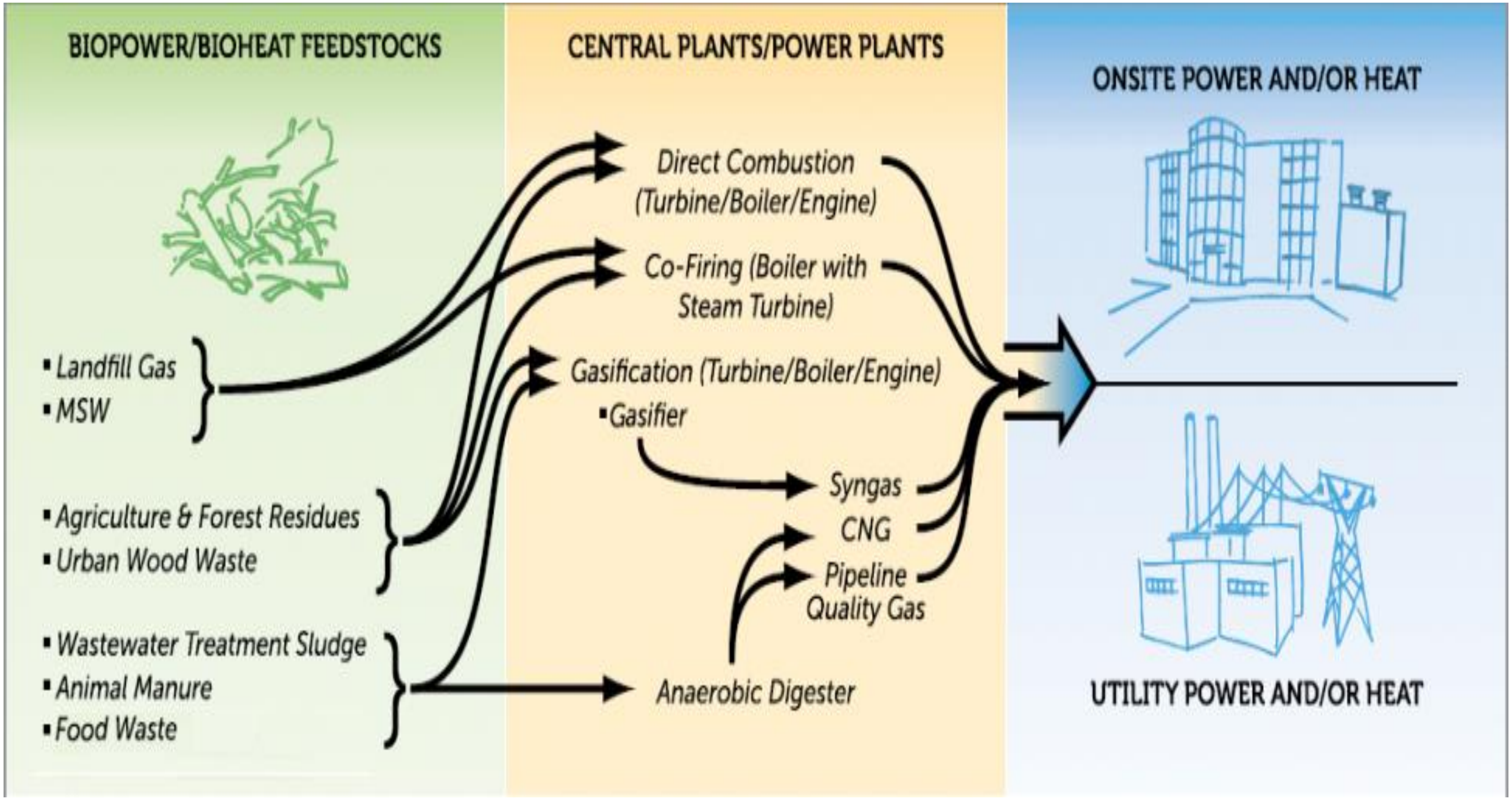
THERMOCHEMICAL CONVERSION

- Combustion → Power Generation, CHP & Heat, Power for EVs
- Gasification → Syngas Catalytic Treatment → CHP Power Generation, Liquid Fuels, Chemicals
- Pyrolysis → Pyrolysis oil Catalytic Treatment → Liquid Fuels, Biochar & Chemicals

BIOCHEMICAL / CHEMICAL CONVERSION

- Hydrolysis → Acid Hydrolysis → Enzyme Hydrolysis → Fermentation → 2^{nd} Generation Ethanol, Chemicals
- Fermentation → 1^{st} Generation Ethanol, DDG
- Trans-Esterification → Biodiesel; Fuel, Power, Heat, Glycerin
- Anaerobic Digestion → CH_4 for Power, CNG, LNG, Bio-based Products

BIOPOWER & BIOHEAT PATHWAYS



BIOPOWER/BIOHEAT FEEDSTOCKS

- Landfill Gas
- MSW

- Agriculture & Forest Residues
- Urban Wood Waste

- Wastewater Treatment Sludge
- Animal Manure
- Food Waste

CENTRAL PLANTS/POWER PLANTS

Direct Combustion (Turbine/Boiler/Engine)

Co-Firing (Boiler with Steam Turbine)

Gasification (Turbine/Boiler/Engine)
- Gasifier

Syngas
CNG
Pipeline Quality Gas

Anaerobic Digester

ONSITE POWER AND/OR HEAT

UTILITY POWER AND/OR HEAT

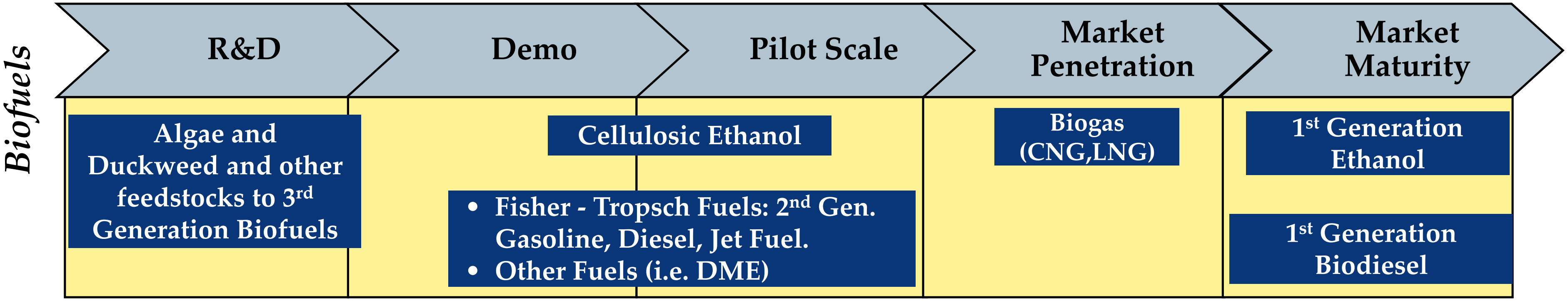
State Bioenergy Primer
http://www.epa.gov/statelocalclimate/documents/pdf/bioenergy.pdf

* State Bioenergy Primer

Technologies for Biopower Generation:

- **Direct combustion** is the primary form of biomass utilization for power generation. It is a mature technology that is applied broadly in industrial CHP and stand-alone grid power applications.
- **Gasification** of biomass mostly considered to convert biomass into transportation fuels however there have been considerations to utilize part of syn-gas to generate power and heat for the process needs.
- **Anaerobic Digestion** is commonly practiced in wastewater treatment plants and increasingly on animal farms. Food waste anaerobic digestion is currently being considered as an emerging technology. Landfill gas is also a product of natural anaerobic digestion in landfills. Power generation and smaller CHP are the most common applications.
- **Trans-esterification** is commonly practiced to produce biodiesel from vegetable oils and waste oils. Biodiesel is commonly blended into diesel in transportation applications. Biodiesel is also used in small power generation units and blended into home heating oil in small percentages.

Status of Biofuels Technologies



Biofuels

R&D

Demo

Pilot Scale

Market Penetration

Market Maturity

Algae and Duckweed and other feedstocks to 3rd Generation Biofuels

Cellulosic Ethanol

- **Fisher - Tropsch Fuels: 2nd Gen. Gasoline, Diesel, Jet Fuel.**
- **Other Fuels (i.e. DME)**

Biogas (CNG,LNG)

1st Generation Ethanol

1st Generation Biodiesel

Technology Assessment: Biofuels Technologies

Biofuels technologies are categorized as 1st generation, 2nd generation and 3rd generation.

1st Generation Biofuels

- ***Ethanol*** produced from Corn and Sugar cane. It is a clean burning, high-octane alcohol fuel used as a replacement and extender for gasoline
  - Technology: Fermentation
- ***Biodiesel*** produced from soy bean and other oily seeds. It is a high-cetane, sulfur-free alternative to (or extender of) diesel fuel and heating oil
  - Technology: Trans-esterification.

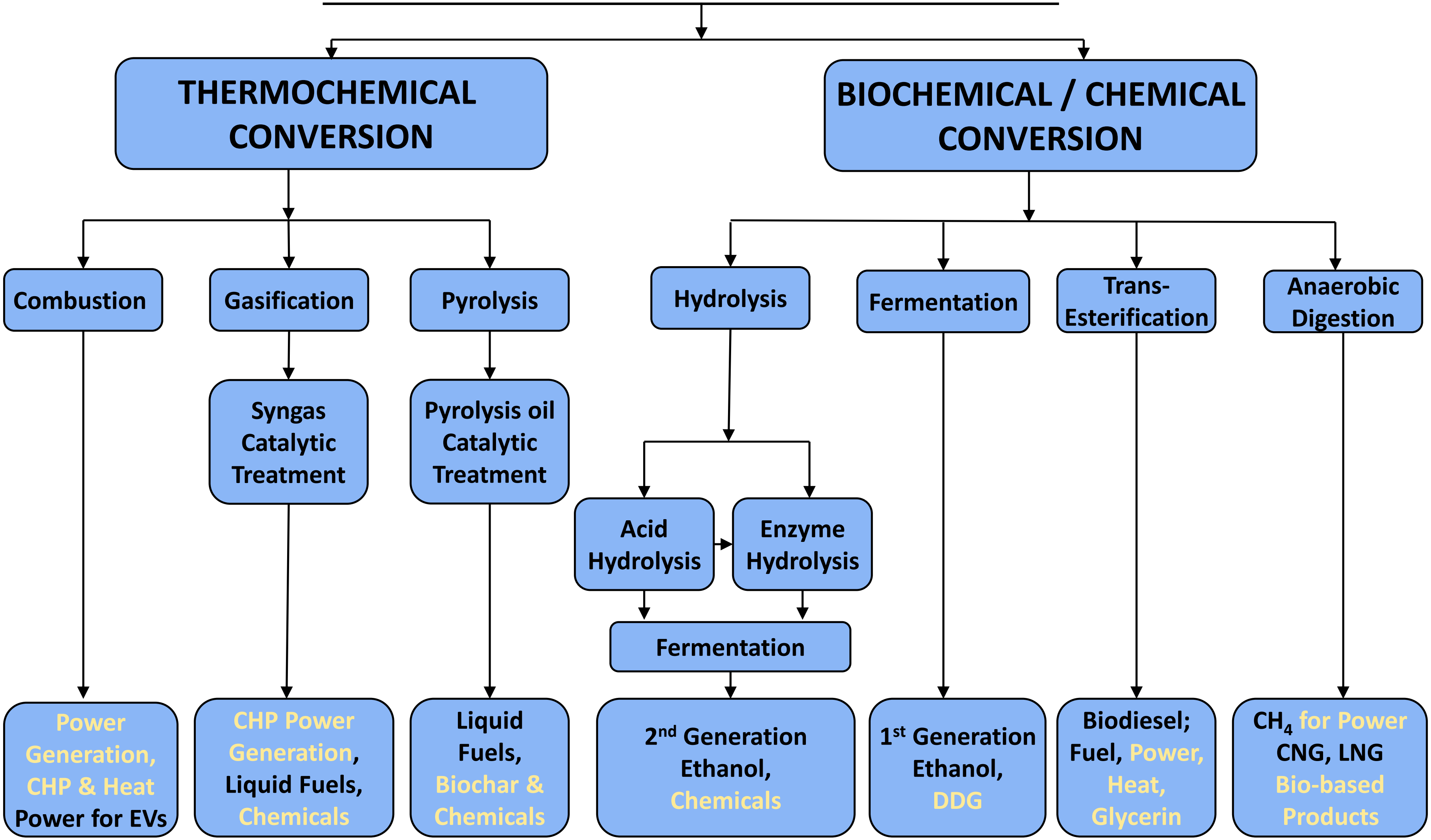
2nd Generation Biofuels

- ***Advanced ethanol and drop-in fuels such as renewable diesel and renewable jet fuel.*** Produced from dedicated energy crops , waste biomass i.e., forestry and agricultural waste, and other suitable organics.
  - Technology: Hydrolysis (acid and/or enzyme) followed by fermentation, Gasification to syn-gas, and pyrolysis to pyrolysis oils followed by Fisher – Tropsch and other catalytic treatments.
- ***Renewable biodiesel: Biodiesel*** from waste oils
  - Technology: Trans-esterification.
- ***Renewable Natural Gas (RNG):*** *Produced from food waste and/or waste water anaerobic digestion, Landfill gas. RNG can either be utilized as compressed natural gas (CNG) for transportation applications or clean power generation*

3rd Generation Biofuels

- ***Advanced ethanol , biodiesel and jet-fuel .*** produced from Algae or duckweed
  - Technology: Fermentation or trans-esterification

BIOMASS-to-BIOFUELS CONVERSION PATHWAYS



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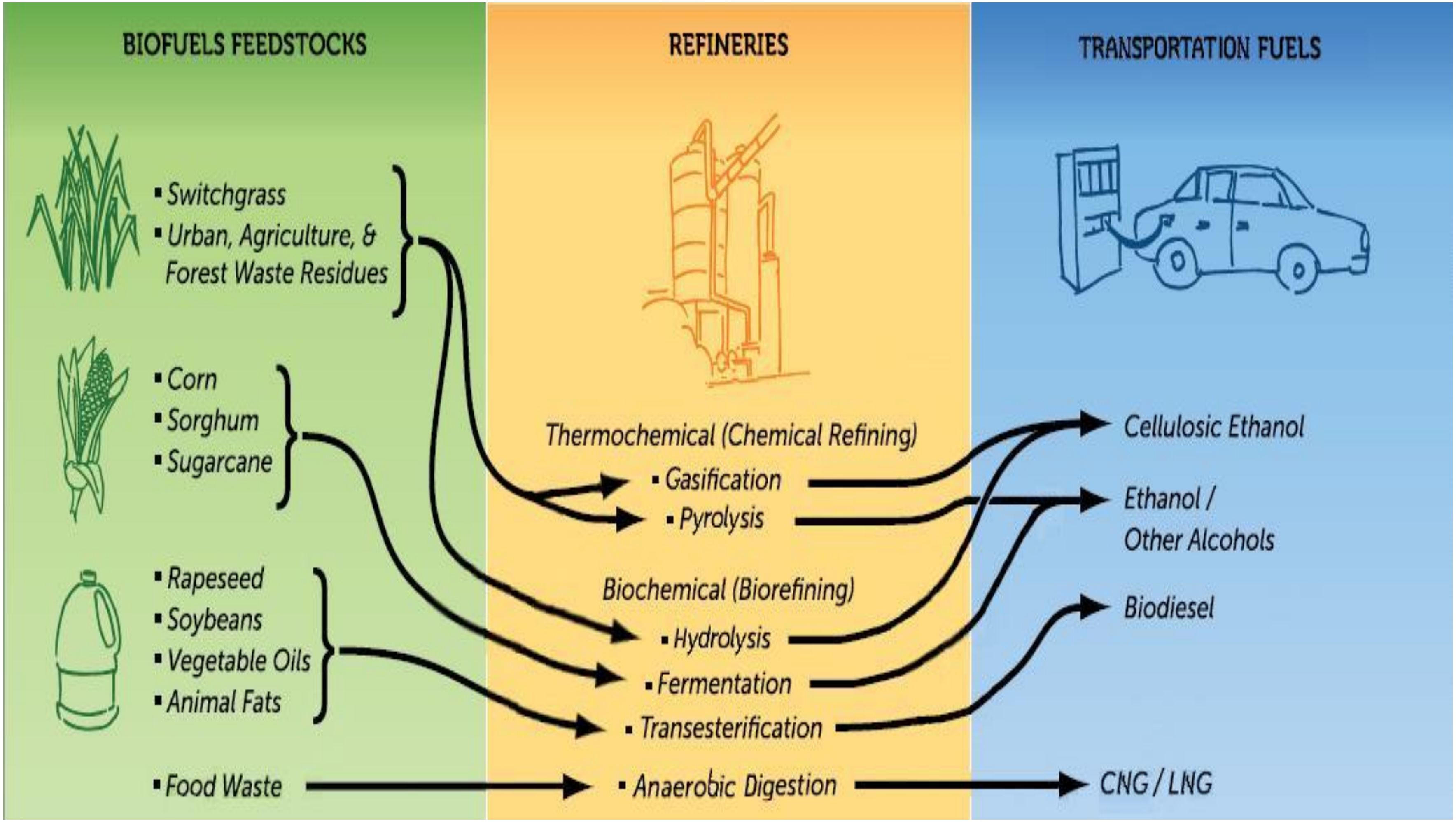
- Anaerobic Digestion → CH_4 for Power CNG, LNG Bio-based Products

BIOFUELS PATHWAYS



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

Biomass to Biofuels and Bioproducts

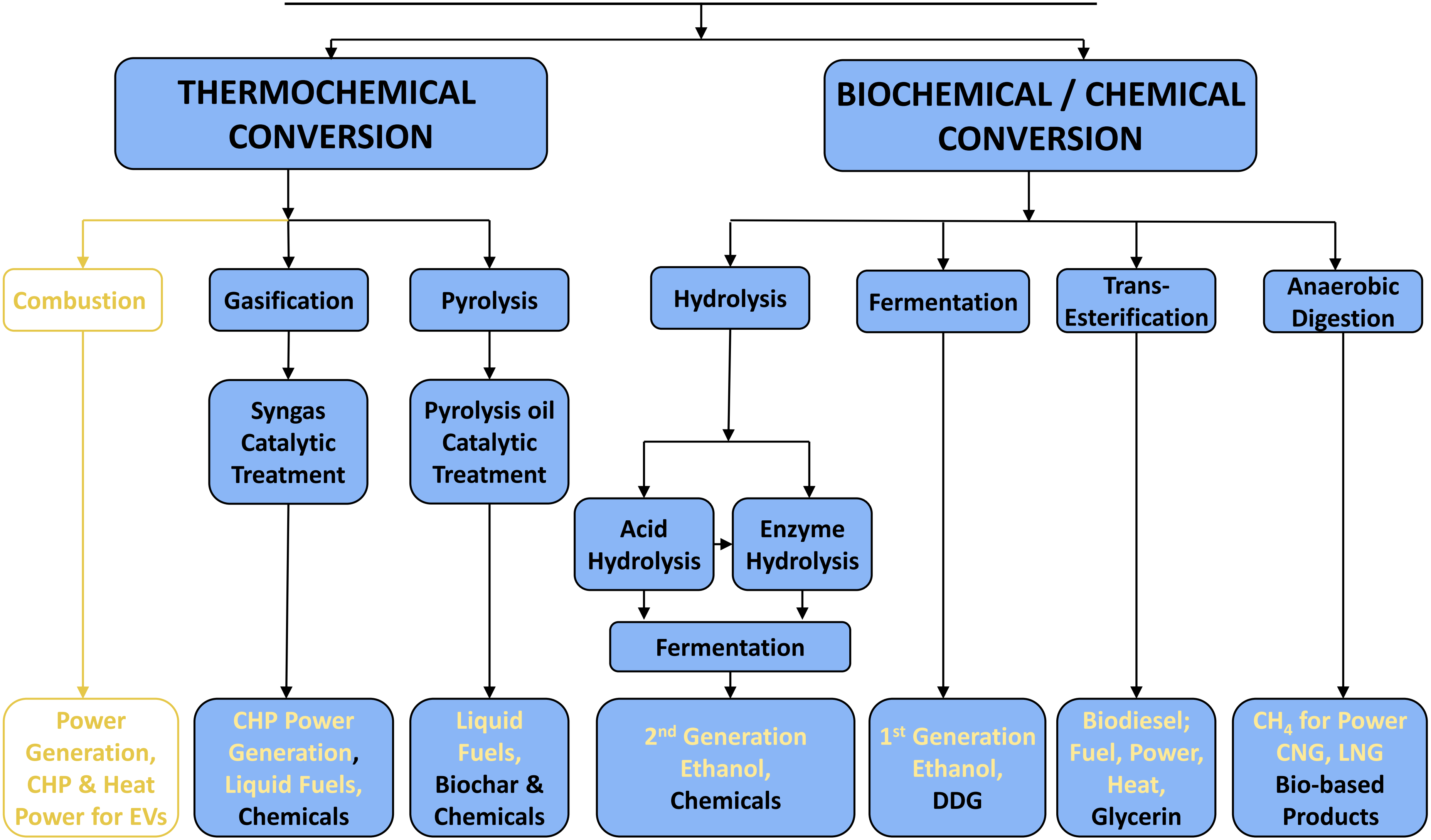
Thermochemical Conversion

- **Gasification** converts carbon-containing materials, including waste and biomass, into electricity and other valuable products, such as chemicals, fuels, and bio-based products. It does not involve combustion by using limited amount of oxygen or air in a closed reactor to convert carbon-based materials directly into a synthetic gas, or syngas which is a mixture of H_2 and CO. Generated syn-gas can be cleaned and further catalytically converted into liquid fuels, chemicals, and bio-based products. Gasification is considered as an emerging technology and researchers are currently optimizing the pilot and demo- scale applications.
- **Pyrolysis** converts organic materials by rapidly heating them at medium or high temperatures 50 - 600 °C. In the absence of air into organic vapors, pyrolysis gases and charcoal are produced. The vapors are condensed to bio-oil. Typically, 60-75 wt.% of the feedstock is converted into oil. Pyrolysis oil needs either further catalytic treatments or go through a process similar to petroleum crude refining. Pyrolysis is also considered as an emerging technology and process optimization and scale-up studies are needed.
- **Gasification and pyrolysis** processes can be designed based on the feedstock characteristics and desired end products such as liquid transportation fuels including 2nd generation ethanol, gasoline, long-chain hydrocarbons similar to diesel and jet fuel, intermediaries for chemical industry and bio-based end products.

Biochemical Conversion

- **Hydrolysis** technology is used to release the sugar components in the cell walls of cellulose and hemicellulose parts of biomass. The hydrolysis can be performed either via acid hydrolysis or enzyme hydrolysis. After these steps released sugars, via fermentation, can be converted in to 2nd generation ethanol also known as cellulosic ethanol. In some cases they are performed simultaneously. First acid-hydrolysis is used to pre-treat the biomass and then followed by enzymatic hydrolysis.
- **Fermentation** is the most common form of producing transportations fuels (ethanol) from biomass today. The most common feedstocks are corn starch and sugarcane . The ethanol produced via this pathway is also known as 1st generation Ethanol.
- **Trans-Esterification** of vegetable oils (virgin or used) is a common and mature technology for producing biodiesel. Product biodiesel can be utilized as transportation fuel and by-product glycerin can be utilized as a feedstock in chemical applications.
- **Anaerobic digestion** is commonly practiced in wastewater treatment plants and increasingly on animal farms. Landfill gas is also a product of natural anaerobic digestion in landfills. The product CH_4 can be utilized in CNG, LNG forms for transportation applications and by-products can be designed for soil remediation products such as bio-fertilizers.

BIOMASS-to-BIOPRODUCTS CONVERSION PATHWAYS



THERMOCHEMICAL CONVERSION

BIOCHEMICAL / CHEMICAL CONVERSION

Combustion

Gasification

Pyrolysis

Hydrolysis

Fermentation

Trans-Esterification

Anaerobic Digestion

Syngas Catalytic Treatment

Pyrolysis oil Catalytic Treatment

Acid Hydrolysis

Enzyme Hydrolysis

Fermentation

Power Generation, CHP & Heat Power for EVs

CHP Power Generation, Liquid Fuels, Chemicals

Liquid Fuels, Biochar & Chemicals

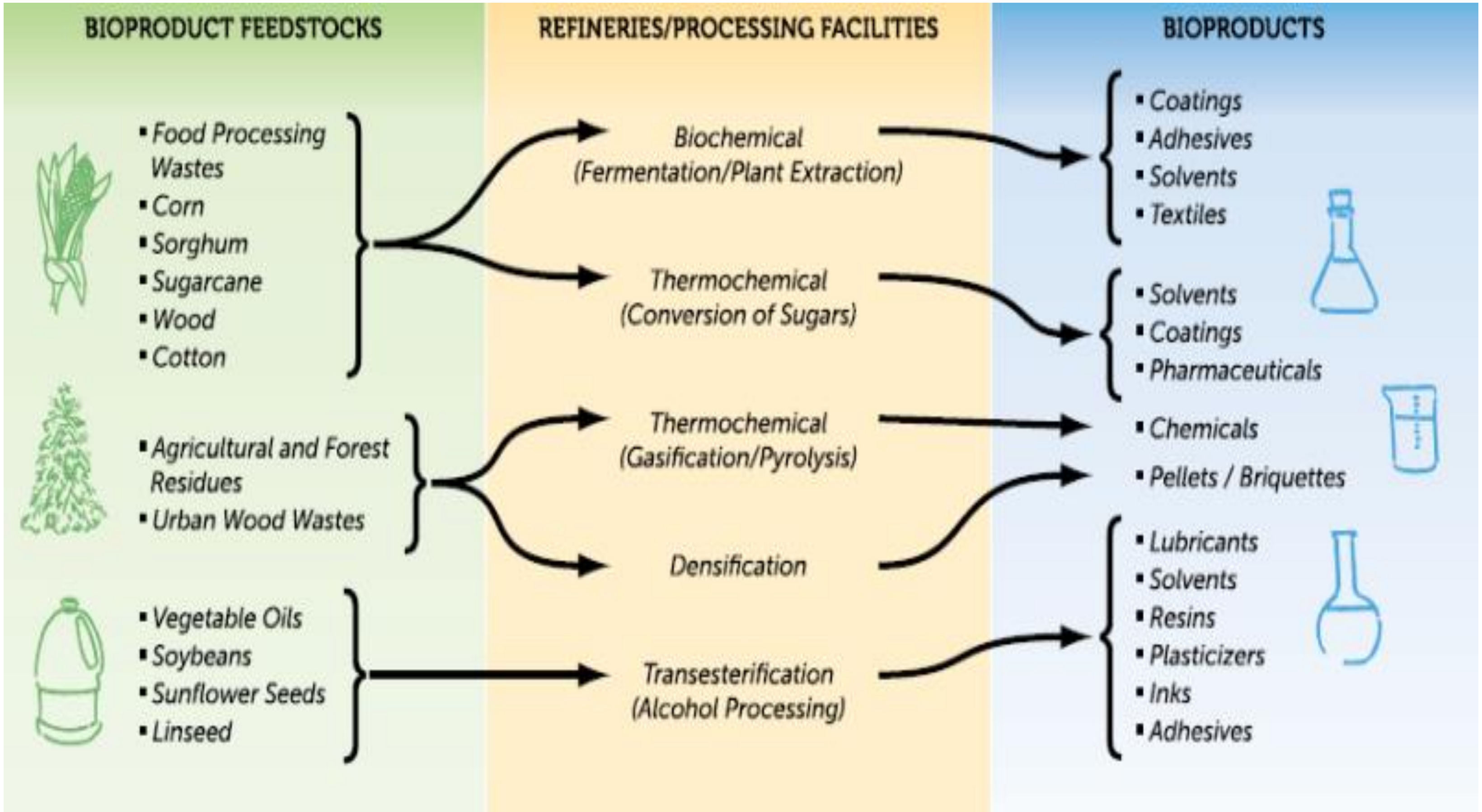
2nd Generation Ethanol, Chemicals

1st Generation Ethanol, DDG

Biodiesel; Fuel, Power, Heat, Glycerin

CH_4 for Power CNG, LNG Bio-based Products

BIOPRODUCT FEEDSTOCKS



State Bioenergy Primer
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III. Technology Assessment

Technology Profiles

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Technology Assessment

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

Technology Assessment

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Technology Assessment: Thermochemical Conversion » *Combustion*

RUTGERS
New Jersey Agricultural Experiment Station

Biomass combustion is commonly used for electricity and heat generation. Low carbon electricity can also be a good power source for electric vehicles.

Feedstock

Power can be produced from a range of solid biomass resources:

- Wood and wood residues, mostly from forest products mills, but also from urban sources (e.g., used pallets, tree trimmings, construction debris) is the primary feedstock.
- Agricultural residues can also be used although they present some additional challenges (e.g., ash content and properties).
- In the future woody or herbaceous energy crops may be grown.
- Municipal waste is also largely composed of biomass, and about 15% nationally is burned today in waste to energy plants.

Conversion

Biomass power production via direct combustion is mature technology:

- High-pressure steam is produced in a boiler, which is then expanded in a steam turbine to generate electricity.
- The high moisture content of the fuel and the relatively small scale of the plants (<50MW, likely much smaller in New Jersey) results in relatively low overall net electrical efficiencies of about 20-25%.
- Steam can be extracted for use in industrial processes in CHP applications, in which case the electrical generation efficiency will be lower, but overall efficiency (measured as electricity + use thermal output), will be higher (70-80%).
- In co-firing, 2-15% biomass (energy basis), depending on the boiler type and feed system, can be co-combusted with coal in existing utility boilers at much higher efficiency (30-35%).

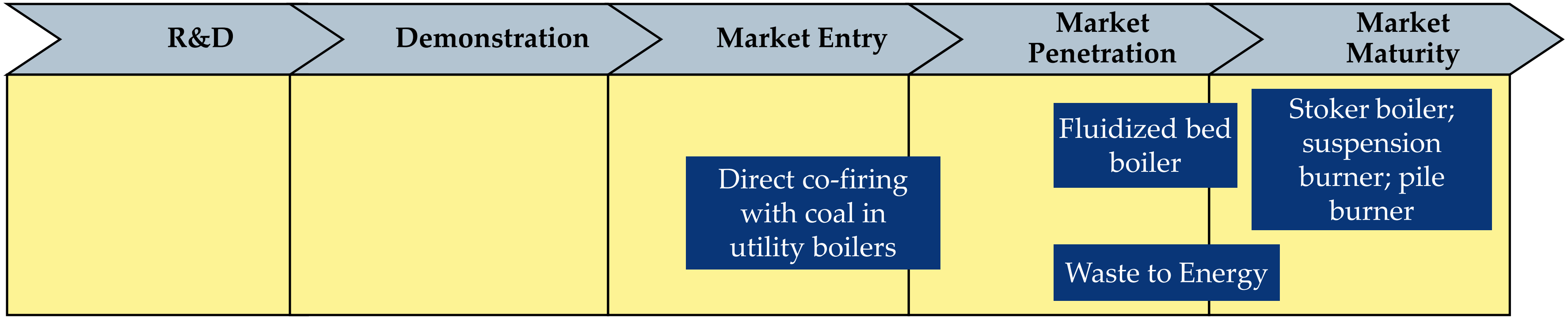
End-Use

Power is generally sold into the grid or used onsite as part of a CHP system.

- Most biopower in the United States today is CHP in the forest products industry (~5,000 MW).
- In some states, stand-alone biopower is also common, e.g., California, New England (~1,000 MW).
- Municipal solid waste fuels about 2,700 MW of waste-to-energy (WTE) plants, with about 75% of the fuel being biomass.
- Biomass generated electricity can power electric vehicles therefore biomass electricity contributes transportation fuel solutions.

Technology Assessment: Thermochemical Conversion» *Combustion*

Direct combustion is a well developed technology with several boiler types available. Fuel type is an important factor in boiler type choice.



R&D

Demonstration

Market Entry

Market Penetration

Market Maturity

Direct co-firing with coal in utility boilers

Fluidized bed boiler

Waste to Energy

Stoker boiler; suspension burner; pile burner

Emerging Technologies

- Developments are focused on increasing cycle efficiency, reducing CAPEX and OPEX and reducing emissions.
- The fluidized-bed (FB) combustors are more efficient combustors and they burn biomass in a bed of hot granular material. Air is injected at a high-rate underneath the bed to create the appearance of a boiling liquid. This helps to evenly distribute the fuel and heat. FB combustors are becoming the systems of choice for biomass fuels, due to good fuel flexibility and good emissions characteristics.
- Developments in stoker technology involving the introduction of a much higher fraction of air above the grate could result in lower emissions, essentially turning a stoker into a two-stage gasification/combustion technology. For example, see http://mass.gov/doer/rps/hemphill.pdf.

Established Technologies

- The stoker boiler is the most mature and widely deployed. Biomass is added to a stoker boiler in a thin layer on a grate near the bottom of the boiler. Air is introduced both above and below the grate. There are three types of stoker boilers – stationary sloping grate, traveling grate and vibrating grate.
- Suspension burners are used in niche applications when the biomass fuel is available in small diameters (<1mm), typically through other processes (e.g., sawdust).
- Pile burners have been around since the 1700s and have limited applicability today.
- Co-firing with coal is relatively common in industrial boilers designed for that purpose, and it has been well demonstrated in utility boilers, especially using woody biomass. However, non-technical factors have limited market adoption among utilities.
- For waste-to-energy, so-called mass-burn, RDF fueled and modular combustors are available.

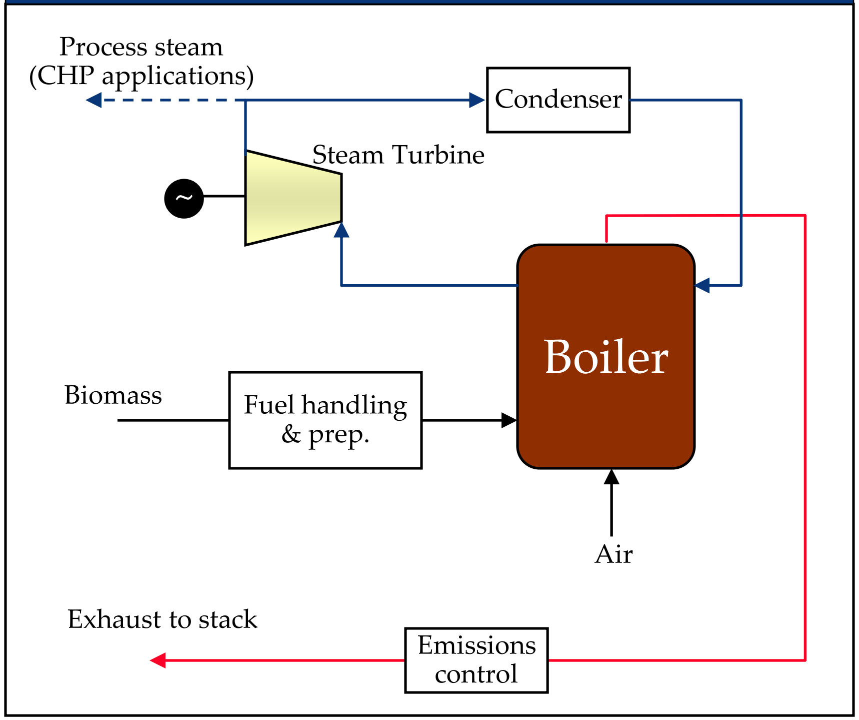
Technology Assessment: Thermochemical Conversion» *Combustion*

Direct combustion uses the same Rankine cycle technology as coal plants, only at a smaller scale.

Honey Lake Power Plant in California

http://ucanr.edu/sites/WoodyBiomass/newsletters/Industry_Information33479.pdf

Biomass Power Plant (Rankine cycle)



Source: Navigant Consulting, Inc.

- Emissions controls, such as an electrostatic precipitator (ESP) or baghouse for particulates, and some form of NOx control, such as ammonia injection or staged combustion, are standard on new plants today to meet typical emissions requirements.

Biomass can be co-fired with coal at rates of up to 15% (Btu basis) in existing boilers.

- Co-firing is relatively routine in industrial multi-fuel boilers, but most utility coal boilers were not designed to co-fire biomass.
- The two types of direct fire options are blended feed and separate feed. The choice depends on the boiler type and the amount of co-firing.
  - For pulverized coal boilers (the most common type), blended feed systems can be used up to about 2% biomass.
  - For values of 2-15% biomass, a separate biomass feed system must be installed, and other modifications may be needed. Each potential application must be evaluated on a case-by-case basis.
- Gasified biomass (syngas) can also be fed into a coal boiler.[1] This would require fewer boiler modifications, but have higher capital costs for the gasifier.

Fuel mixing at the NIPSCO Power Plant in Bailey, Indiana

Source: NREL.

- The emissions impacts of co-firing will vary but generally, since biomass has less sulfur than coal, co-firing results in lower SO_2 emission. Also, in plants without NOx controls, it is generally accepted that co-firing should reduce NOx formation.

[1] Not discussed here. This application is at a much earlier stage of development than direct co-firing of solid biomass.

Feedstock supply is the least well developed aspect of the biomass power supply chain.

Supply Chain

- Except for CHP, where the fuel is typically a residue produced onsite, biomass feedstock supply is the key challenge and risk factor for biomass power plants.
  - Both the price and availability of biomass over the long-term are major risk factors.
  - The feedstock supply "industry" is highly fragmented and it can be difficult to secure long-term contracts for fuel.
- Once the power is sold, the supply chain is essentially the existing electric power supply chain.

Other Issues Unique to Co-firing

- Co-firing has been limited because of several barriers.
  - Inability to sell fly ash because it would not meet the ASTM specifications (loss of revenue for coal plant).
  - Potential trigger for a New Source Review (NSR), which could result in other retrofits required at the plant.
  - Co-firing receives limited incentives and is not always eligible for state RPS programs.

Markets

- The power is either used onsite (CHP applications) or sold to the grid (stand-alone systems and excess power from CHP).
- Biomass power benefits from Federal and state incentives and is also eligible for various state RPS programs.
  - In New Jersey, the biomass eligibility requirements are relatively stringent, which may preclude the use of many of the resources identified in this report for RPS compliance.

Technology Assessment

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Technology Assessment: Thermochemical Conversion» *Gasification*

Gasification is an emerging viable technology to convert biomass into syn-gas for fuels synthesis and small power and heat generation applications.

Feedstock

Gasification can use a range of solid biomass resources, similar to combustion.

- Wood and wood residues, mostly from forest products mills, but also from urban sources (e.g., used pallets, tree trimmings, construction debris) is the primary feedstock.
- Agricultural residues can also be used. The challenges faced by combustion technologies (e.g., ash content a properties) are generally less of an issue with thermochemical conversion.
- In the future, woody or herbaceous energy crops may be grown.
- Municipal waste must be processed into refuse derived fuel (RDF) before it can be used.

Conversion

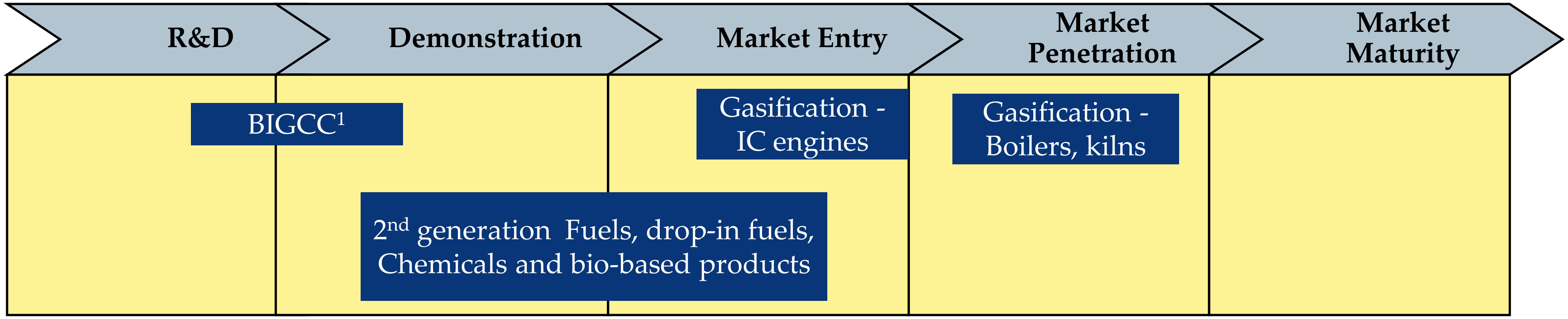
- Gasification produces a low-medium Btu syn-gas (100-300 Btu/scf) that can be cleaned and used in power generation or in fuel synthesis.
- Biomass Integrated Gasification combined Cycle (BIGCC) is a large scale power generation and not practiced wide-spread because of economic feasibility concerns.
- Steam can be co-produced for biomass gasification & CHP applications.
- For power generation, air-blown or oxygen-blown gasifiers are appropriate.
- For fuel synthesis, pressurized, oxygen-blown gasifiers, or indirectly heated gasifiers, are required.
  - Syn-gas produced by gasification can be catalytically converted into liquid fuels by the Fischer- Tropsch process.

End-Use

- For power or CHP, the end-use is the same as for direct combustion (electricity).
- For gasification to fuels, the end-use is transportation fuels. The current biomass gasification efforts concentrate on production of liquid transportation fuels and bio-based chemicals and bio-based products. to be the blending of biofuels. The produced Fischer-Tropsch (FT) fuels can be blended in any quantity, up to 100%, since their properties are consistent with petroleum-based fuels.

Technology Assessment: Thermochemical Conversion» *Gasification*

Gasification is an emerging viable technology to convert biomass into syn-gas for fuels synthesis and small power, heat, biofuels and by-products generation applications.



R&D

Demonstration

Market Entry

Market Penetration

Market Maturity

BIGCC[1]

Gasification - IC engines

Gasification - Boilers, kilns

2nd generation Fuels, drop-in fuels, Chemicals and bio-based products

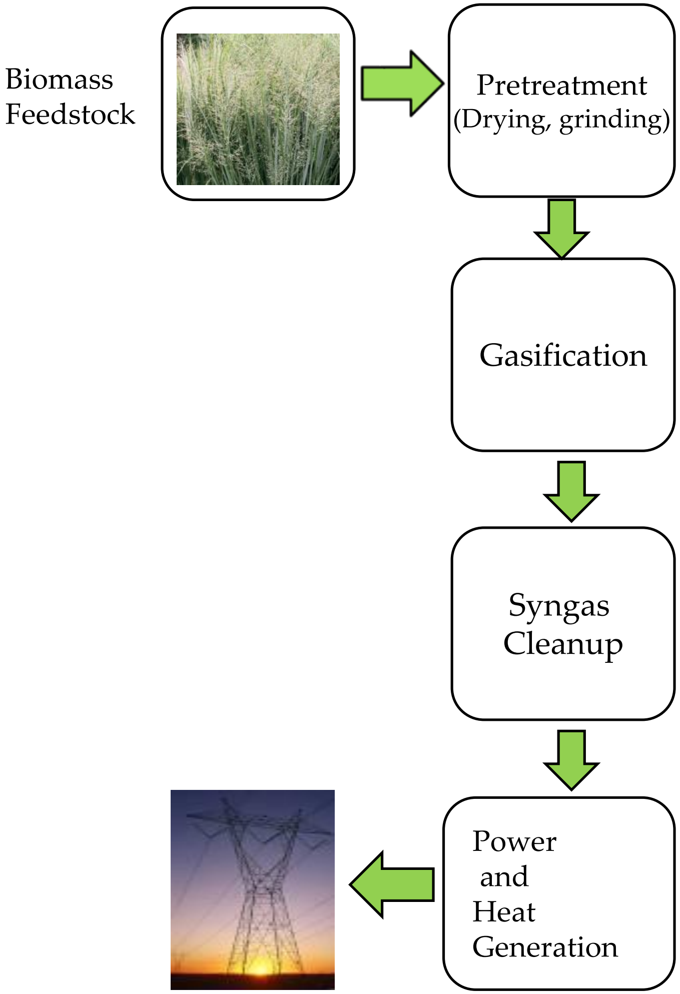
<u>Gasification</u>

- Although gasification has been developed over many decades, biomass gasification has not seen significant commercial market penetration – its main use has been to produce low-Btu “producer gas” that can be used as a substitute for fuel oil or natural gas in existing boilers and kilns (e.g., pulp & paper mill lime kilns).
- Nevertheless, many of the technology platforms are in place and are relatively well developed – what has been lacking is integration and successful commercialization.
- There is a recent push to develop small-scale biomass gasification power systems (<2MWe) using reciprocating engines around the world.
- Recent biomass gasification applications in the US and Europe concentrate liquid transportation fuels synthesis via FT and other catalytic treatments.
- Based on the feedstock and gasification conditions, the produced syn-gas composition and HHV vary. The reaction conditions should be optimized based on available feedstock and desired end-products and cost considerations.

1. Biomass Integrated Gasification Combined Cycle.
2. Biomass to liquids – the production of biofuels via catalytic synthesis of syngas derived from biomass gasification.
3. http://www.se-ibss.org/documents/presentations/conversion-biomass-gasification-and-fischer-tropsch-synthesis-of-liquid-fuels

Technology Assessment: Thermochemical Conversion» *Gasification*

Biomass Gasification for Power and Heat Generation



Biomass Feedstock

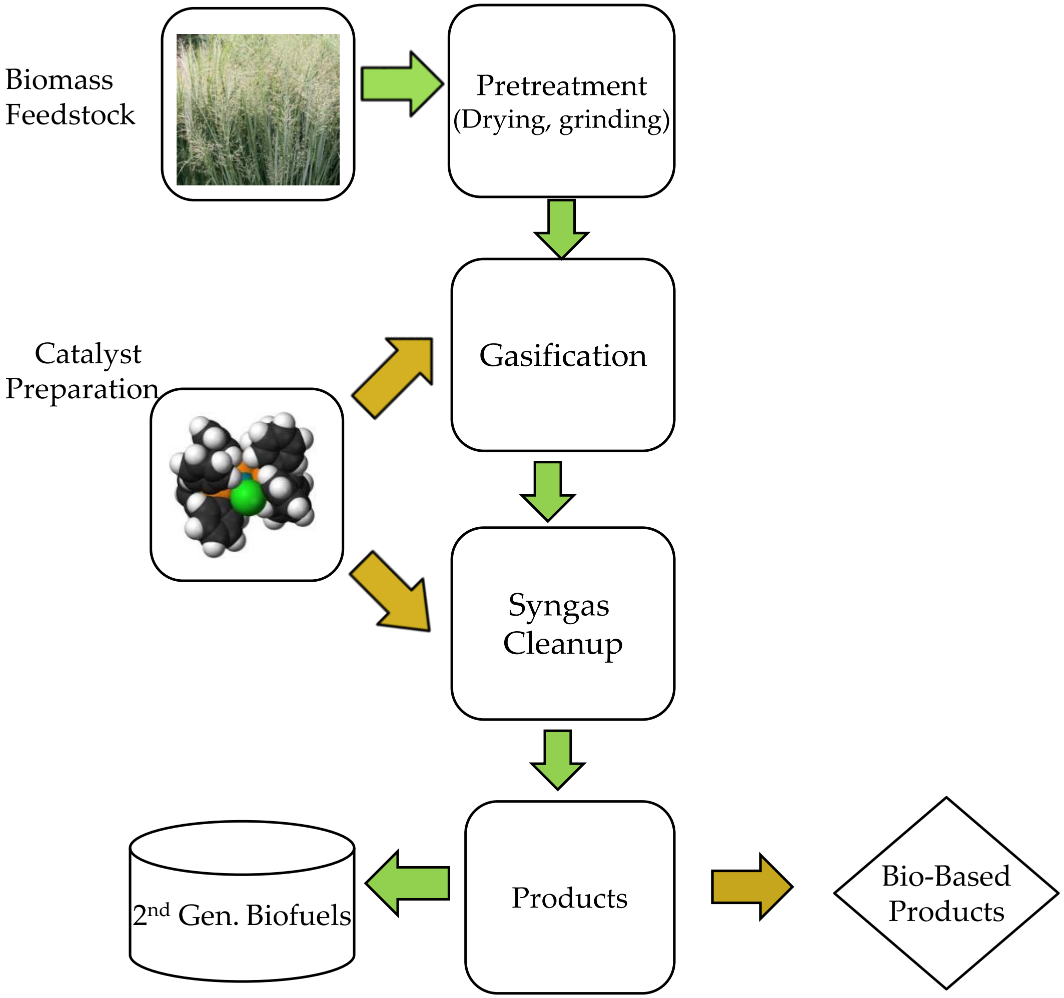
Pretreatment
(Drying, grinding)

Gasification

Syngas Cleanup

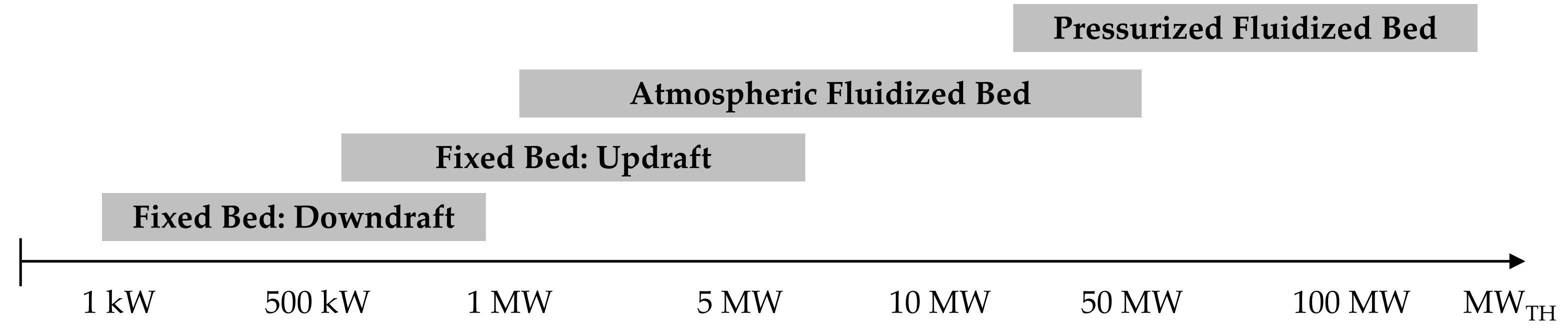
Power and Heat Generation

Biomass Gasification into 2nd Generation Biofuels



Fixed-bed gasifiers are suitable for small-scale application – fluidized bed gasifiers can achieve more efficient conversion.

Gasifier design vs. biomass input rates



Pressurized Fluidized Bed

Atmospheric Fluidized Bed

Fixed Bed: Updraft

Fixed Bed: Downdraft

1 kW | 500 kW | 1 MW | 5 MW | 10 MW | 50 MW | 100 MW | MW_{TH}

Note: 1 MWth of biomass input is approximately 4.5 dry tons per day of woody biomass.

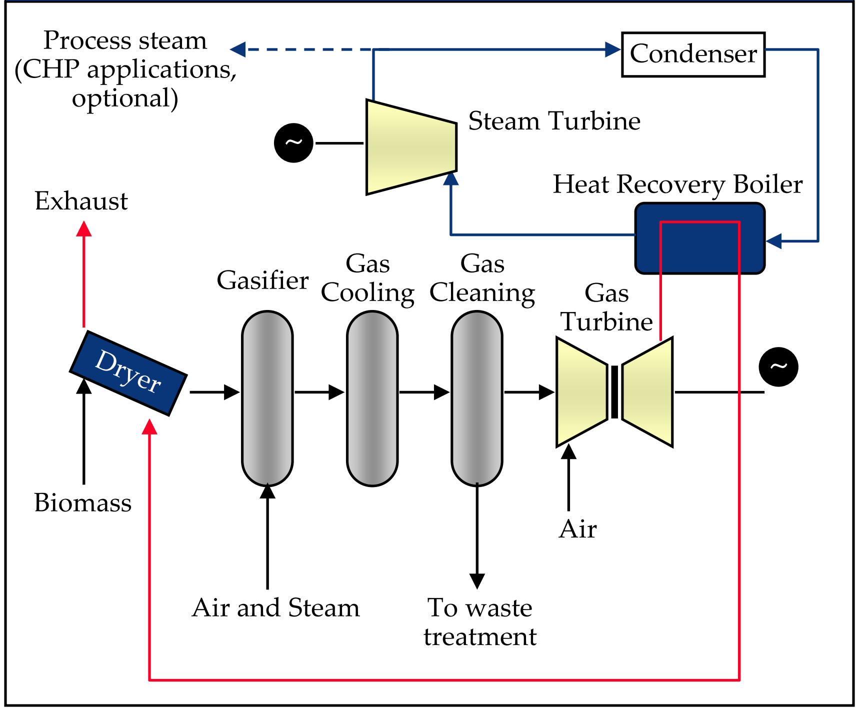
- **Fixed Bed** Gasifiers are cheaper to build, easier to operate and produce a synthesis gas that is suitable for IC engines (lower content of dust and tars and lower temperature).
- **Fluidized Bed** technologies have been developed for power and fuel synthesis applications up to about 50MWe. Benefits of this design are:
  - Compact construction because of high heat exchange and reaction rates. Scalable applications.
  - Greater fuel flexibility than fixed-bed units in terms of moisture, ash, bulk density and particle size.
  - Pressurization and the ability to use pure oxygen instead of air make them suitable for fuels synthesis.
  - Complicated design and operation. Higher cost.
  - Efficient biomass conversion.

Technology Assessment: Thermochemical Conversion» *Gasification*

Biomass integrated gasification combined cycle (IGCC) technology offers the prospect of high conversion efficiency and low emissions.

- The use of a gas turbine and steam turbine (a combined cycle), coupled with heat integration from the gasifier, offers the potential for efficiencies about 50% higher than for direct combustion.
- The syngas is a mixture of mainly H_2, CO, CO_2, CH_4, N_2, and other hydrocarbons.
  - At a minimum, the syngas must be cleaned of particulates, alkali compounds, and tars to make it suitable for combustion in a gas turbine.
- BIGCC systems are inherently low polluting when compared to biomass combustion.
  - The syn-gas must be clean enough so as not to damage the gas turbine.
  - Because combustion occurs in the gas turbine, emissions of NOx, CO and hydrocarbons are comparable to those of a natural gas-fired GTCC.
  - Depending on the type of biomass, the ash can be used as fertilizer.
  - Higher CAPEX & OPEX.

Biomass Integrated Gasification Combined Cycle (BIGCC)

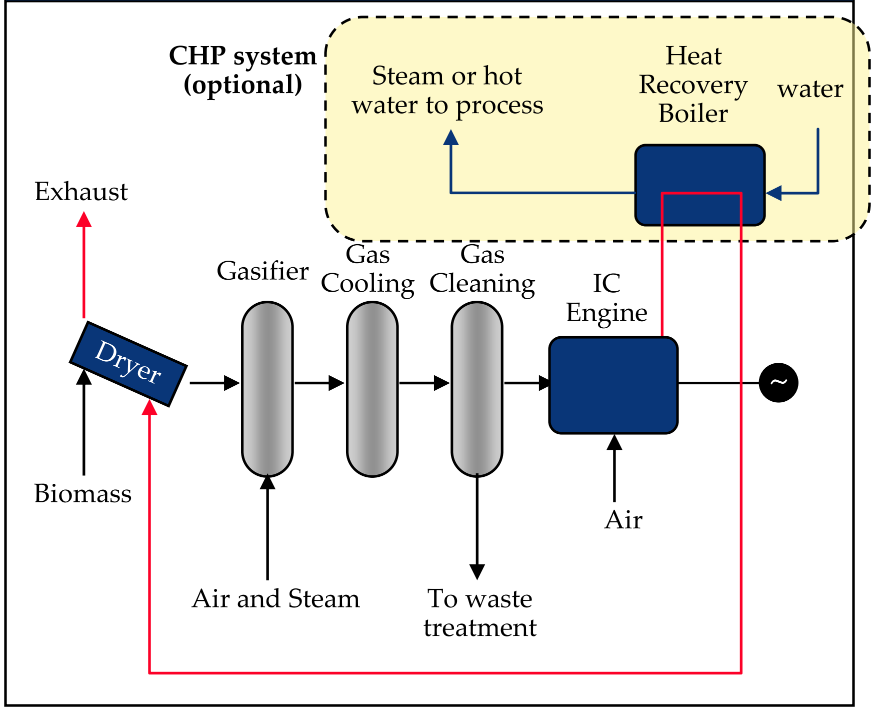


Source: Navigant Consulting, Inc.

Small-scale gasification can be used to supply syn-gas to an internal combustion engine or a small gas turbine.

- For small-scale applications, biomass combustion for use with a steam cycle may not be practical (e.g., need for high-pressure steam).
    - — Gasification coupled to an IC engine is more practical at small scales.
- The syngas is a mixture of mainly H_2, CO, CO_2, CH_4, N_2, and other hydrocarbons.
    - — At a minimum, the syngas must be cleaned of particulates, alkali compounds, and tars to make it suitable for combustion in a gas turbine or internal combustion engine.
- Both compression ignited (diesel) and spark ignited (otto) engines can be used; the power output of both deteriorates when operating on producer gas but emissions should be similar to natural gas operation.

Small-scale Biomass Gasifier with Internal Combustion (IC) Engine



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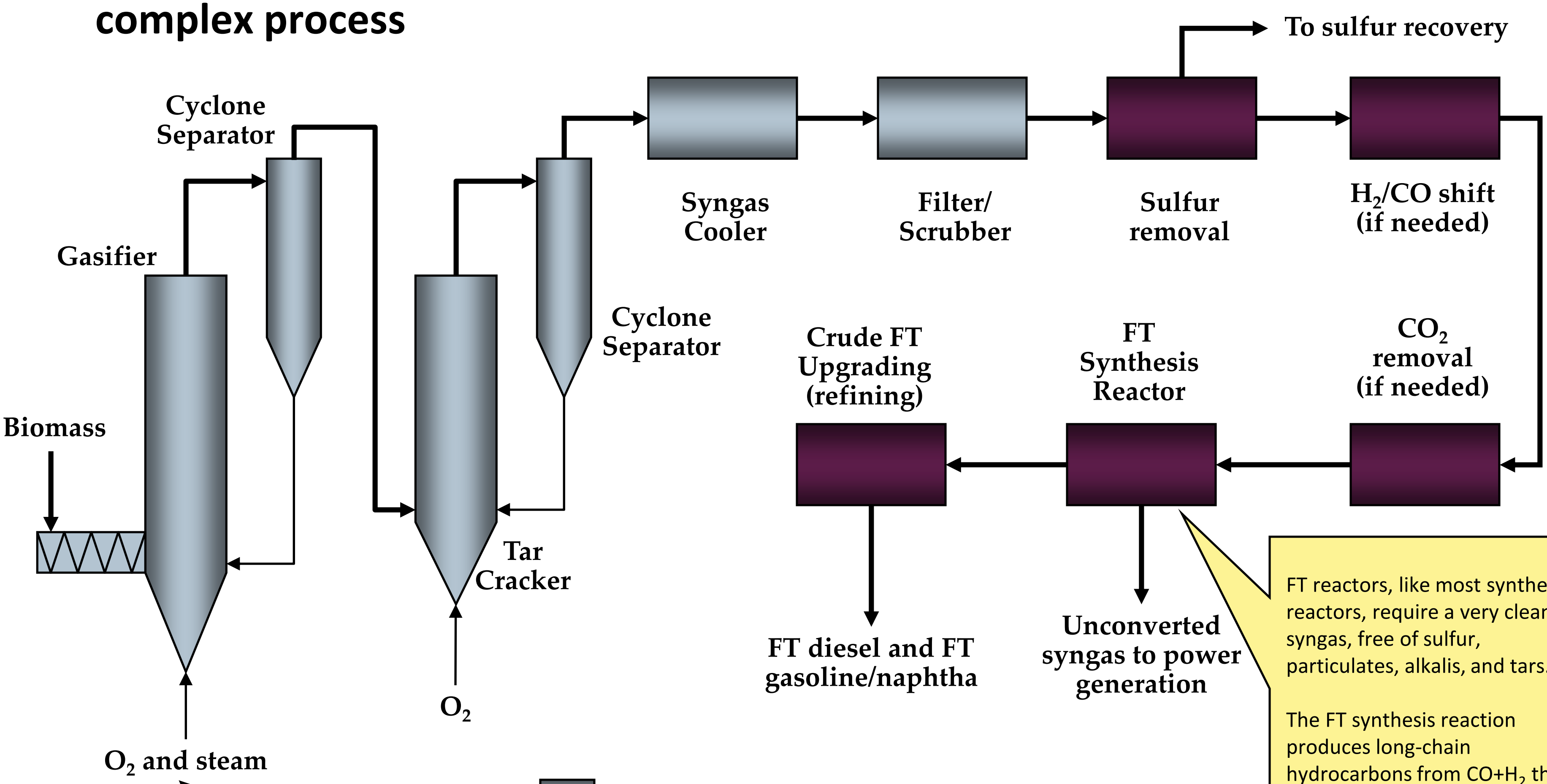
Technology Assessment: Thermochemical Conversion» *Gasification*

Production of liquid transport fuels such as Fischer-Tropsch fuels, is a complex process



Requires oxygen instead of air to prevent N_2 dilution

FT reactors, like most synthesis reactors, require a very clean syngas, free of sulfur, particulates, alkalis, and tars.

The FT synthesis reaction produces long-chain hydrocarbons from CO+H_2 that must then be upgraded (refined) into transportation fuels.

▨ Similar to power applications using gasification

■ Additional steps needed for liquid fuel synthesis

Technology Assessment: Thermochemical Conversion» *Gasification*

Supply Chain

- Securing biomass feedstocks suitable for gasification conversion is a barrier to overcome.
- In addition to purpose grown solid biomass, low-moisture organic part of municipal solid waste appear to be a feasible feedstock for gasification technology, such as wood chips, cardboard, waste paper, C&D wood waste.
- Small scale efficient gasifiers are needed.
- Gasification product of syn-gas clean up/conditioning also an important step before utilizing syngas for either power generation or converting syn-gas into liquid transportation fuels.

Markets

- Power generation from gasification to syn-gas pathway should prove that it is economically feasible.
- Syn-gas catalytic conversion into liquid fuels is still at demonstration scale. With USEPA RFS mandate and efforts to develop low carbon advanced fuels this pathway is nearing commercialization.

Technology Assessment

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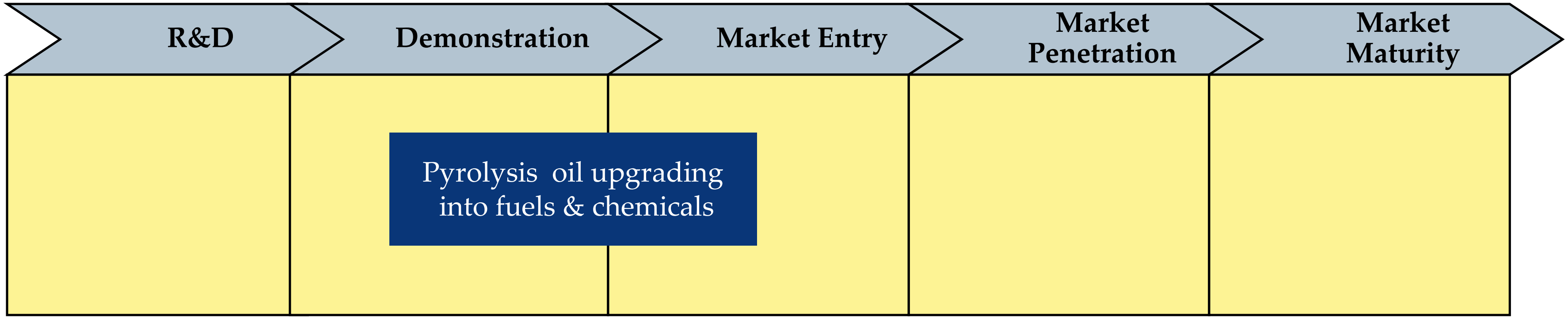
Technology Assessment: Thermochemical Conversion» *Pyrolysis*

Pyrolysis of Biomass is used to convert biomass into bio-crude oil which can be upgraded into clean chemicals and fuels.



<u>Pyrolysis :</u>

- Pyrolysis oil consists of different classes of oxygenated compounds with properties such as low heating value. Incomplete volatility, acidity, instability restrict its wide-range applications.

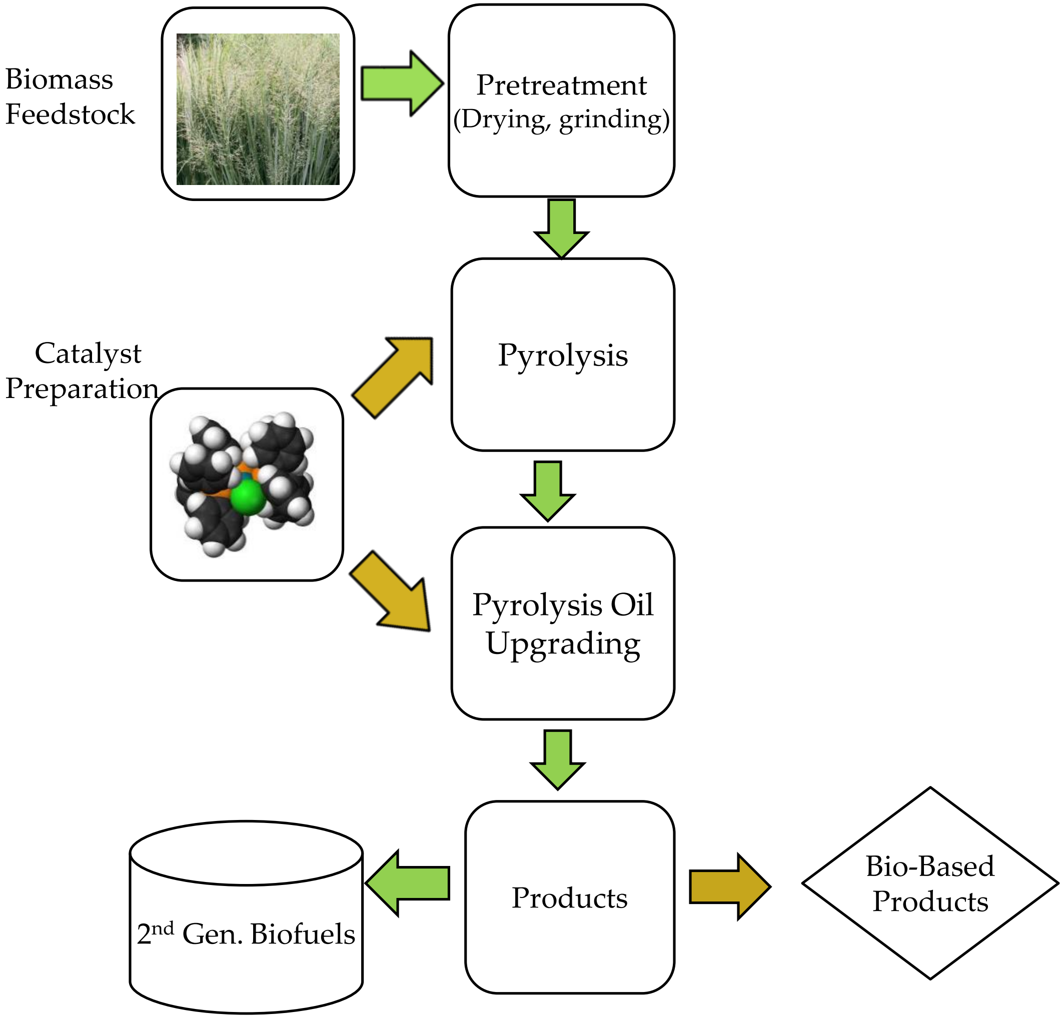
-The oxygen elimination can be achieved by various methods such as hydro-treating in which hydrogen is used to remove oxygen in the form of water and catalytic cracking which is achieved by catalysts through simultaneous reactions of dehydration, decarboxylation and decarbonylation reactions.

- Recent demo-scale applications concentrate on optimizing the feeding of bio-crude oil into existing refineries.
- Pyrolysis of biomass is not a viable option for just power generation.

1. French, R., & Czernik,S., Fuel Processing Technology, 91(2010) 25-32

Technology Assessment: Thermochemical Conversion» *Pyrolysis*

Biomass Pyrolysis into 2nd Generation Fuels


Biomass Feedstock

Pretreatment (Drying, grinding)

Catalyst Preparation

Pyrolysis

Pyrolysis Oil Upgrading

Products

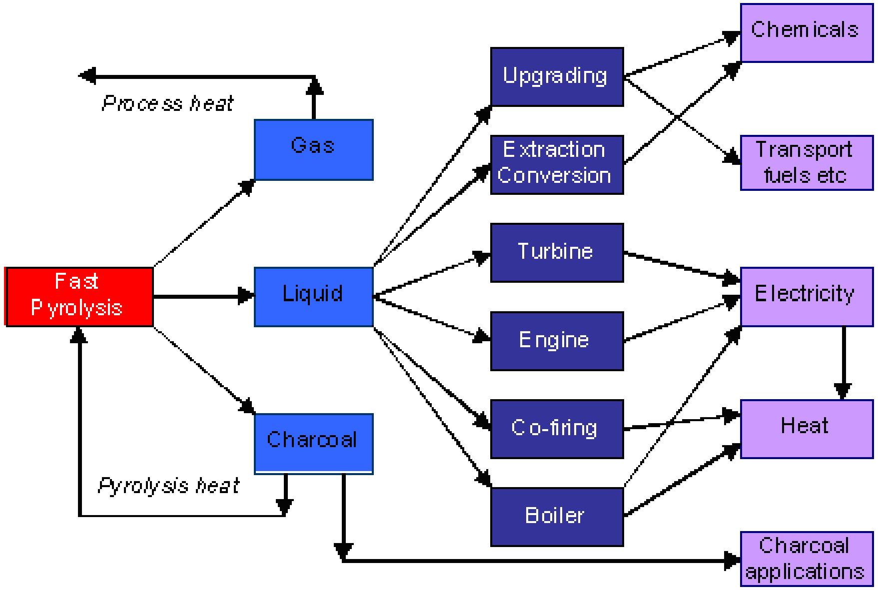
2nd Gen. Biofuels

Bio-Based Products

Technology Assessment: Thermochemical Conversion» *Pyrolysis*

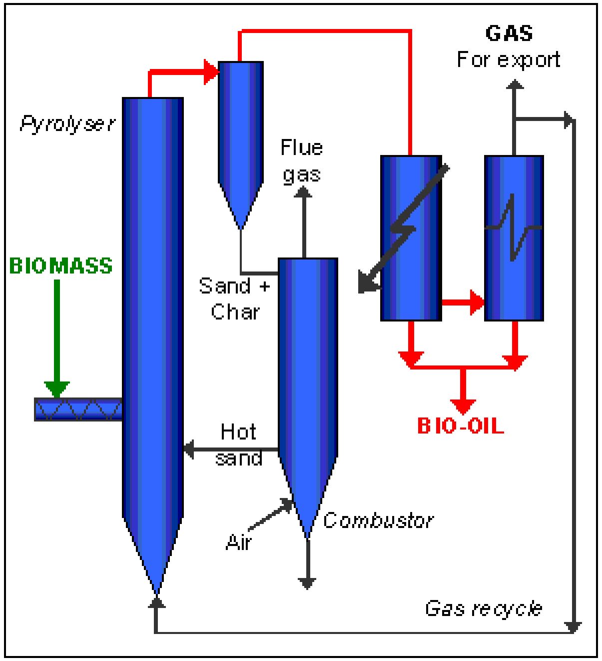
Pyrolysis converts biomass to a mixture of gases, solids and liquids (pyrolysis oils or bio-oils) using technology similar to gasification.

Pyrolysis Products and Applications



Source: The Pyrolysis Network (PyNE)

Circulating Fluidized Bed System



- Pyrolysis involves the rapid heating of biomass in the absence of oxygen and rapid quenching of the gas, which produces mostly condensable hydrocarbons.
- The liquid bio-oil is the primary product (typically 60-75% by weight of the incoming biomass) - it is about 20-25% water by weight, has a low pH (~2) and contains suspended char and ash particles.

Technology Assessment: Thermochemical Conversion»
Pyrolysis

Supply Chain

- Securing biomass feedstocks suitable for pyrolysis conversion is a barrier to overcome.
- Conversion of bio-oil into liquid transportation fuels and chemicals will be necessary to integrate the pyrolysis bio-oil with the existing petroleum supply chain. Depending on the product, this may occur upstream or downstream of the refinery.

Markets

- The fuels and chemicals development from pyrolysis oil is still at the demonstration scale.

Technology Assessment

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

Technology Assessment

Application	Thermochemical Conversion			Bio-Chemical/Chemical Conversion			
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Technology Assessment: Bio-Chemical Conversion» *Hydrolysis- enzymatic hydrolysis*

“Enzymatic Hydrolysis” converts biomass into fuels and chemicals by utilizing enzymes.

Feedstock

Suitable lignocellulosic and hemicellulosic biomass feedstocks include energy crops (switchgrass, aspen, poplar) woody biomass (forest residue) agricultural waste (corn stalks and stover, wheat straw), yard waste and animal waste.

- Feedstocks utilized for this conversion technology are not used for food consumption.
- The carbon foot print of fuels and chemicals from this pathway are proven to be lesser than the fossil fuels they would displace.

Conversion

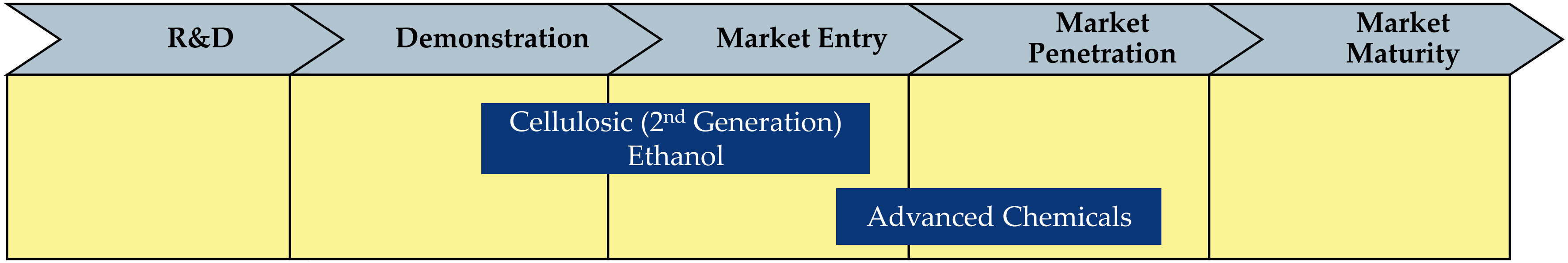
- With enzymatic hydrolysis, cellulose based materials can be broken down to 5-6 carbon sugars and these sugars can be fermented into ethanol and other by-products.
- Utilizing economically feasible cellulase enzymes are key to a successful conversion.
- Technical and economic hurdles still need to be overcome before the technology can be deployed.
- Enzymatic hydrolysis has received attention as the most promising enabling technology.
- A notable method to produce from lignocellulosic biomass is also known as simultaneous saccharification and fermentation(SSF).

End-Use

- 2nd generation ethanol produced from lignocellulosic feedstocks eliminates food-to fuel pathway concerns. It can be used as gasoline blendstock up to 15 % that can be used in conventional cars. In addition ethanol can be utilized up to 85% in flex-fuel vehicles.
- The sugars resulting from SSF can also be used for acetic acid, amino acids, antibiotics and other chemical production.

Technology Assessment: Bio-Chemical Conversion» *Hydrolysis - enzymatic hydrolysis*

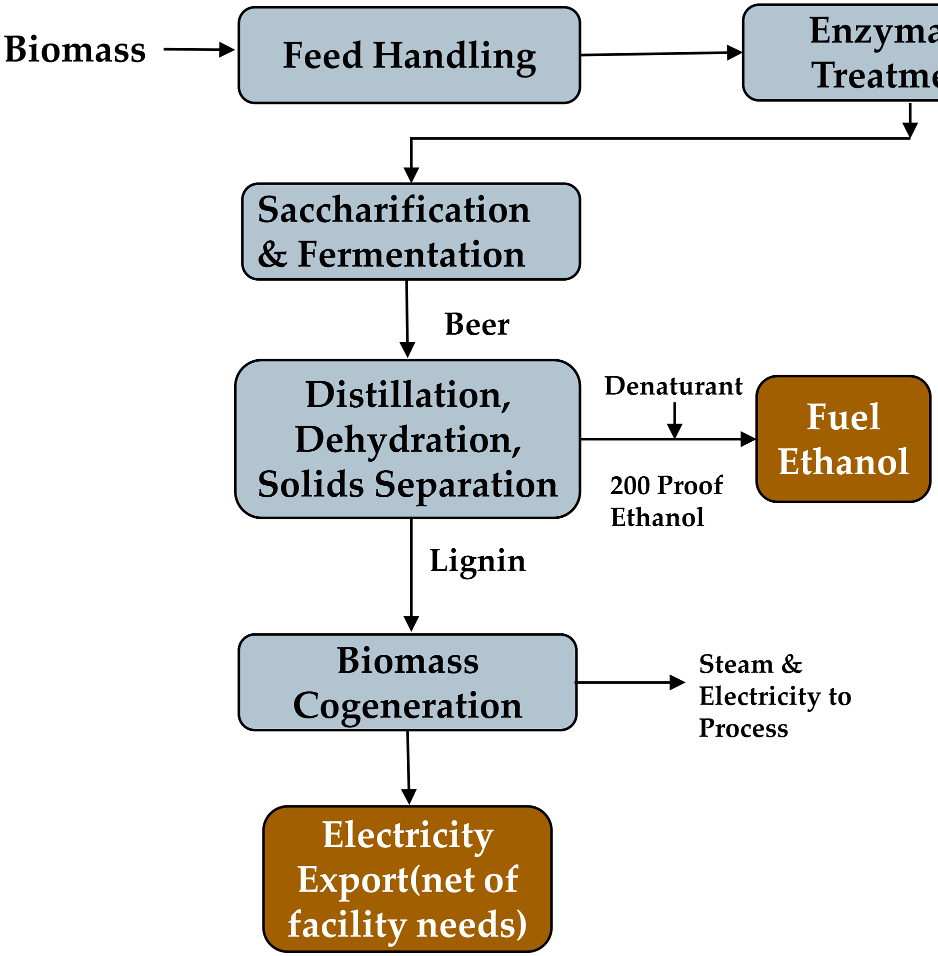
Advanced biofuels and chemicals production with enzyme hydrolysis is currently at the demonstration scale and rapidly nearing commercialization.



Cellulosic ethanol

- The conversion technologies still need to be fully developed and validated. Areas of research include:
  - Processes that will break-up the complex biomass matrix to free the sugar precursors for hydrolysis and fermentation to ethanol: **enzymatic hydrolysis** is the most promising area of research; significant reductions in the cost of enzymes have already been achieved.
  - Micro-organisms that will efficiently ferment sugars from both cellulose and hemicellulose.
  - Significant private and public money is funding these research activities.
- Other areas of technology research include the genetic engineering of ideal energy crops (for example by reducing the lignin content, increasing yields).

Enzymatic Hydrolysis of biomass into fuels and chemicals



Technology Assessment: Bio-Chemical Conversion»

Hydrolysis - dilute-acid hydrolysis

Dilute-acid hydrolysis is suitable for fuels and chemicals production from most lignocellulosic feedstocks. Sometimes it is used in combination with enzymatic hydrolysis.

Feedstock

Suitable biomass feedstocks include energy crops such as aspen, poplar & switchgrass, agricultural residues such as corn stover, woody biomass and a range of cellulosic biomass waste, such as paper sludge, yard and wood wastes.

- The process can accept feedstocks with varying moisture contents.
- Feedstocks with very strong bonds between the various macromolecules, such as untreated hardwoods and wood wastes, can be processed.

Conversion

The dilute acid hydrolysis process can either be used as stand alone biomass conversion technology followed by fermentation or as pre-treatment step for enzymatic hydrolysis conversion of biomass to produce fuels and chemicals .

- The dilute acid hydrolysis breaks down cellulose and hemicellulose, decomposing them into intermediate chemicals for conversion into a range of marketable chemicals, such as furfural, formic acid and levulinic acid.
- The intermediate chemicals can be further processed to fuels. The most promising conversions in addition to fermentation, are the hydrogenation or the esterification of levulinic acid to a range of fuels (ethers and esters).

End-Use

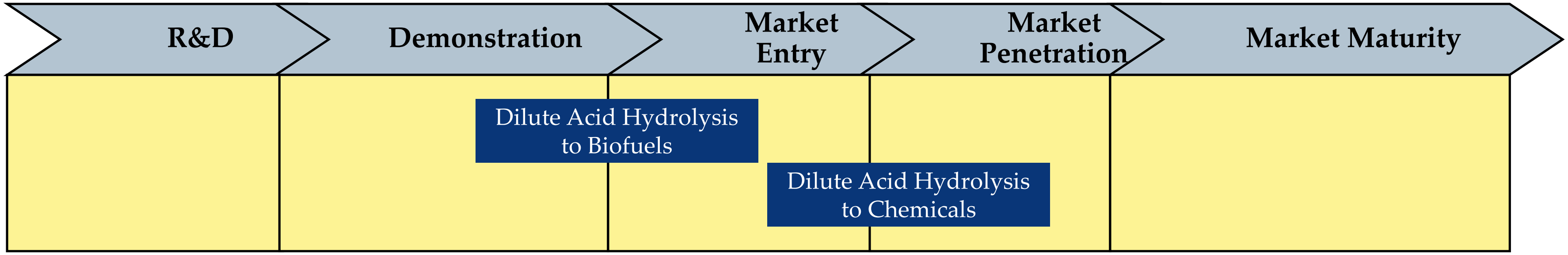
On the chemicals side, levulinic acid is used in food, fragrance and other specialty chemical applications. Furfural and formic acid are also specialty chemicals. The process will also produce sizeable quantities of sodium sulfate (a generic chemical).

The most promising fuels include:

- Ethanol, MeTHF (methyltetrahydrofuran), an ether produced by hydrogenation of levulinic acid, can be used as a gasoline additive. Methyl or Ethyl-levulinate, produced by esterification of levulinic acid, are biomass derived diesel fuel and heating oil replacements or additives.

Technology Assessment: Bio-Chemical Conversion» *Hydrolysis - dilute-acid hydrolysis*

Dilute-acid hydrolysis is being commercialized for chemicals production. The technology can also be deployed for biofuels production.



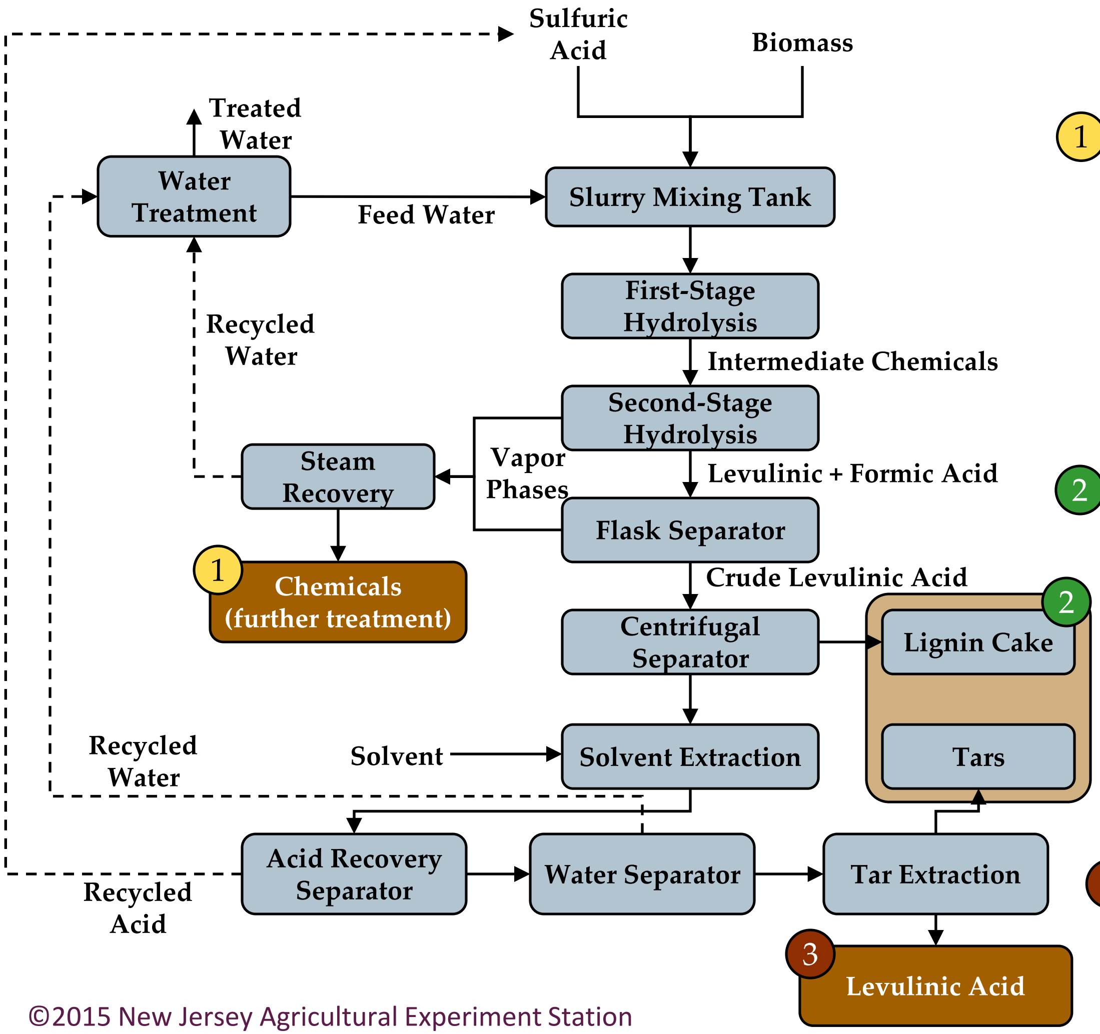
Dilute-acid Hydrolysis to Biofuels

- Major routes for converting the intermediate chemicals (levulinic acid), to marketable fuels:
  - o Esterification
  - o Hydrogenation
  - o Furfural (another intermediate chemical) can also be converted to an alcohol grade fuel
- Two-stage acid hydrolysis is preferred because of increased sugar yield which can be easily fermented into ethanol and fewer fermentation –inhibiting components yields.
- 2nd generation fuels have better LCA than petroleum counterparts.
- The technology has not been fully commercially deployed.

Dilute-acid Hydrolysis to Chemicals

- Depending on the characteristics of the biomass and the demand for chemicals, the process can be geared to produce a number of specialty chemicals.
- A number of small demonstration projects are operating in the US; in addition, a first commercial (300 tons/day) facility has recently started operation.

Dilute-acid hydrolysis to Biofuels and Chemicals



1

Two chemicals produced at this phase:

- Furfural (FF) can be sold directly as a chemical or converted to either Furfuryl Alcohol (for sale to the foundry binders market) or THFA (a solvent that is also a P-series fuel component).
- Formic Acid can be sold as a chemical or used to produce hydrogen.

2

Lignin / Tar slurry is a low sulfur substitute for #6 fuel oil:

- It can be used in a boiler to provide the heat requirements for the process.
- It can be sold for its energy content.
- In the case of fuels production, it can be used to produce hydrogen needed for the hydrogenation of levulinic acid.
- The inorganic residue in the boiler or gasification chamber can be disposed of in a landfill or used for concrete aggregate (unless the feedstock contains hazardous inorganic contaminants).

3

Levulinic acid can be sold as a chemical or converted to fuels through

- Esterification to produce Methyl-levulinate (a substitute for #2 heating oil) or Ethyl-levulinate (a diesel fuel additive).
- Hydrogenation to produce methyltetrahydrofuran (MeTHF), an ether used as a gasoline additive or replacement.

Technology Assessment

Application	Thermochemical Conversion			Bio-Chemical/Chemical Conversion			
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Technology Assessment: Bio-Chemical Conversion» *Trans-Esterification*

Biodiesel is a low-sulfur, high-cetane substitute for petroleum diesel derived from organic oils and fats.

Feedstock

Biodiesel can be obtained from any lipid-bearing feedstock:

- Most (95%) of the 7 bgpy[1] of biodiesel consumed world-wide is derived from the virgin vegetable oils of food crops (canola, soy, sunflower, palm). This feedstock source has limited scalability potential due to low land yields and competition from food uses.
- Opportunities exist for the conversion of recycled vegetable oils and animal fats to biodiesel.
- Significant efforts are in place to develop alternative biodiesel crops, with higher land yields, no food use and lower costs (jatropha). Also algae and duckweed to biodiesel pathway is currently researched.

Conversion

Biodiesel production from soy and other food crops is a mature technology:

- The methyl-esters of fatty acids (biodiesel) are the product of the trans-esterification reaction between glycerides (oils and fats) and an alcohol (generally methanol) in the presence of a base catalyst.
- Glycerin is the by-product of biodiesel production and, traditionally, an important source of revenue: over-supplied markets for glycerin are a major concern for the industry.
- Technology improvements and breakthroughs include new low-cost biodiesel crops and innovative conversion technologies.

End-Use

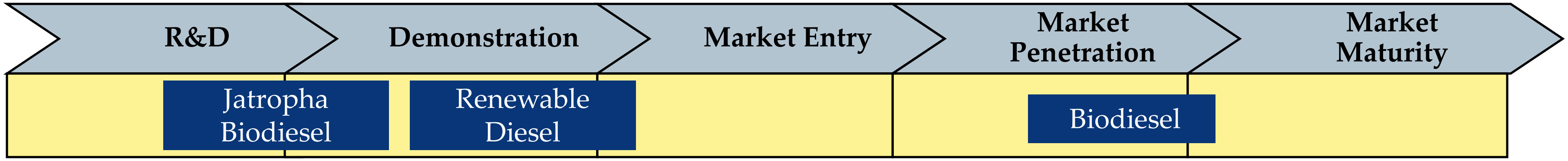
- Biodiesel is mainly used as an additive to, or extender of, petroleum based distillate fuels, such as diesel and heating oil. Differences in product characteristics occur as a consequence of the use of different feedstocks: cold flow properties and storage stability will vary significantly.
- 150 Plants in operation in the US (1.1 billion gpy capacity).

1: Billion Gallons Per Year

**http://www.oecd.org/site/oecd-faoagriculturaloutlook/48178823.pdf*

Technology Assessment: Bio-Chemical Conversion» *Trans-Esterification*

Biodiesel is a developed technology; the use of other feedstocks as well as innovative approaches are being demonstrated.



Emerging Technologies

- Biodiesel from non-food crops and waste oils:
  - Lower costs: grown on marginal lands and no competition from food and feed markets.
  - Jatropha and other suitable energy crops, lipid forming algae strains , duckweed are potential feedstocks.
  - Restaurant waste oils and trap grease also proven to be potential feedstocks.
  - No major technology breakthrough is needed, but the entire supply chain needs to be built.
- Catalytic hydro-processing of vegetable oil (Renewable Diesel):
  - Produces straight chain paraffinic hydrocarbons (identical to the high cetane components of diesel) with very low sulfur content.
  - Likely to be adopted by the petroleum industry as it is a "refinery friendly" renewable option.

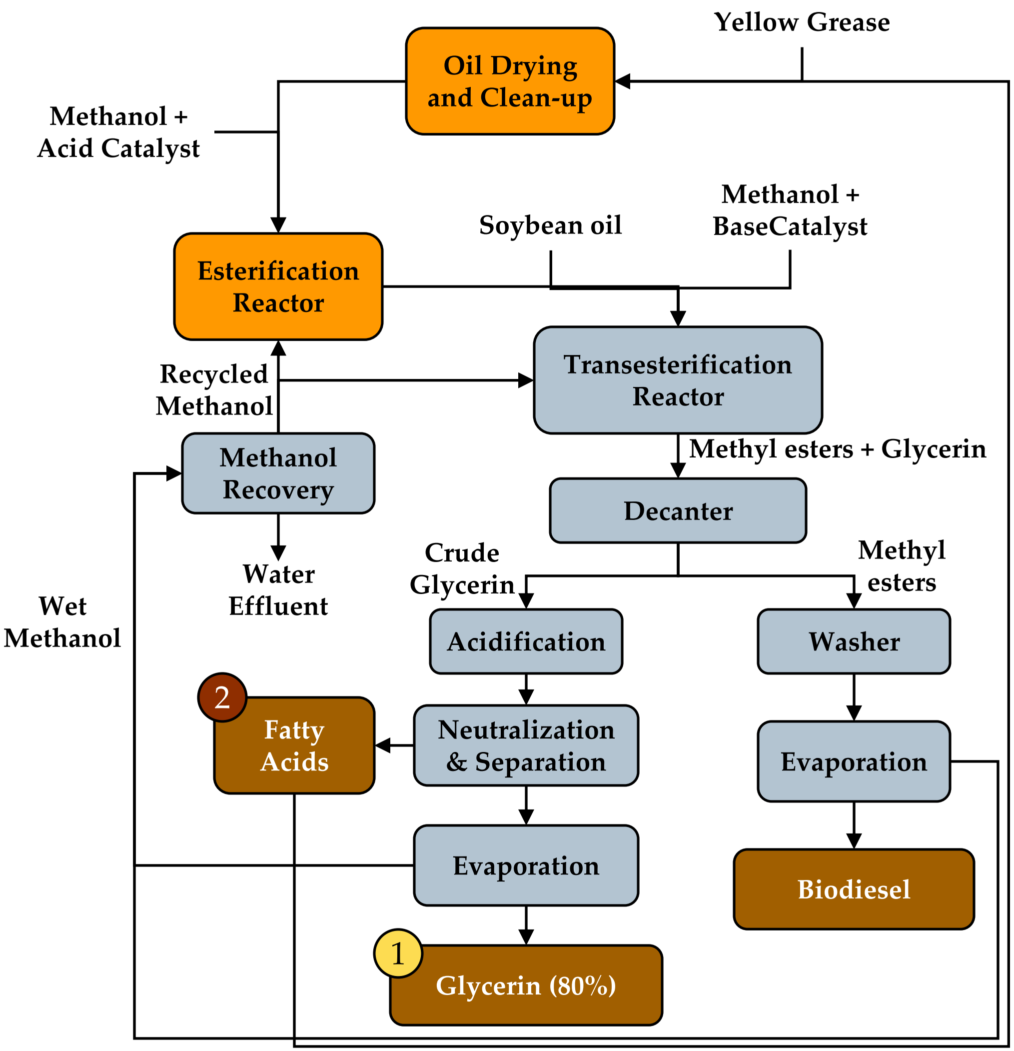
Biodiesel

- Biodiesel is a mature technology with limited market penetration:
  - 150 Plants in operation in the US (1.1 billion gpy capacity).
  - Sustainability remains a very important issue with regard to biofuels, in particular, indirect land use change (ILUC) GHG emissions.
  - Global biodiesel supply will have to double over the 2010-2020 timeframe to accommodate demand requirements that governments around the world are aiming to implement. Fewer new facilities will be built but that utilization at existing facilities increases by 2020.*

*http://www.unece.lsu.edu/biofuels/documents/2013Mar/bf13_04.pdf

Technology Assessment: Bio-Chemical Conversion» *Trans-Esterification*

The Biodiesel process description:



Yellow Grease
Oil Drying and Clean-up
Methanol + Acid Catalyst
Esterification Reactor
Soybean oil
Methanol + BaseCatalyst
Transesterification Reactor
Recycled Methanol
Methanol Recovery
Methyl esters + Glycerin
Decanter
Water Effluent
Wet Methanol
Crude Glycerin
Methyl esters
Acidification
Washer
② Fatty Acids
Neutralization & Separation
Evaporation
Evaporation
Biodiesel
① Glycerin (80%)

🟧 Process step typical of a YG-based operation

①

Markets for glycerin:

- Refined to 99.7% glycerin and sold as a specialty chemical in the food and cosmetics industry.
- Boiler fuel (low btu content).
- Filler in animal feed (no protein value).

Increased biodiesel production has created oversupply of glycerin. New applications include:

- To produce Propylene Glycol (a building block chemical).

②

Fatty Acids are either:

- Recycled in the plants in an esterification pre-treatment unit and converted to biodiesel.
- Sold into the oleochemical industry.

50 MGPY Soy Biodiesel	
Feedstock flow (gal/day)	140,000
Co-product flow – Glycerin (lbs/day as is)	100,000
Electricity Requirements (kWh/gal)	0.26
Heat Requirements (MMBtu/gal)	0.004

The biodiesel supply chain crosses the agriculture and petroleum sourcing and distribution infrastructures.

Supply Chain

- Soy oil is produced at bean crushing facilities:
  - These are concentrated in dense soybean growing regions such as the Midwest and owned by a handful of agribusinesses (ADM, Cargill, Bunge, co-ops).
  - Soy oil is shipped for conversion to a biodiesel plant or converted onsite if the biodiesel and bean crushing plant are co-located.
- The fuel is distributed to the market through the petroleum distribution infrastructure:
  - In Europe, blending with petroleum products occurs mostly upstream (at the refinery).
  - In the US, it typically occurs at the downstream (wholesale) terminal through splash blending (due to the limited quantity of biodiesel sold and to concerns of pipeline operations).

Markets

- Biodiesel is mostly used as a transportation fuel:
  - In blends of 5-20% (B5 – B20) with petroleum diesel
  - Higher blends are less common (though feasible) due to poor cold flow properties and engine warranty issues.
  - Has received interest as a low blend additive to enhance the lubricity and increase cetane of ULSD[1] and to improve the performance of DPF[2]
  - In some markets (including NJ) biodiesel is being marketed for heating oil or power generation.
  - In blends with #2 and #6 fuel oil
  - Lower value reference product (#2 and #6 fuel oil and of lower quality, and price, than on-road diesel)
  - Targeted subsidies may distort the basic economics (REC's[3] obtained by the use of biodiesel in power generation and sales tax exemptions for "Bioheat" can be additive to other incentives such as the federal tax credit and blending requirements).

1: Ultra Low Sulfur Diesel
2: Diesel Particulate Filter
3: Renewable Energy Certificates

Technology Assessment

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Technology Assessment: Bio-Chemical Conversion» *Fermentation to 1st Generation Ethanol*

Ethanol is a clean burning, high octane additive for petroleum gasoline.

Feedstock

Corn ethanol is produced by fermenting the starch contained in corn.

- Other established feedstocks for ethanol production are those containing sugars (sugar crops, sorghum, molasses) or where sugars can be easily extracted (barley, wheat, potatoes, rye).
- Food-to-fuel pathway issues should be address through Life Cycle Analysis including direct and indirect and Land Use Change Effects when new feedstock are considered.

Conversion

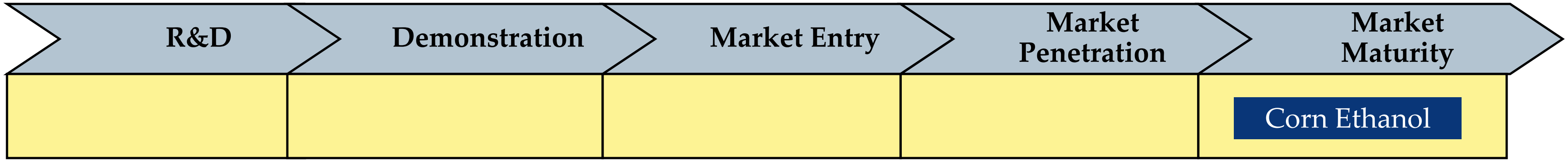
Corn ethanol production is a mature technology.

- In a dry mill, the starch fraction is extracted from the grain, grinded, liquefied and hydrolyzed to liberate the sugars for fermentation. The alcohol is then distilled and denatured. Distiller's Dried Grain (DDG), an animal feed ingredient, is the by-product.
- Wet mills are more capital intensive and designed to optimize the value of co-products.
- Technology improvements including using low carbon process fuels can reduce carbon footprint and lower costs.

End-Use

- Ethanol in the US is mostly used as an additive to gasoline (up to 10% and in some applications 15%) for environmental and regulatory compliance, as an octane enhancer or to reduce fuel costs.
- The use of ethanol as a replacement for gasoline (E85) can be achieved with only flex-fuel vehicles.

Technology Assessment: Bio-Chemical Conversion» *Fermentation to 1st Generation Ethanol*



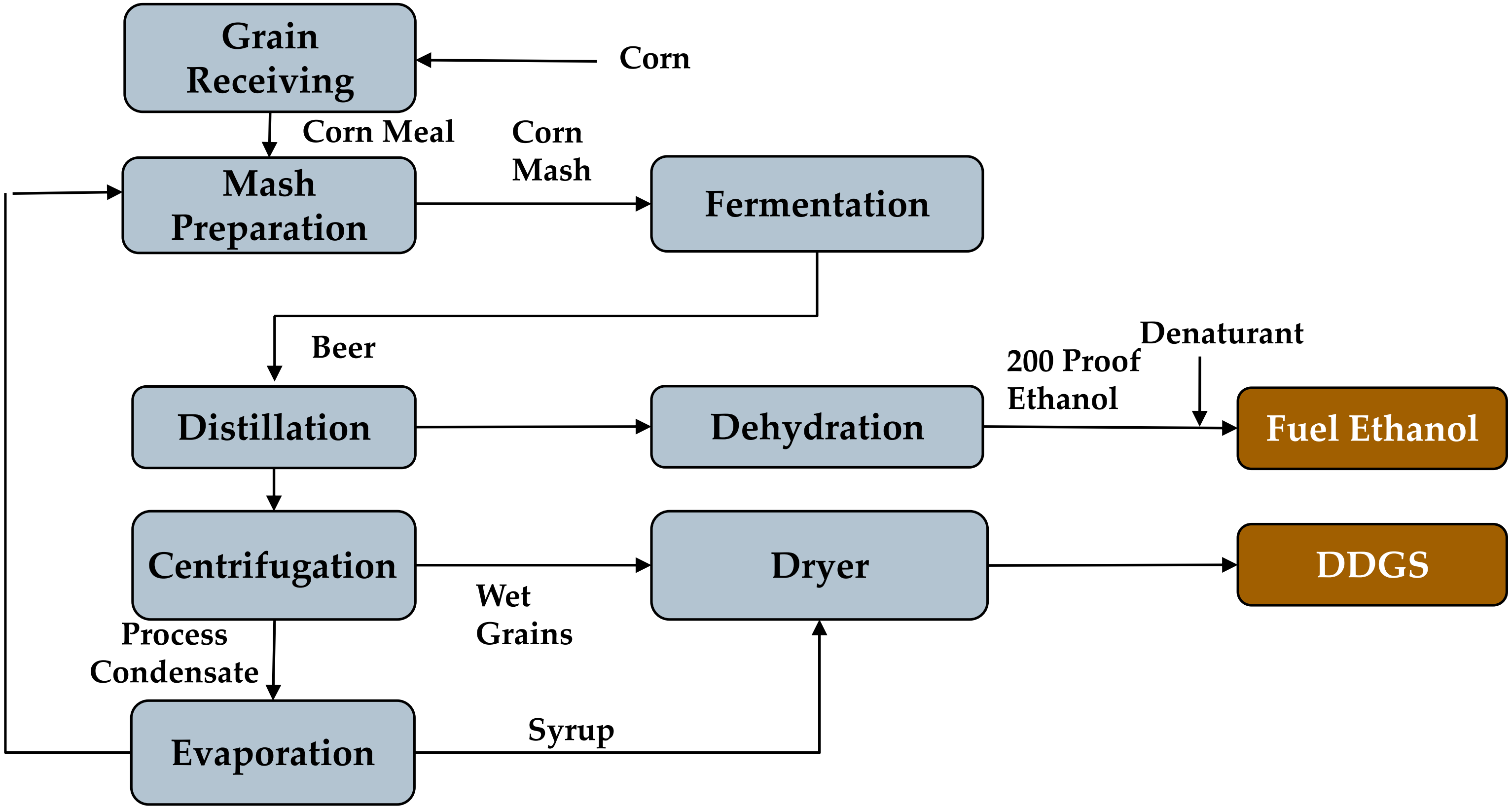
R&D	Demonstration	Market Entry	Market Penetration	Market Maturity
				Corn Ethanol

Corn Ethanol

- Established and commercially deployed technology:
  - >100 plants in operation in the US (producing 850,000 barrels of ethanol/day approximately $2.23/gallon.
  - Larger plants (80-100 mgpy) are being built to exploit economies of scale.
  - Smaller operations are at a significant disadvantage.
  - Major capacity build-up occurred in the past 2 years with high oil prices and favorable policies and incentives.
- Continuous technology improvements, such as genetically enhanced seeds, fractionation and corn oil extraction will further reduce costs of corn ethanol.
- While technology risk is low, a corn ethanol operation presents significant commodity price risk.
- Sustainability remains a very important issue with regard to biofuels, in particular, indirect land use change (ILUC) GHG emissions.

http://www.eia.gov/todayinenergy/detail.cfm?id=9791

Fermentation



Feedstock sourcing costs are critical to the economics of both corn and cellulosic ethanol supply chains.

Supply Chain

- Corn ethanol plant locations are generally served with the corn harvested in a 50-100 mile radius:
  - Transportation of corn for long distances is less cost effective than shipping ethanol.
  - Locating a plant far away from a corn supply requires special circumstances, such as highly concentrated demand or a good outlet for the DDG co-product.
- The fuel is distributed to the market in blends with regular gasoline; blending occurs downstream at the wholesale terminal:
  - Ethanol is shipped to local petroleum terminals by barge and truck; use of barges is increasing.
  - Due to ethanol's low water tolerance and corrosive nature, transportation by pipeline (which would be the most cost-effective mode) is not practiced.

Markets

- Ethanol is used in low blends (<10%) with gasoline:
  - For environmental compliance to meet oxygen content requirements in ozone non-attainment areas (such as most of NJ), The rapid phase-out of MTBE[1] has given ethanol an almost-monopoly of the market.
  - To meet blending requirements such as the Renewable Fuels Standard or State mandates
  - In "discretionary blends", when the wholesale price of ethanol, net of subsidies and corrected for energy content, is lower than that of gasoline (with the added benefit of enhancing the octane rating)
- Ethanol is used as a fuel in concentrated (85% = E85) blends with gasoline:
  - Distribution is limited to areas of the Midwest.
  - E85 requires special infrastructure, such as specifically designed retail pumps and slightly modified engines (FFV).

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[1] methyl tertiary-butyl ether

Technology Assessment

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Technology Assessment: Bio-Chemical Conversion» *Anaerobic Digestion*

Biogas (AD gas/LFG) can be utilized as renewable natural gas for power generation and as transportation fuel in the form of CNG/LNG.

Feedstock

- Some types of biomass naturally high in moisture content are considered ideal for AD because the micro-organisms need a water-rich environment (and because it is less suited to other technologies, such as combustion).
- Landfills naturally produce biogas (LFG).
- Traditional AD feedstock include farm waste (manure), waste water treatment sewage sludge, food wastes (Institutional, commercial and residential).

Conversion

AD of biomass is a well understood and commercially developed technology :

- Farm based digesters for animal manure are the most typical installation. In addition to energy production, they address broader environmental and agricultural issues.
- In Europe, regional digesters processing manures, crops and urban (organic) waste and food waste are common. Technology advancements, including biomass pre-treatment, two-stage AD and innovative flow designs, are being developed to improve economics and process more cumbersome and drier waste streams.

End-Use

The AD Gas/LFG is typically used to generate power (and heat/steam in CHP[2] applications):

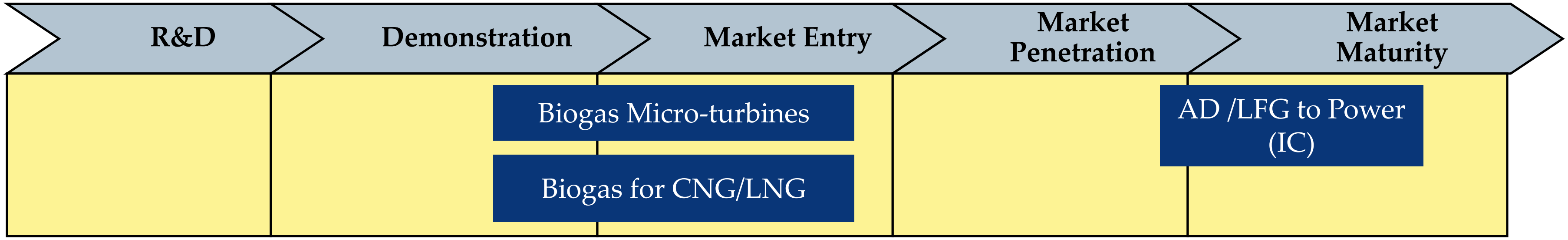
- Biogas is a medium-energy gas (40-70% methane).
- The IC engine is the most common prime mover for small scale power generation(< 5MW).
- Steam turbines are used for larger applications (> 10MW), such as wastewater treatment plants.
- Bio-based soil treatment products are also part of AD end products.

More recent technology development include the clean-up of biogas to Natural Gas and the further processing of this to chemicals or transportation fuels (CNG/LNG).

1: Municipal Solid Waste 2: Combined Heat and Power

Technology Assessment: Bio-Chemical Conversion» *Anaerobic Digestion*

Biogas production and combustion for heat, steam and electric power are established technologies. Biogas to CNG& LNG applications are emerging.



Biogas to Transportation Fuels

- The biogas will need to be cleaned up (reduce H_2O and H_2S) prior to undergoing the 2-stage CO_2 removal.
- A pure methane stream will be produced (in addition to a food grade CO_2 stream).
- The methane can then be compressed to CNG[1] or liquefied to LNG[2] (to take advantage of the higher energy density) and used as a transportation fuel.
- Alternatively, the methane could also be injected into a natural gas pipeline.
- The technology is established but has seen limited deployment due to mostly unfavorable economics.

AD / LFG to Power

- Established technology with renewed attention
- Small operations (farm wastes & crops, most LFG, food wastes) generally use IC engine as prime movers.
- Operations such as regional digesters and waste water treatment plants may be large enough for a steam cycle. Gas turbines are less common.
- Landfill gas to power is an established technology and unused flared LFG should also be utilized for power generation if economically feasible.

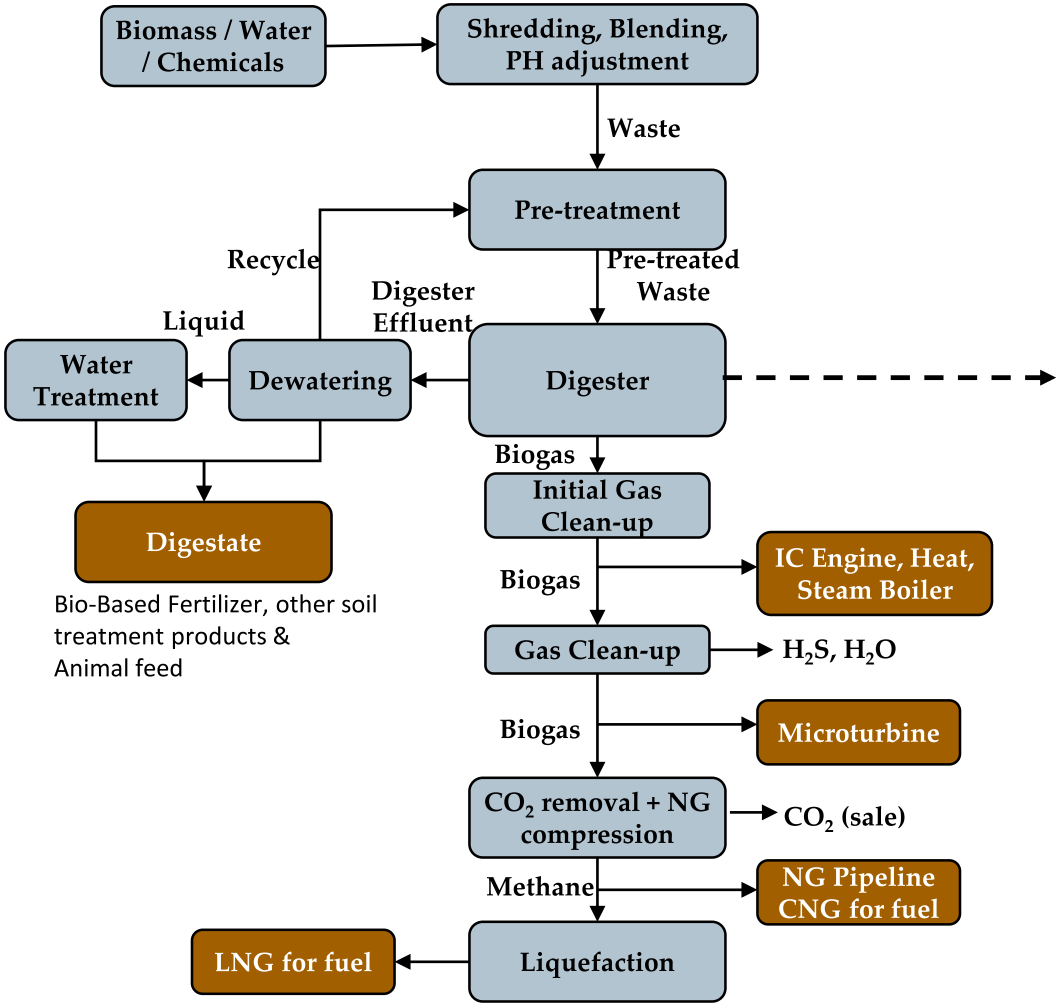
Biogas Micro-turbines (for power)

- Significantly more extensive biogas clean-up is needed than for use in an IC engine.

[1] Compressed Natural Gas

[2] Liquefied Natural Gas

Anaerobic Digestion



Anaerobic Digestion Process

Four main microbial steps of the AD process:

- **Hydrolytic bacteria** break down organic materials into sugars and amino-acids.
- **Fermentative bacteria** convert these into organic acids.
- **Acidogenic bacteria** convert acids into CO, H2 and acetate.
- **Methanogenic archea** convert these into methane.

In the **two phase digesters**, the acidogenic and methanogenic micro-organisms operate in separate tanks in optimum environments. The first tank can be also pressurized to achieve fast hydrolysis. The benefits are:

- Lower capital costs due to smaller tanks.
- Ability to process higher solid content material.
- 30% higher biomass conversion rates.
- Higher methane content and cleaner biogas.
- Reduced pathogen content in the digestate solids.

Technology Assessment: Summary and Conclusions

New Jersey’s large municipal waste biomass resource, combined with its proximity to a petrochemical infrastructure, makes it a good location to utilize advanced power and fuels technologies.

- Some technologies approaching commercial use appear better suited to exploit New Jersey’s largest biomass resources:
  - For fuels, emerging biomass-to-liquids technologies, such as enzymatic and dilute acid hydrolysis, gasification with fuel synthesis and biogas to LNG/CNG present some of the best opportunities.
  - For power, direct combustion, biomass gasification and anaerobic digestion are among the most developed technologies to process waste biomass streams.

IV. GHG Reduction Scenarios

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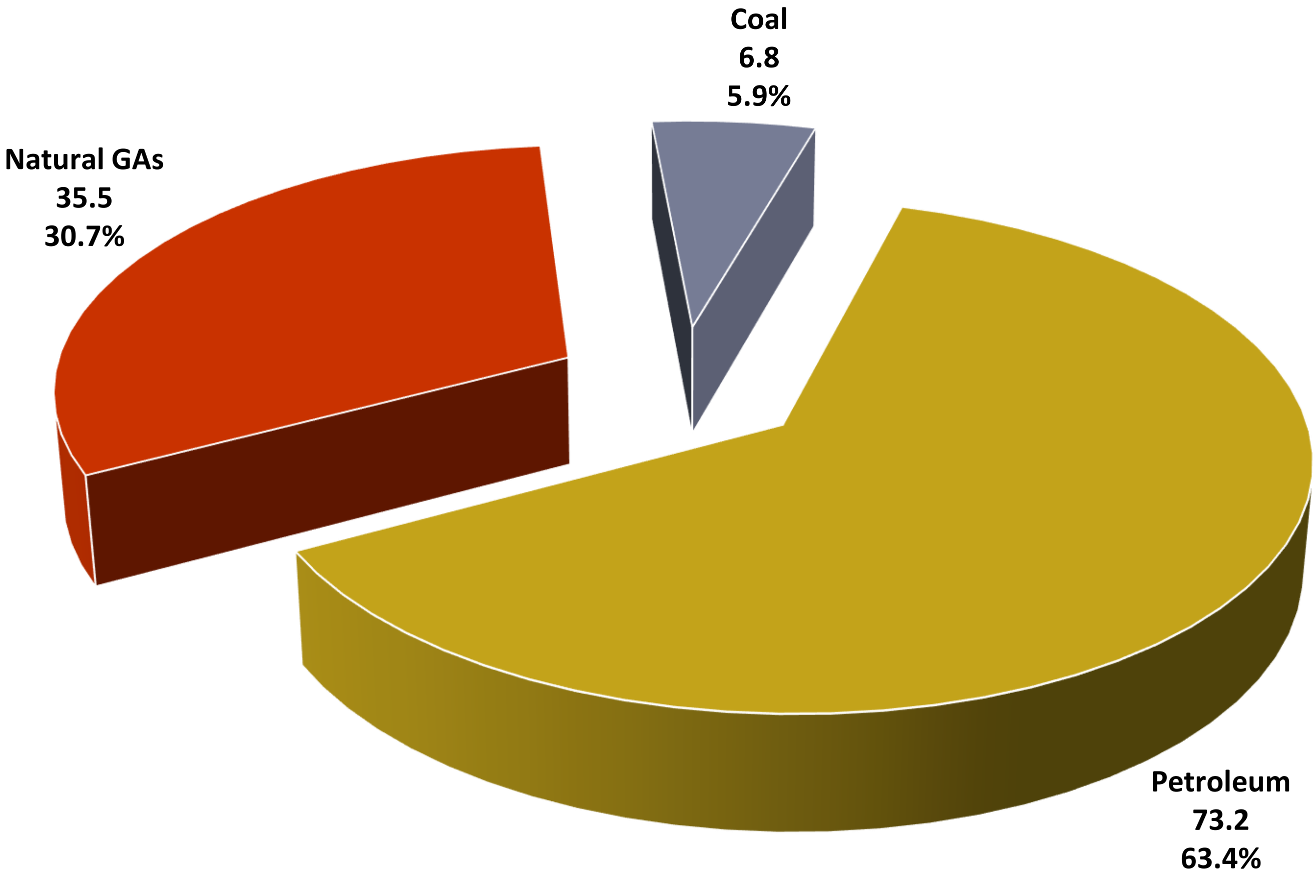
Greenhouse Gas Reduction Potential: NJ ENERGY CO_2 EMISSIONS*,**

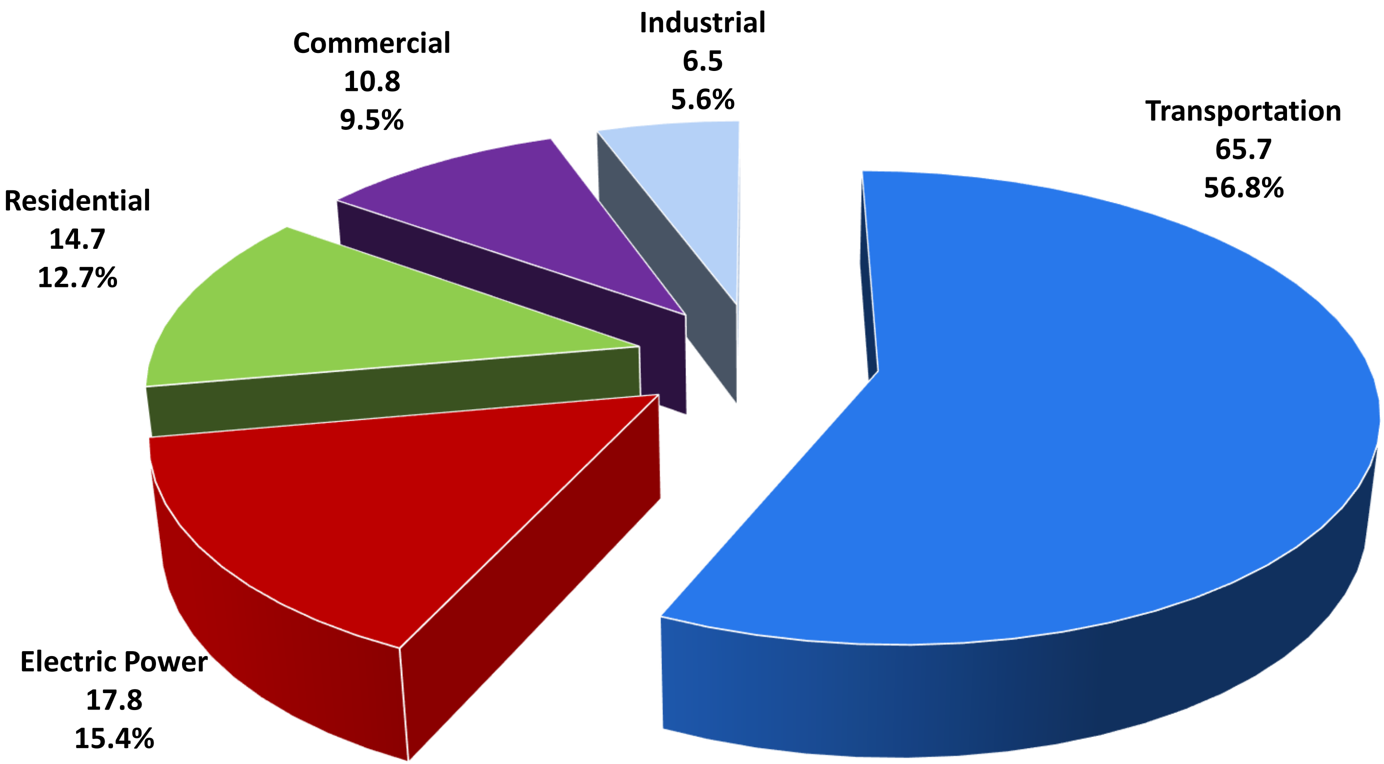
NJ Energy Related CO_2 Emissions by Fuel (million mtons/y, %)



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

Greenhouse Gas Reduction Potential: NJ ENERGY CO_2 EMISSIONS*,**

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



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

Greenhouse Gas Reduction Potential

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

- In this section, 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 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).

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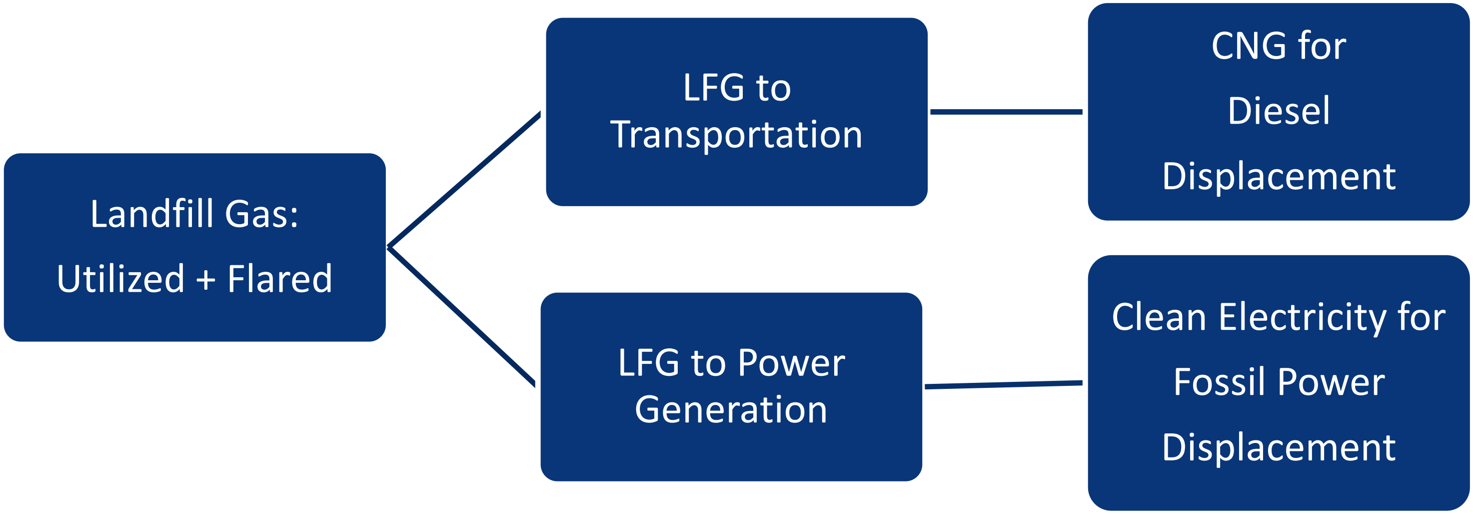
Greenhouse Gas Reduction Potential: Landfill Gas to Energy

SCENARIO: Landfill Gas to Energy



Landfill Gas:
Utilized + Flared

LFG to Transportation

CNG for Diesel Displacement

LFG to Power Generation

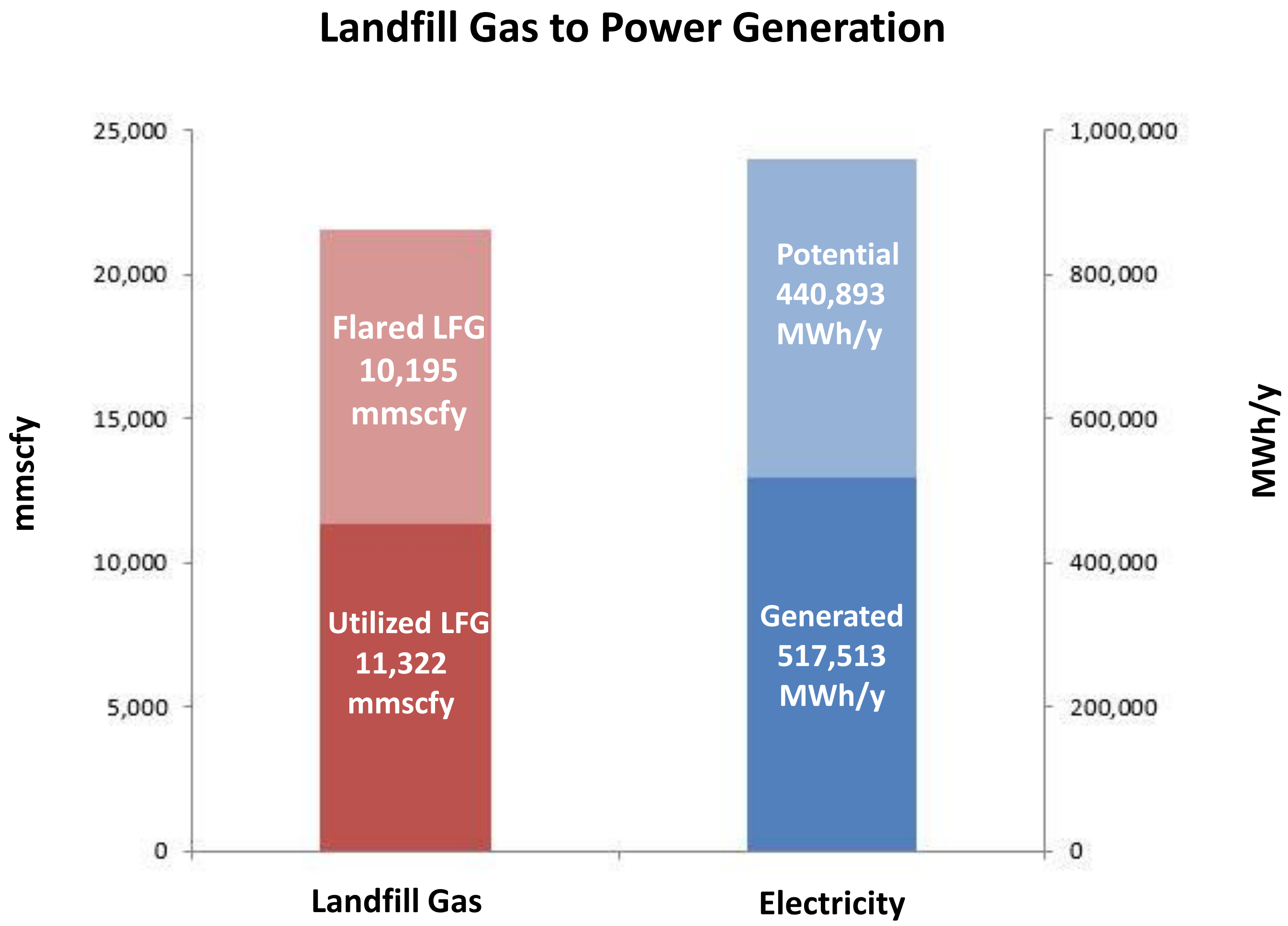
Clean Electricity for Fossil Power Displacement

Greenhouse Gas Reduction Potential: Landfill Gas to Power Generation

New Jersey has the potential to generate an additional 440,893 MWh per year of electricity from flared LFG. This assumption is theoretical and can be realized if technical and economical feasibility is achieved.

	Total LFG Generation (mmscfy)	Current LFG Used for Power (mmscfy)	Current LFG Flared (mmscfy)	Current Power Generation from LFG (MWh/y)	Potential Additional Power Generation from LFG (MWh/y)	Total Power Generation Potential (MWh/y)
Scenario: New Jersey LFG to Power Generation	21,516.31	11,321.74	10,194.57	517,513.36	440,893.47	958,406.83

Greenhouse Gas Reduction Potential: Landfill Gas to Power Generation



Greenhouse Gas Reduction Potential: Landfill Gas to Power Generation

If all, current and potential, LFG generated power is assumed to displace coal-generated power, the potential CO_2 emissions avoidance would be 515,059 tons per year.*

	Total Power Generation Potential (MWh/y)	CO_2 Emissions from LFG to Power (tons/y)	CO_2 Emissions from Equivalent Coal power (tons/y)	Potential to reduce CO_2 (if the power displaces coal generated power) (tons/y)
Scenario: New Jersey LFG to Power Generation	958,406.83	562,668.90	1,077,727	515.059.00

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

Greenhouse Gas Reduction Potential: Landfill Gas to Power Generation

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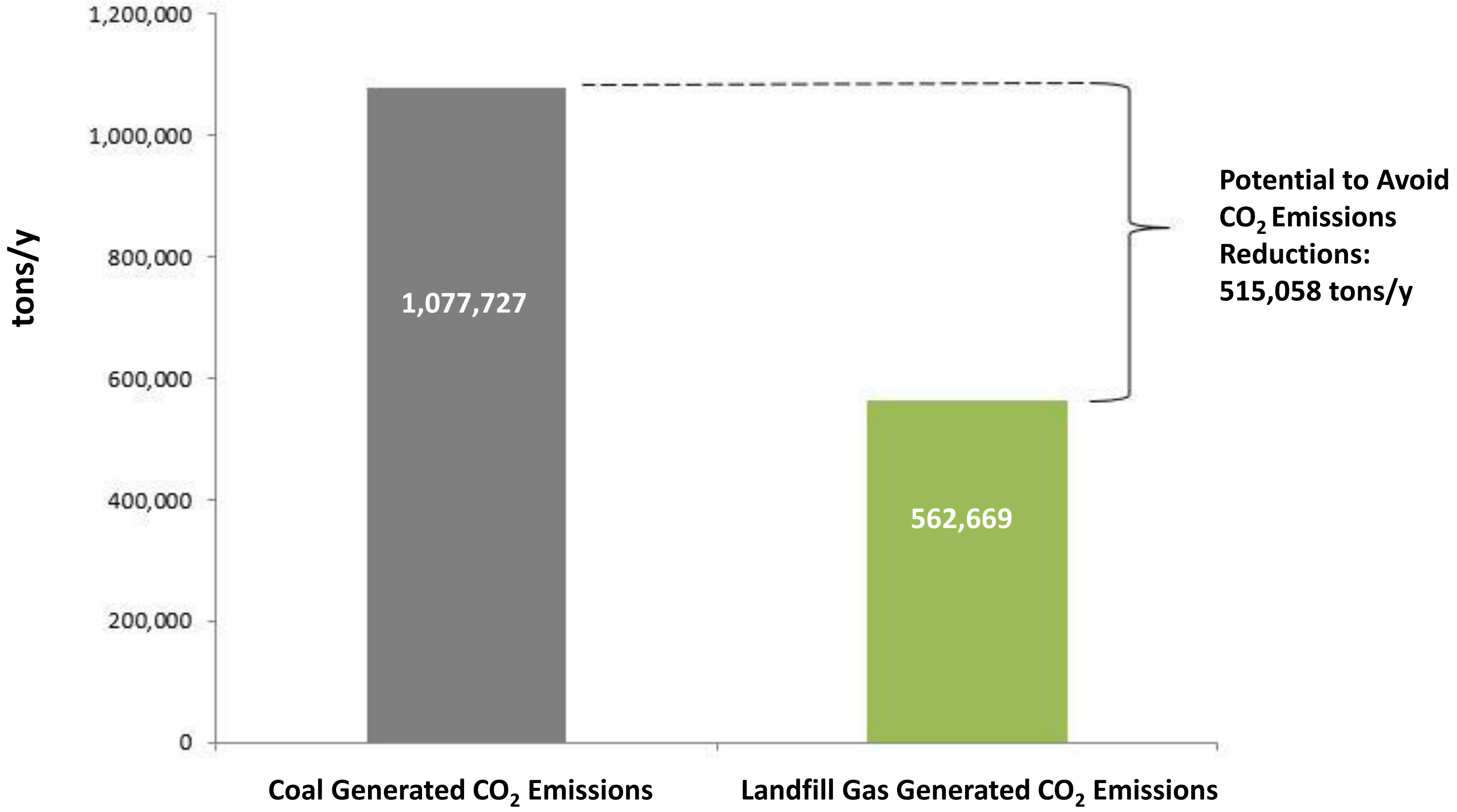
If the total LFG to electricity generation is achieved and assumed to displace coal generated power, New Jersey's net CO_2 reduction potential would be 515,058 tons per year.*



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

Greenhouse Gas Reduction Potential: Landfill Gas to CNG/LNG as Transportation Fuel

If New Jersey's flared LFG is utilized for CNG, thereby displacing fossil diesel fuel for LDV and HDV, 366,881 tons of fossil CO_2 can be displaced by recycled CO_2 with total reduction of 100,285 tons CO_2/y.*

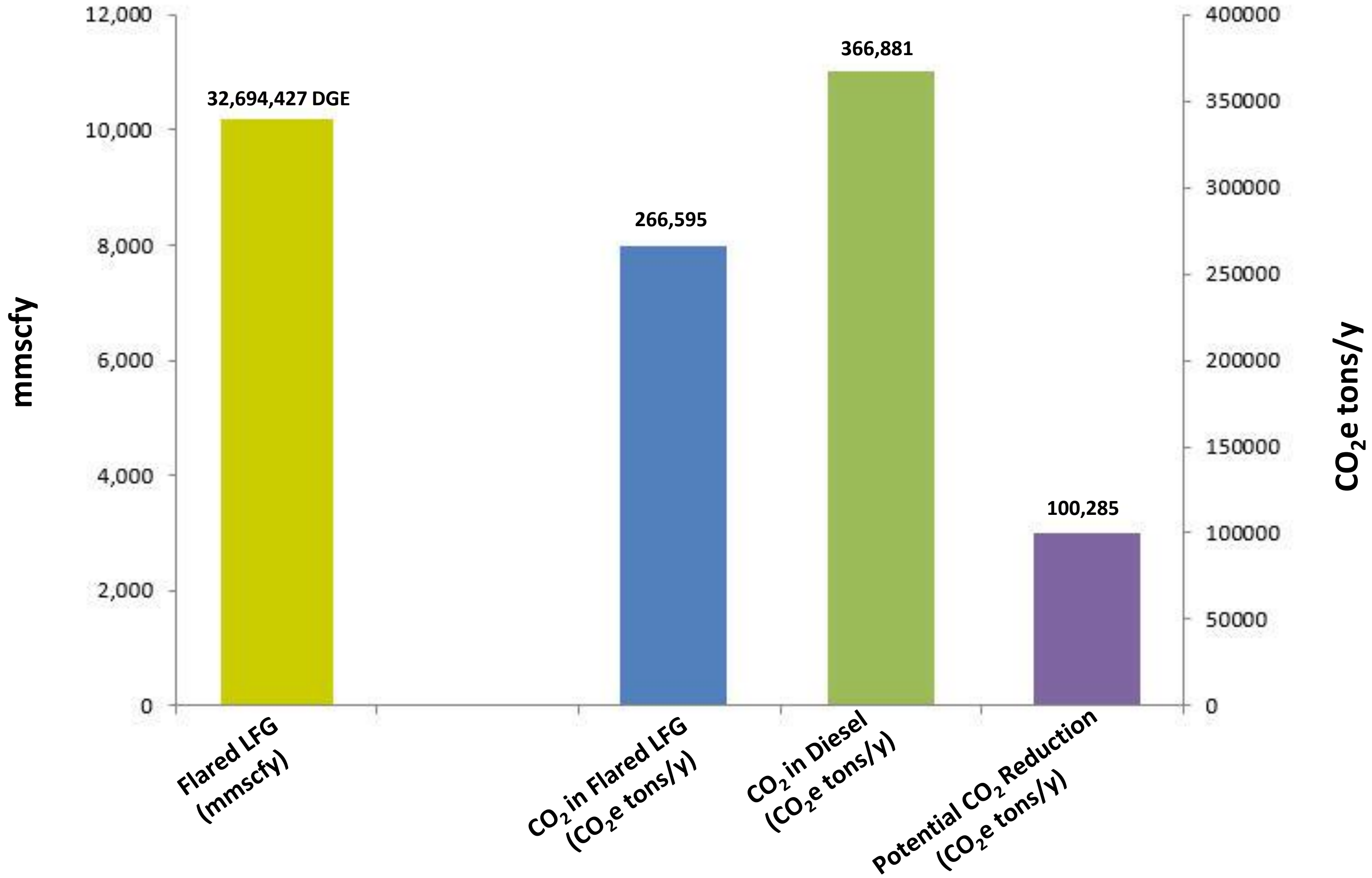
	Total LFG Flared (mmscfy)	Potential CO_2 Content of Flared LFG (tons/y)	Transportation Fuel Potential (DGE/y)	CO_2 Produced: Fossil diesel (equivalent amount) (tons/y)	Potential avoided CO_2 amount (tons/y)
Scenario: New Jersey LFG to Transportation	10,194.57	266,596	32,694,427	366,881	100,285

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

Greenhouse Gas Reduction Potential: Landfill Gas to CNG/LNG as Transportation Fuel

RUTGERS
New Jersey Agricultural Experiment Station

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.

Greenhouse Gas Reduction Potential: Landfill Gas to CNG as Transportation Fuel

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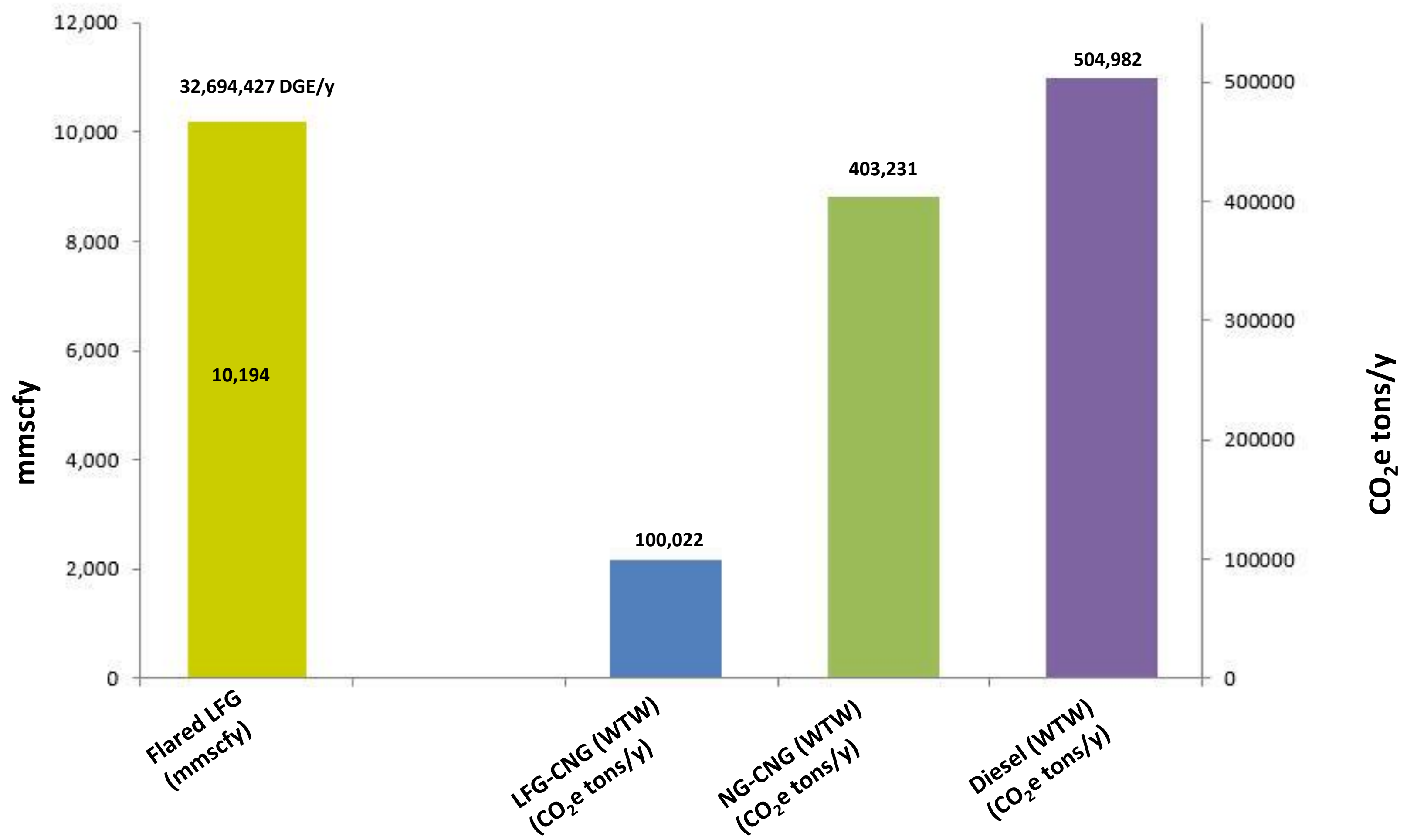
	Total LFG Flared (mmscfy)	Flared LFG (MMBTU)	LFG-CNG (WTW) CO_2 e tons/y	NG-CNG (WTW) CO_2 e tons/y	Diesel (WTW) CO_2 e tons/y
Scenario: New Jersey LFG to Transportation GREET Comparison	10,194.57	5,158454	100,022	403,231	504,981

*Mintz, M., et al. *“Well-to-Wheels Analysis of Landfill Gas-Based Pathways and Their Addition to the GREET Model” Argonne National Laboratiry,May,2010, ANL/ESD/10-3*

GREET “**The Greenhouse Gases, Regulated Emissions and Energy Use in Transportation**” Model

Greenhouse Gas Reduction Potential: Landfill Gas to CNG as Transportation Fuel

LFG to CNG GREET Comparison



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Greenhouse Gas Reduction Potential: Food Waste AD to Energy

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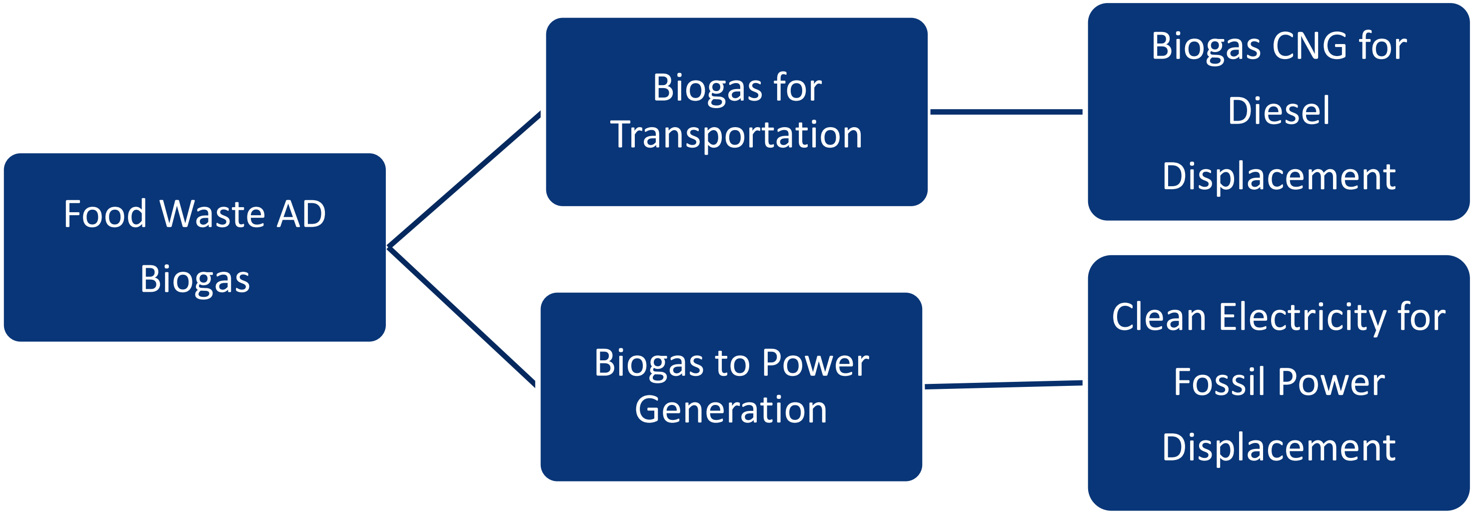
New Jersey Agricultural
Experiment Station

SCENARIO: Food Waste AD to Energy



Food Waste AD Biogas

Biogas for Transportation

Biogas CNG for Diesel Displacement

Biogas to Power Generation

Clean Electricity for Fossil Power Displacement

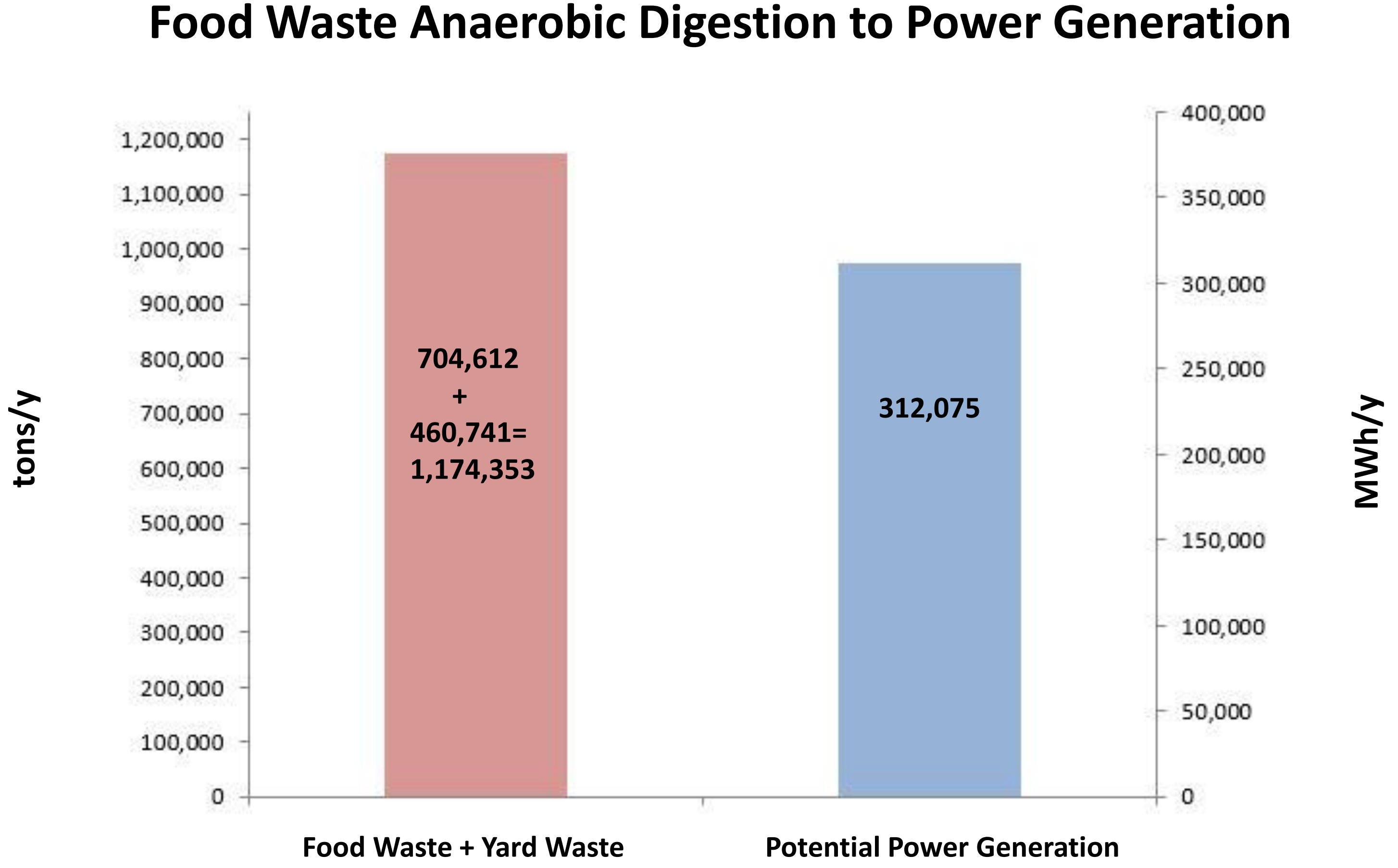
Greenhouse Gas Reduction Potential: Food Waste AD to Power Generation

If New Jersey's food & yard waste are utilized through AD for power generation, New Jersey can avoid 368,262 (351,084 + 17,178) tons CO_2 emissions per year.

	Total Food & Yard Waste (60/40%) (tons/y)	Electricity Generation Potential (MWh /y)	Potential CO_2 Produced from food waste to power (tons/y)	Potential to reduce CO_2 (if the power displaces coal generated power) (tons/y)	Potential avoided CO_2 amount (tons/y)	GREET Comparison CO_2 amount (tons/y)
Scenario: New Jersey AD of Food Waste & Yard Waste to Power Generation	**1,374,353**	312, 075	175,631	351,084	175,453	-17,178

Greenhouse Gas Reduction Potential: Food Waste AD to Power Generation

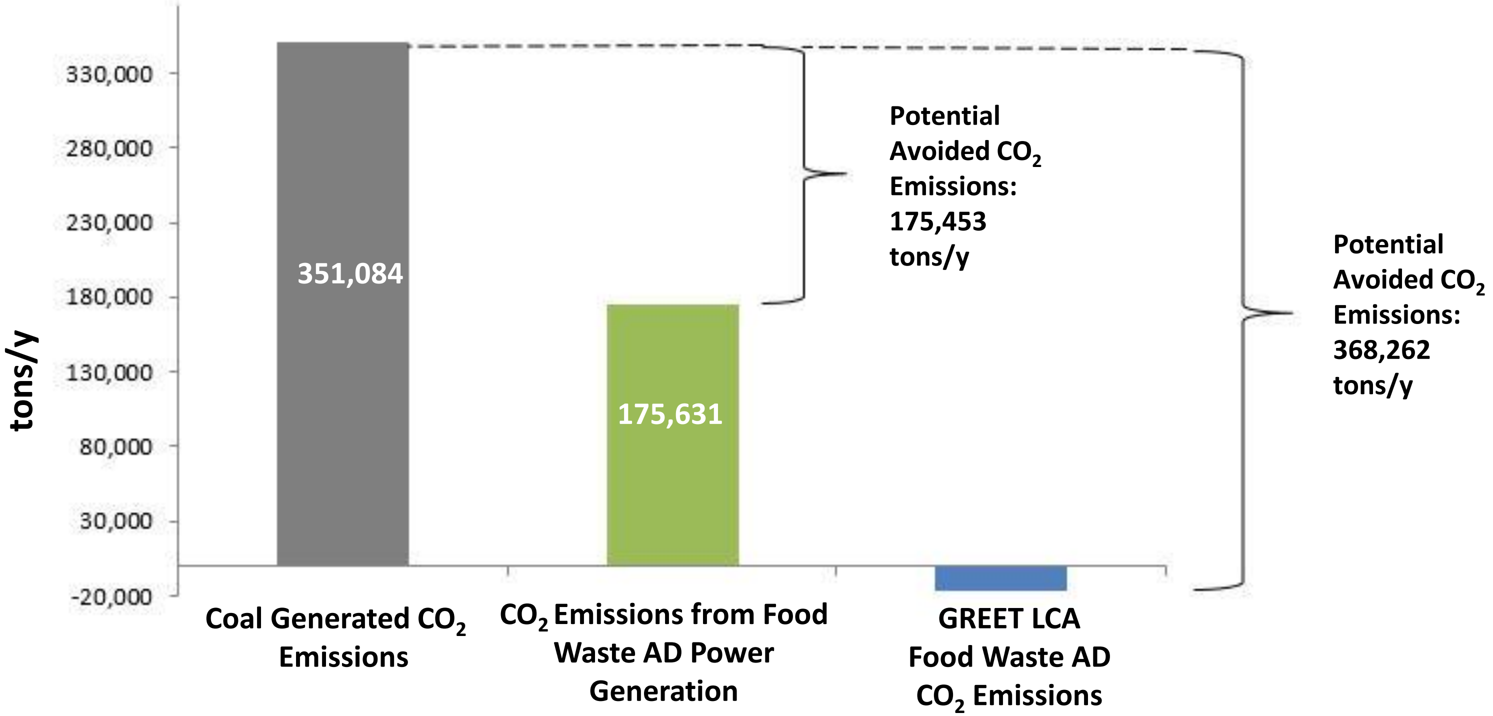
RUTGERS
New Jersey Agricultural
Experiment Station



Greenhouse Gas Reduction Potential: Food Waste AD to Power Generation

RUTGERS
New Jersey Agricultural Experiment Station

Food Waste AD Biogas for Power Generation Potential CO_2 Reductions Comparison



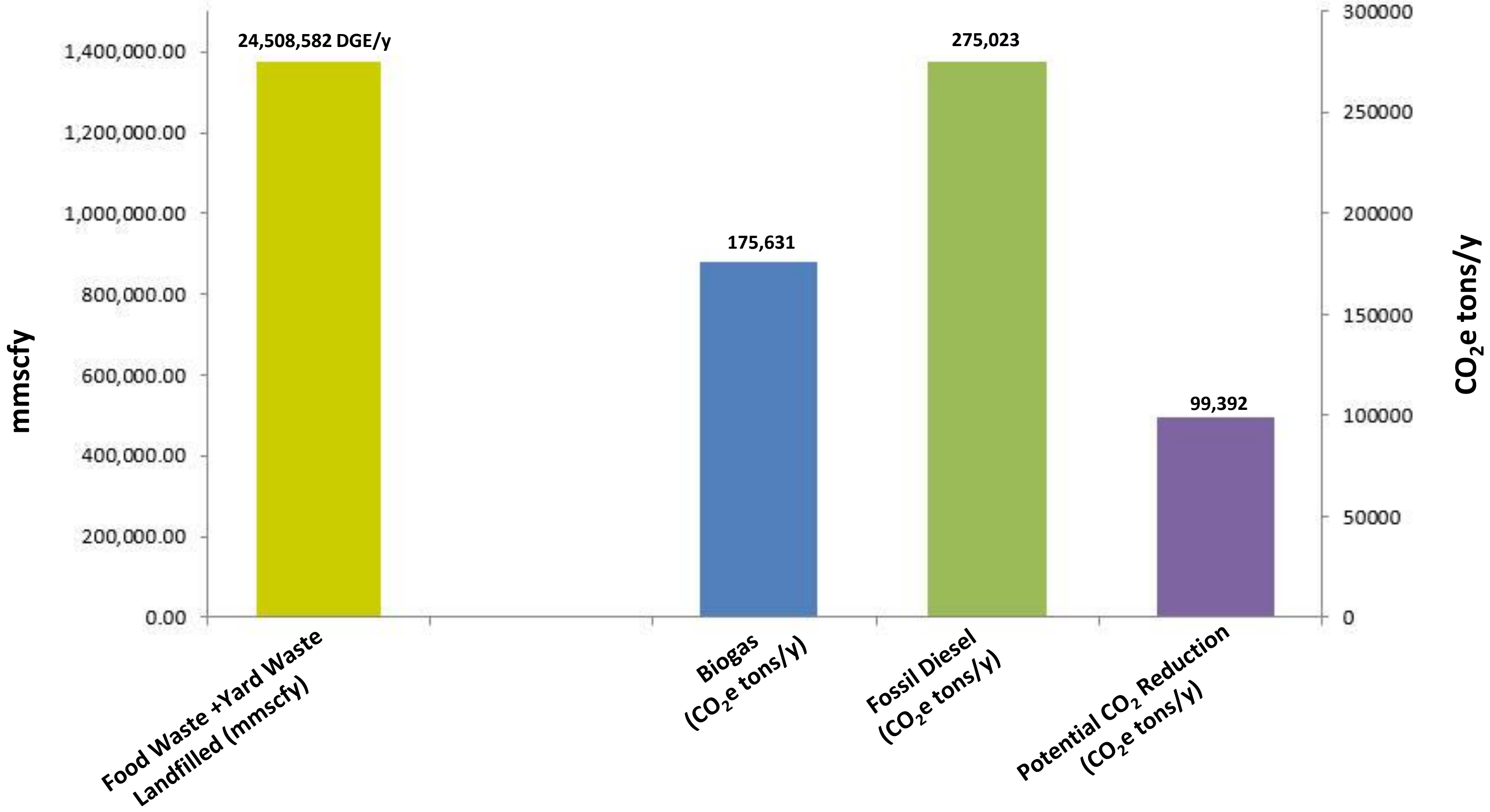
Greenhouse Gas Reduction Potential: Food Waste AD to CNG/LNG as Transportation Fuel

If New Jersey's food waste is converted into biogas and utilized as CNG, thereby displacing fossil diesel fuel for LDV and HDV, 24.5 million gallons of fossil diesel and 275,023 tons of fossil CO_2 can be displaced by recycled CO_2 with total reduction of 99,392 tons of CO_2/y.

	Total Food Waste & Yard Waste (60/40%) (tons/y)	**Potential CO_2 Content of Biogas from Food Waste & yard waste (tons/y)**	**Transportation Fuel Production Potential (DGE/y)**	**CO_2 Produced: Fossil gasoline (equivalent amount) (tons/y)**	**Potential avoided CO_2 amount (tons/y)**
Scenario: New Jersey "AD of Food Waste & Yard Waste" to Transportation	1,374,353	175,631	24,508,582	275,023	99.392

Greenhouse Gas Reduction Potential: Food Waste AD to CNG/LNG as Transportation Fuel

Food Waste AD Biogas 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.

Greenhouse Gas Reduction Potential: Food Waste AD to CNG/LNG as Transportation Fuel

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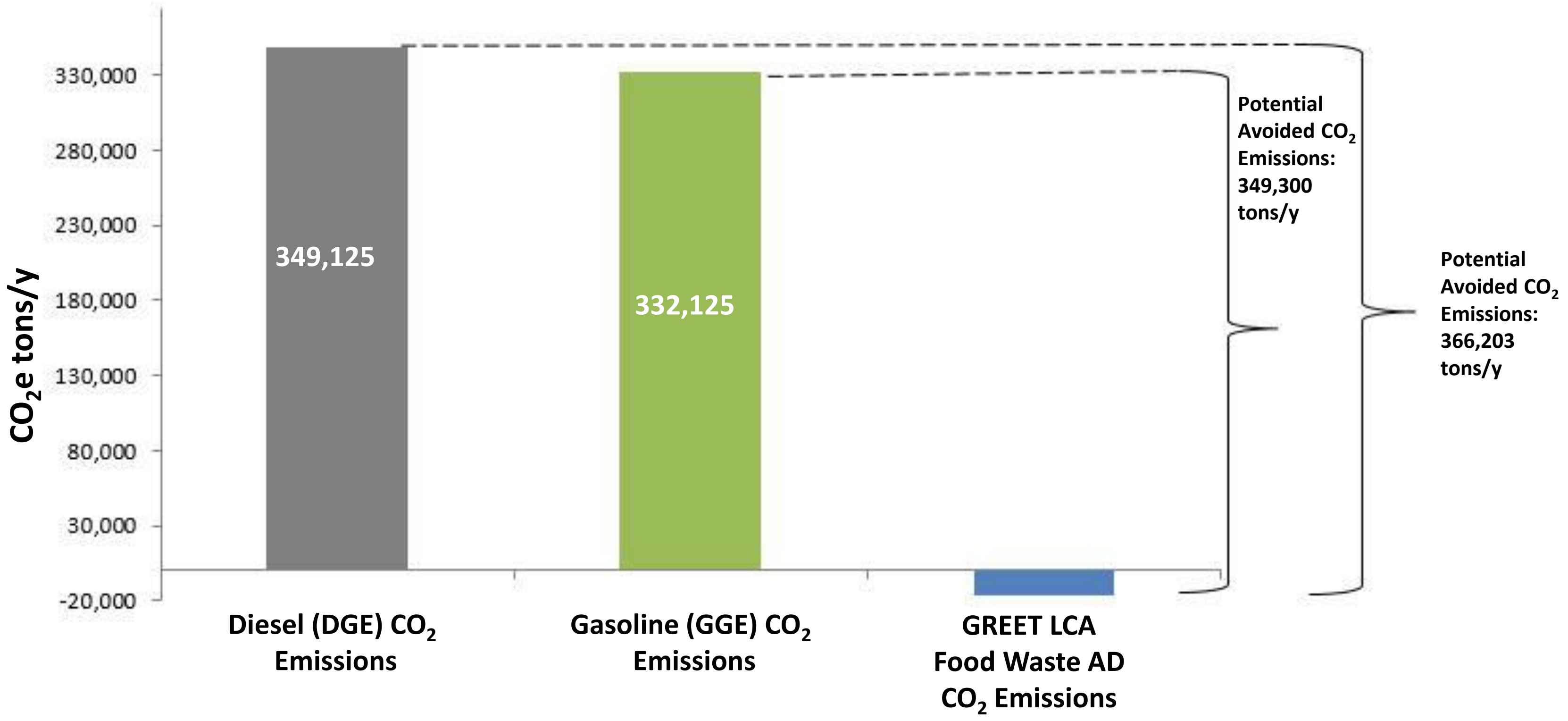
Food Waste AD Biogas as Transportation Fuel Potential CO_2 Reductions Comparison



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Greenhouse Gas Reduction Potential: Yellow Grease Biodiesel to Energy

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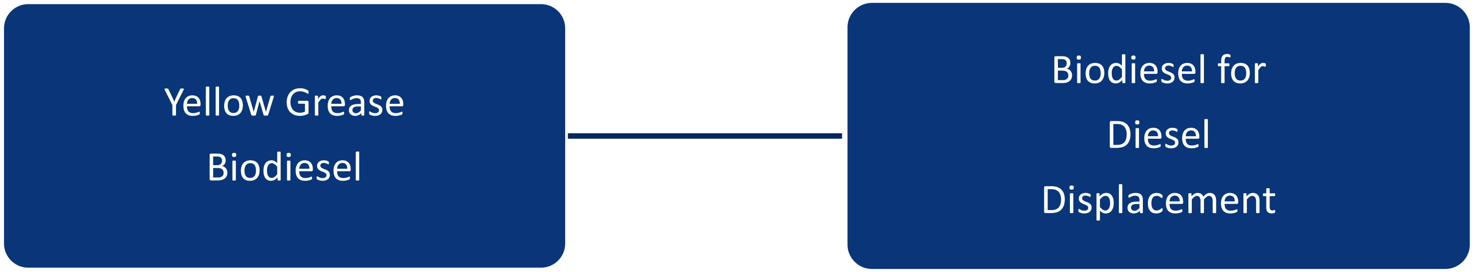
Experiment Station

SCENARIO: Yellow Grease to Biodiesel for Energy



Yellow Grease Biodiesel

Biodiesel for Diesel Displacement

Greenhouse Gas Reduction Potential: Yellow Grease Biodiesel as Transportation Fuel

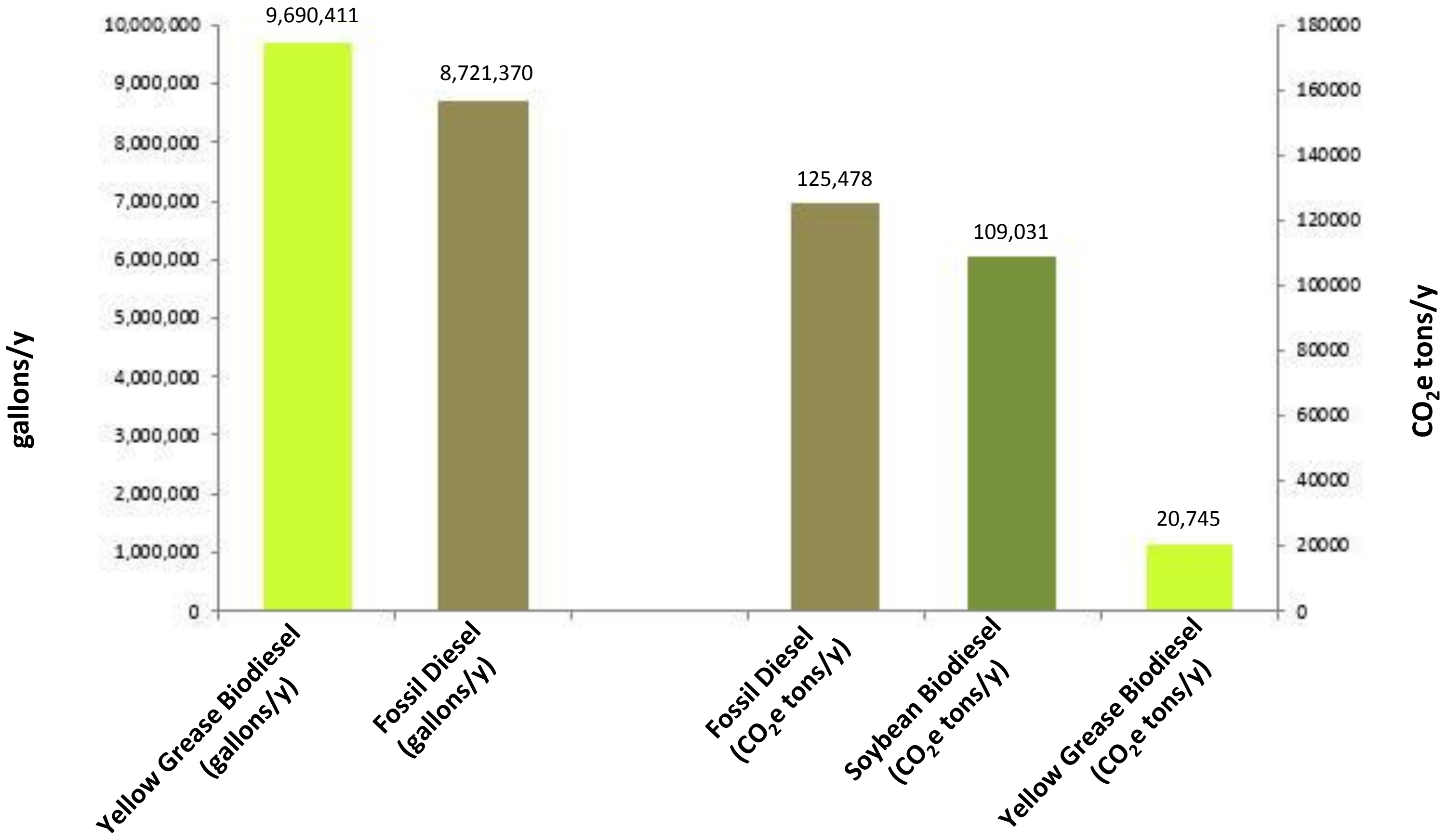
If New Jersey's yellow grease waste is converted into biodiesel and utilized for transportation, the biodiesel amount potentially would displace 8.7 million gallons of fossil diesel and 125,478 tons of fossil CO_2e per year.

	Total Yellow Grease Generation (lbs/y)	**Potential Biodiesel (gallons/y)**	**Potential Displaced Fossil Diesel (gallons/y)**	**Grease Biodiesel (Cooking Required) CO_2e (tons/y)**	**Soybean Biodiesel FTW CO_2e (tons/y)**	**Diesel WTW CO_2e (tons/y)**
Scenario: New Jersey Yellow Grease Biodiesel for Transportation	77,368,667	9,690,411	8,721,370	20,745	109,031	125,478

**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: Yellow Grease Biodiesel as Transportation Fuel

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

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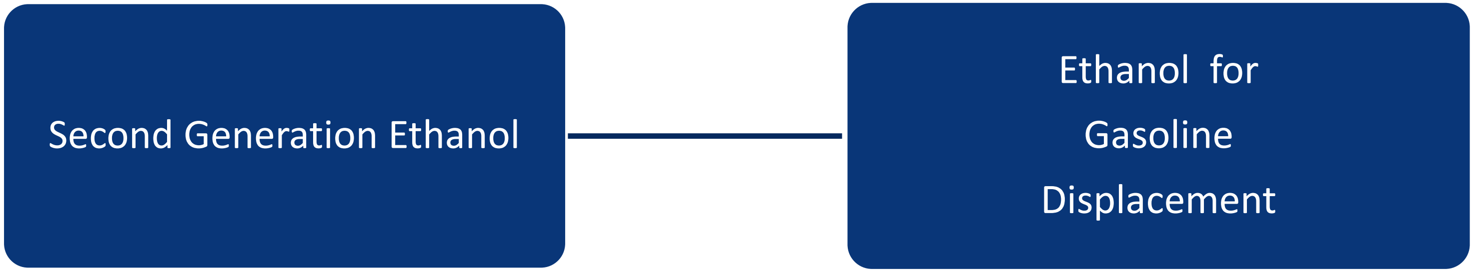
Greenhouse Gas Reduction Potential: Forestry Waste to 2nd Generation Ethanol

SCENARIO: Forestry Waste to 2nd Generation Ethanol



Second Generation Ethanol

Ethanol for
Gasoline
Displacement

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

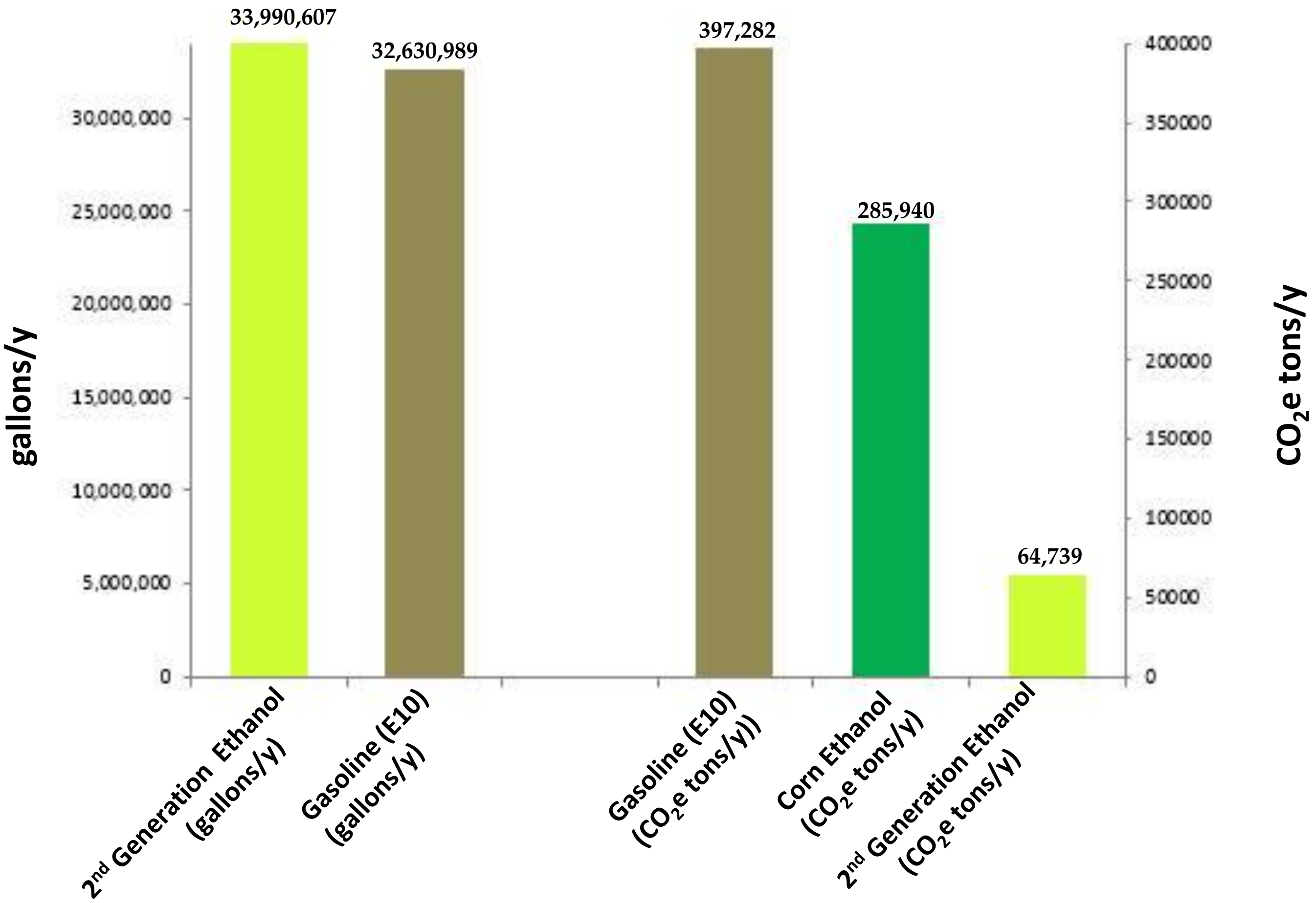
If New Jersey's forestry residuals are converted into 2nd generation ethanol through gasification and mixed alcohol synthesis, 32.6 million gallons of petroleum gasoline would be displaced per year.

	Recoverable Forestry Waste Biomass (12% Moisture) (tons/y)	2nd Generation Ethanol (gasification & alcohol synt.) (gallons/y)	Displaced Fossil Gasoline (asE10) (gallons/y)	2nd Gen. Ethanol CO2e (tons/y)	Corn ethanol FTW CO2e (tons/y)	Gasoline WTW CO2e (tons/y)
Scenario: New Jersey Forest Biomass to 2nd Gen. Ethanol for Transportation	520,530	33,990.606	32,630,000	64,739	285,940	397,282

**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

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*

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V. Economic Assessment

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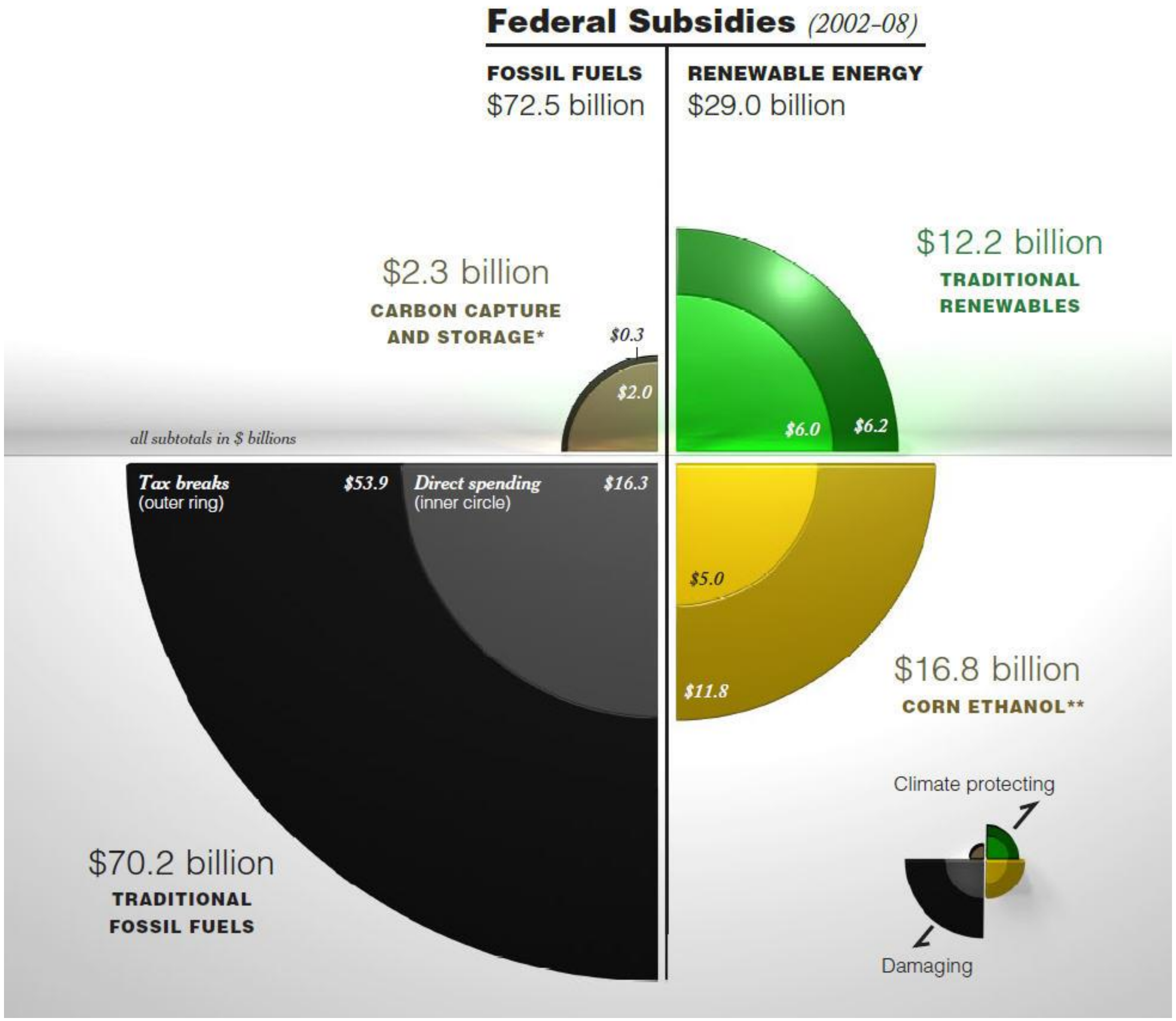
U.S. ENERGY & FUEL SUBSIDY FACTS:

- The vast majority of federal subsidies for fossil fuels and renewable energy supports energy sources that emit high levels of greenhouse gases when used as fuel.
- Fossil fuel subsidies are supporting mature, developed industry that has enjoyed government support for many years compared to renewable fuels which is a relatively young and developing industry.
- Most of the largest subsidies to fossil fuels were written into the U.S. Tax Code as permanent provisions. By comparison, many subsidies for renewables are time-limited initiatives implemented through energy bills, with expiration dates that limit their usefulness to the renewable industry.
- The vast majority of fossil fuel subsidy dollars can be attributed to "Foreign Tax Credit" and the "Credit for Production of Nonconventional Fuels".
- The Foreign Tax Credit applies to overseas production of oil through a provision of the Tax Code, which allows energy companies to claim a tax credit for payments that would normally receive less-beneficial tax treatment.

http://www.eli.org/pressdetail.cfm?ID=205

Economic Assessment: Price of Energy



http://www.eli.org/pressdetail.cfm?ID=205

Economic Assessment: Price of Energy

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*

Biomass Co-firing Capital Costs : Methods vs. Fuel Rate Amount

Co-firing Level (%)	Fuel Blending ($/kW)	Separate Injection ($/kW)	Gasification ($/kW)
5	1000-1500	1300-1800	2500-3500
10	800-1200	1000-1500	2000-2500
20	600	700-1100	1800-2300
30	-	700-1100	1700-2200

http://bv.com/docs/reports-studies/nrel-cost-report.pdf

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

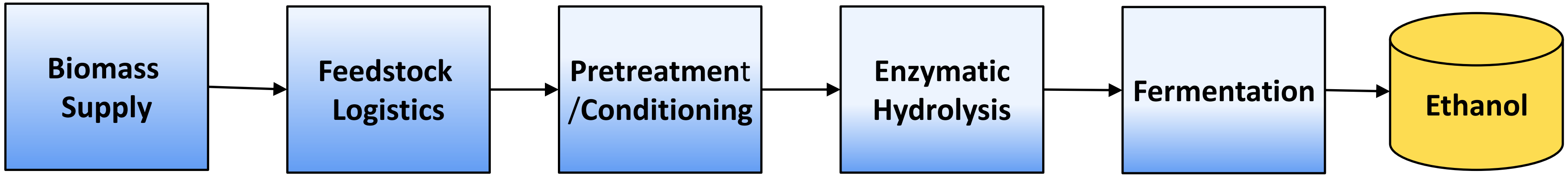
- Global demand is growing rapidly.
- Interest levels for low-carbon products are promising.
- Flexibility to produce bio-chemicals and bio-products secures operational continuity if market conditions become unattractive for advanced biofuels production.
- USDA Bio Preferred program and new voluntary 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.*

Economic Assessment: Bio-Chemical Conversion to 2nd Generation Ethanol

New Jersey Agricultural
Experiment Station

Enzymatic Conversion of Corn Stover into Advanced Ethanol*



Production Cost Improvements: (2001=$9.16; 2012=$2.15)

-------------2001=$1.25/gal---------------------
2012=$0.34/gal
2012=$0.49/gal

2001= $1.37/gal
2012= $0.27/gal

2001=$4.05/gal
2012=$0.39/gal

2001= $0.60/gal
2012=$0.15/gal

2001=$1.90/gal
2012=$0.51/gal
(Balance of Plant)

Technology Improvements:

Improved Biomass Supply Analysis

- economic availability of feedstocks
- feedstock prices specified by quality and year
- incorporation of sustainability metrics
- development of four yield scenarios
- spatial distribution

Better Collection Efficiency
- 43% to 75%

Higher Bale Density
- 9.2% to 12.3%

Lower Storage Losses
- 7.9% to 6%

Higher Grinder Capacity
- 17.6 to 31.2 tons/hr

Better Xylan to Xylose Yields
- 63% to 81%

Lower Degradation Product Formation
- 13% to5%**Lower**

Lower Acid Usage
- 3% to 0.3%

Reduced Sugar Losses
- 13% to <1%

Reduced Ammonia Loading
- decreased by>70%

Enzyme Cost Reduction
- $3.45 to $0.36 /gal

Enzyme Loading Reductions
- 60 to 19 mg/g

Higher Cellulose to Glucose Yields
- 64% to 78%

Process Efficiency Improvements
- washed solids to whole slurry mode of hydrolysis

Improved Biomass Supply Analysis
- 52% to 96%
- Better Xylose to Ethanol Yields
- 0%-93% Improved Ethanol Tolerance
- 36 to 72g/L titers

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* Thomas Foust, "Cellulosic Technology Advances", NREL, http://www1.eere.energy.gov/bioenergy/pdfs/biomass_2013_agenda.pdf

Economic Assessment: Bio-Chemical Conversion to 2nd Generation Ethanol

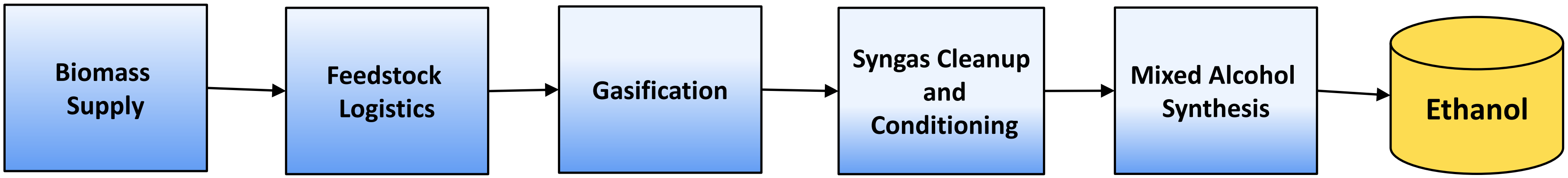
- The data is based on conceptual design characteristics.*

BioChemical Conversion Type	Ethanol Production MMgal/y	Ethanol Yield gal/dry ton feedstock	Minimum Ethanol Selling Price : $/gal
Dilute Acid Pretreatment & Enzymatic Hydrolysis and Co-Fermentation	**61**	**79**	**2.15**

Total Direct Costs ($ 2007)	Total Indirect Costs $ ($ 2007)	Land and Working Capital ($ 2007)	Total Capital Investment ($ 2007)
250,400,000	**150,200,000**	**21,800,000**	**422,400,000**

**Humbird,D., et al. "Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol", Technical Report, NREL/TP-5100-47764, May 2011.p62.*

Economic Assessment: Thermochemical Conversion to 2nd Generation Ethanol



Production Cost Improvements: (2007=$4.75; 2012=$2.05)

-------------2007=$1.40/gal---------------------

2012=$0.17/gal

2012=$0.56/gal

2007= $0.37/gal
2012= $0.28/gal

2007=$1.49/gal
2012=$0.35/gal

2007= $1.52/gal
2012= $0.69/gal

2007=$0.03/gal
2012=$0.00/gal
(Balance of Plant)

Technology Improvements:

Improved Biomass Supply Analysis

- economic availability of feedstocks
- feedstock prices specified by quality and year
- sustainability metrics
- development of four yield scenarios
- spatial distribution

Increased Harvest Efficiency

- 65% to 80%

Improved Collection Efficiency

- 65% to 75%

Decreased Moisture During Transport

- 50% to 30%

Increased Grinder Efficiency

- 65 to 75 tons/hr

Economic Analysis of Available Gasifiers

- Impact of Gasifier type, scale and produced syngas composition

Better Understanding of Biomass Gasification Fundamentals

- Chemistry mechanisms, flow characteristics and feedstock variability

Development of Analytical Methodology

- Comprehensive tar and heteroatom quantification

Improved Methane Conversion

- 20% to 80%

Improved Tar Conversion

- 80% to 99%

Lower Catalyst Replacement Rate

- 1 to o,15% per day

Optimized Catalyst Reforming and Regeneration

- Enables continuous operation

Higher Ethanol Productivity

- 101 to>160g/kg/hr

Improved Overall Ethanol Yield

- 62 to >84 gal/ton

Improved Repeatability

Decreased Cost of Catalyst Production

Scale Improvements:

National to county level detail

National to county level detail

Pilot (1ton/day)

Bench (g) to Pilot (1000 kg)

Bench (g) to Pilot (kg)

* Thomas Foust, “Cellulosic Technology Advances”, NREL, http://www1.eere.energy.gov/bioenergy/pdfs/biomass_2013_agenda.pdf

Economic Assessment: Biomass Gasification to Syn-Gas to 2nd Generation Ethanol Production

RUTGERS
New Jersey Agricultural Experiment Station

- Various gasifier technologies available to convert biomass to syngas
- Based on available biomass, gasifier and tar reformer technology the capital cost of the Biomass gasification varies*:

Gasifier Type	Feed Rate dmt/day	Biomass Type: Wood Residue	Syngas Production	Total Project Investment Cost : (2011)
Oyxgen Blown Autothermal Bubbling Fluidized bed	**1000**	**wood chips and bark**	**153,000 lbs/h (wet syngas)**	**70,590,000**
Indirect Heating Circulating Fluidized Bed, Separate Combustion of Char with Air	**1000**	**wood chips and bark**	**1,580,000 scf/h (dry syngas)**	**59,700,000**
Pressurized, Autothermal, Bubbling Fluidized bed Partial Oxidation	**1000**	**wood chips and bark**	**172,300 lbs/h (wet syngas)**	**70,720,000**

*http://www.nrel.gov/docs/fy13osti/57085.pdf

Economic Assessment: Corn Stover to 2nd Generation Ethanol » *Process Engineering Analysis*

- The data is based on conceptual design characteristics*.

Thermochemical Conversion Type	Ethanol Production MMgal/y	Ethanol Yield gal/dry ton feedstock	Minimum Ethanol Production Cost : $/gal
Direct Gasification and mixed Alcohol Synthesis	**50.4**	**65.3**	**2.05**

Capital Costs ($ 2005)	Indirect Costs ($ 2005)	Total Capital Investment ($ 2005)
182,700,000	**71,400,000**	**254,000,000**

**Dutta,A., & Phillpis, [‘S.D., “Thermochemical Ethanol via Direct Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass”, Technical Report, NREL/TP-510-45913, July, 2009. p79.*

Economic Assessment: Food Waste Anaerobic Digestion for Power Generation

Technology	Capacity (tons/y)	Energy Output (MWh/y)	Tipping Fee ($/ton)
Anaerobic Digestion of Food Waste	10,000	2,400	60

Capital Costs ($)	Operational Cost ($/ton)	Average Installed Capital Cost in North America ($/ton)
6,000,000	34	600

**Moriarity,K., "Feasibility Study of Anaerobic Digestion of Food Waste in St. Bernard, Louisiana, Technical Report, NREL/TP-7A30-57082, January 2013,p31.*

VI. Policy Recommendations/Next Steps

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BIOFUELS TARGETS

- Biofuels industry has two critical targets to achieve:
    - Consumers and vehicle manufacturers need to adopt new environmentally friendly fuels and displace fossil fuels.
    - Advanced biofuel manufacturers need to 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.
- Conventional ethanol demand has 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. Concerns from consumers and vehicle manufacturers limit uptake of E15.
- The use of E85 gasoline faces similar challenges since very few vehicles can handle the blend.

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

Policy Recommendations/Next Steps: Biofuels Development

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: Bioenergy Development

RECOMMENDATIONS FOR ACCELERATING PENETRATION OF BIOENERGY:

- 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)

Policy Recommendations/Next Steps: Feedstock Development

RECOMMENDATIONS FOR ACCELERATING PENETRATION OF BIOENERGY:

Securing Feedstocks:

- Supportive, consistent policies which will create positive market signals and certainty to grow energy crops
- Scientists, engineers, agronomists, and other experts to improve yield (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!)

Policy Recommendations/Next Steps: Conversion Technologies

Both combustion and gasification technologies present opportunities in New Jersey.

- New Jersey's yard waste collection system could potentially form a backbone of a biomass supply infrastructure for small (<10MW) distributed biomass power facilities that represent a higher-value use of the biomass than current practice (assumed to be mainly composting).
- Biomass co-firing offers environmental benefits when compared to existing coal fired power production.
- The New Jersey RPS should provide additional value for qualifying biomass, but the RPS rules on biomass eligibility are fairly strict.
- Despite a lack of commercial status, gasification technology is relatively well developed and can be deployed at a range of scales for power generation, which makes it suitable to New Jersey's biomass resources. Gasification is also suitable for municipal wastes, and could offer lower emissions than conventional incineration.
- Pyrolysis is at a much earlier stage of development than gasification. New Jersey should monitor developments around the world.

Policy Recommendations/Next Steps: Biogas & Landfill Gas

Anaerobic digestion is a commercialized and well developed technology that can help capture New Jersey's biomass energy potential.

- High population density ensures a concentrated stream of food wastes, landfill gas and MSW (the organic component of which will need to be separated from the non digestible materials).
- Other biomass streams add to this potential:
  - Farm wastes such as manure
  - Yellow and brown grease
  - Lower value in-state crops and crop residues
  - Organic waste from large industrial and food processing facilities
  - Other cellulose-rich biomass (such as waste paper)
- An in-depth analysis of these biomass and waste streams could allow New Jersey to identify optimal location(s) for centralized large-scale digesters.
  - Some European countries (Germany and Denmark) have successfully deployed this regional digester concept.
  - This would allow not only the production of more renewable energy, but also more environmentally friendly waste management practices.
- There also remain untapped opportunities for landfill gas and for installing cogeneration at wastewater treatment plants, and these projects are likely to have very attractive economics.

Policy Recommendations/Next Steps: 1st Generation Biofuels

Feedstock availability for 1st generation biofuels are limited. Any plants of this type would require New Jersey to import feedstock with the exception of biodiesel from yellow grease.

- Corn ethanol would likely require regional importation of feedstock to present a viable commercial-scale technology opportunity in New Jersey.
- Similarly, New Jersey has limited potential in terms of biodiesel feedstock. However some characteristics make it attractive as a location for biodiesel production and trading activities as new industry trends emerge:
    - New Jersey's significant petroleum refining and distribution infrastructure will increasingly become an upstream blending point for biodiesel into petroleum diesel.
    - The high concentration of population in New Jersey and the surrounding states may provide reasonable economies of scale for locating facilities to convert used vegetable oils (in the form of yellow greases) into biodiesel.
- Other examples of ways to leverage New Jersey's petroleum infrastructure include:
    - New Jersey's petroleum and petrochemical industry is in an ideal position to capitalize on some areas of technological innovation, such as the direct conversion of vegetable oils and fats into a renewable diesel at oil refineries.
    - New Jersey's import / export infrastructure, in addition to the substantial local fuel demand, makes the state an ideal center for biofuels trading activities as a global trade emerges.

Policy Recommendations/Next Steps: 2nd Generation Biofuels

Emerging biofuels technologies can provide New Jersey an opportunity to become a recognized leader in biofuels in the future.

- New Jersey has enough biomass resources that are suitable to produce cellulosic ethanol, Fischer-Tropsch liquids, and other 2nd generation biofuels to achieve meaningful economies of scale, and additional resources might be collected in neighboring states.
- As with biodiesel and renewable diesel, the production of FT biofuels presents integration opportunities with the state's existing refining infrastructure (e.g., producing a "crude FT" product and selling that to existing refineries).
- Although not addressed specifically in this report, there may be opportunities to produce syngas or hydrogen from biomass and integrate that directly with the existing petroleum and petrochemical industry.
- Production of LNG and CNG from biogas could fill an important niche, fleet fueling operations.
- However, some of these technologies are not yet commercially available.
  - Current costs are not competitive with either gasoline or corn ethanol and technology development and demonstration are still needed.
  - The first commercial plants will face significant technology, development and market risks and will need government support to "get steel in the ground".
  - While the federal government has already put in place mechanisms for supporting this nascent industry (such as grants, loan guarantees, RFS carve-outs), New Jersey could add its support to become a recognized leader in these technologies.

Policy Recommendations/Next Steps: Capacity Development

Creating an effective regulatory, management and implementation infrastructure at the state level is key to the successful achievement of bioenergy goals.

The following recommended actions could help to establish the capacity and infrastructure needed for rapid biofuels and bio-refinery development and to create sustainable markets for biofuel products. They address four key components:

1) Institutional infrastructure
2) Regulations
3) Market-based incentives
4) Market transformation through technological innovation

Market transformation will take place once the technological and infrastructure capabilities exist and can function in an economical and environmentally viable fashion.

Policy Recommendations/Next Steps: Capacity Development

ESTABLISHING CAPACITY FOR ACHIEVING NEW JERSEY'S BIOENERGY GOALS:

1) *Institutional Infrastructure:*

- Establish/appoint a state agency with primary responsibility for developing the bioenergy industry. This entity will need dedicated personnel, authority and financial resources to accomplish this goal.
- Facilitate policy harmonization across all state agencies so that goals can be successfully achieved. The effort will need to be fully integrated, include public and private partnerships, and incorporate comprehensive research, policy and marketing plans.
- Build regional partnerships with surrounding states to take advantage of related programs, maximize utilization of research activities and biomass feedstocks, and share expertise.

2) *Regulations:*

- Consider a societal benefits charge on petroleum based fuels to support bioenergy incentive programs.
- Identify and alleviate regulatory conflicts across permitting agencies to streamline and simplify approval process.
- Integrate new bioenergy efforts (i.e. biofuels) with existing policies (e.g. RPS, Clean Energy Program, & MSW recycling requirements).

Policy Recommendations/Next Steps: Capacity Development

3) Market Based Incentives:

- Develop a consumer-based biofuels incentive program.
- Provide incentives for waste-based biofuels research, development and production.
- Provide incentives for small companies to pursue bioenergy technology demonstration projects.
- Provide incentives for development of biomass feedstock infrastructure.
- Establish Bioenergy Enterprise Zones around biomass feedstock nodes.

4) Market Transformation Through Technological Innovation:

- Establish an investment fund to support the research and development of new bioenergy technologies. Build partnerships with BPU, EDA, NJCST, NJDA and other state agencies, as well as higher education institutions, federal agencies, private investors, utilities, and foundations to establish a ***Bioenergy Innovation Fund*** with a goal to transform the market for bioenergy through innovations in technology.

- Facilitate bioenergy market development by identifying ways to take advantage of New Jersey's existing petrochemical, refining and distribution infrastructure.

Policy Recommendations/Next Steps: Summary

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

Policy Recommendations/Next Steps: Evaluating Progress

In order to monitor progress and ensure that performance goals are being met, the identification of a comprehensive set of metrics is crucial. Suggested metrics include:

- Gallons of biofuels produced and sold in the state
- MW of biopower produced in the state
- Number of new bioenergy start-up companies or firms re-locating to New Jersey
- Amount of investment made through Bioenergy Innovation Fund
- Number of new bioenergy technologies commercialized
- Amount of energy saved using new energy efficiency programs
- Number of new jobs created in the bioenergy industry
- Amount of waste diverted to bioenergy conversion

Policy Recommendations/Next Steps: Systems Analysis

Systems Analysis:

- A systems approach to maximizing NJ’s bioenergy potential which incorporates the interaction of a large scope of issues (including social, environmental, regulatory, economic, technological, etc.) is needed for a long-term sustainable bioenergy plan.
- A detailed systems analysis can reveal where the largest opportunities are, and more importantly, how various strategies and policies might impact each other.
- The study’s current team of researchers, along with additional collaborators, have the unique diversity of capabilities required to conduct a bioenergy system analysis for New Jersey.

Policy Recommendations/Next Steps: Systems Analysis

Examples of Systems Analysis Components and Proposed Projects:

- *Environmental:*

-Develop a methodology for, and conduct a Bioenergy Lifecycle Analyses, that includes an assessment of carbon intensity, for various biomass feedstocks and technologies appropriate for New Jersey.

-Evaluate environmental and economic impact of converting marginal agricultural lands and lands enrolled in preservation and set-aside programs to bioenergy crop production.

- *Socio-Economic:*

-Update and improve accuracy of biomass resource data and fill in data gaps.

-Evaluate highest and best use of biomass resources that yield greatest societal and economic benefits.

-Identify nodes of biomass feedstocks and develop a gravity model that can optimize bioenergy facility site location.

-Conduct economic analysis of optimal level of various bioenergy incentives and subsidies.

Policy Recommendations/Next Steps: Systems Analysis

- ***Policy/Regulatory:***

  -Develop a comprehensive "Bioenergy Industry Development Plan" based on a systematic approach that incorporates harmonization of state policies, targets most abundant and readily available feedstocks (i.e. waste) and streamlines regulatory process. Build collaborative relationship with other states doing this well, such as California.

  -Develop a utilization policy for publicly managed lands for harvesting biomass from these areas as well as for production of energy crops. Evaluate economics of collection of these resources, as well as conversion into energy.

  -Organize industry roundtables of potential feedstock industries (i.e. food) to engage them in planning process and determine feasibility of various policy options.

- ***Technology:***

  -Conduct demonstration projects so that procedures, processes and technology development can be evaluated and refined to yield desired results.

VII. Appendices

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Appendix I- County Biomass Data

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Appendix I: Statewide Biomass Totals

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**	

Appendix I: Atlantic County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	170	NA
	Rye	272	NA
	Corn for Grain	1,750	NA
	Wheat	356	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***2,549***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	251	3,156
	Rye	1,109	0
	Corn for Grain	0	0
	Corn for Silage	287	3,386
	Alfalfa Hay	849	0
	Other Hay	855	6,672
	Wheat	330	0
	Forestry Residues	93,145	726,531
	Processing Residues (lignocellulosic)	256	4,184
	Yard waste		
	Brush/Tree Parts	6,325	111,945
	Grass Clippings	3,115	48,599
	Leaves	11,268	175,781
	Stumps	607	10,740
	Subtotal	***118,397***	***1,090,995***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	11,274	108,235
	Waste paper, Landfilled	41,584	483,112
	Other Biomass, Landfilled	31,987	334,452
	C&D (Non-recycled wood)	31,032	351,534
	Recycled Products		
	Food Waste	1,042	16,671
	Wood Scraps	1,337	11,831
	Corrugated	16,633	0
	Mixed Office Paper	3,581	0
	Newspaper	8,365	0
	Other Paper/Mag/JunkMail	6,989	101,488
	Subtotal	***153,825***	***1,407,323***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	116	0
	Oils - Used cooking oil "yellow"	1,027	15,402
	Oils - Grease trap waste "brown"	123	3,686
	Subtotal	***1,266***	***19,088***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	139	411
	Dairy Cows	35	307
	Equine	36	315
	Sheep	1,847	5,455
	Goats	30	90
	Swine	6	44
	Poultry (layers)	0	0
	Turkeys	0	0
	Wastewater treatment plant biosolids	9,628	115,536
	Subtotal (other wastes - solid)	***11,721***	***122,159***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	98	60,907
	Landfill Gas	901	455,692
	Subtotal (other wastes - gaseous)	***999***	***516,600***
	Sutotal (other waste - all)	***50,564***	***638,759***
	TOTAL BIOMASS	**326,600**	

Appendix I: Bergen County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	0	NA
	Rye	1	NA
	Corn for Grain	4	NA
	Wheat	0	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***4***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	12	150
	Rye	2	0
	Corn for Grain	2	28
	Corn for Silage	0	0
	Alfalfa Hay	0	0
	Other Hay	100	778
	Wheat	0	0
	Forestry Residues	11,655	90,909
	Processing Residues (lignocellulosic)	1,504	24,566
	Yard waste		
	Brush/Tree Parts	24,473	433,167
	Grass Clippings	7,570	118,092
	Leaves	46,938	732,236
	Stumps	1,482	26,227
	Subtotal	***93,737***	***1,426,153***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	25,933	248,957
	Waste paper, Landfilled	95,651	1,111,232
	Other Biomass, Landfilled	73,575	769,292
	C&D (Non-recycled wood)	83,890	950,305
	Recycled Products		
	Food Waste	4,689	75,029
	Wood Scraps	11,347	100,421
	Corrugated	77,010	0
	Mixed Office Paper	22,299	0
	Newspaper	35,480	0
	Other Paper/Mag/JunkMail	16,013	232,537
	Subtotal	***445,886***	***3,487,774***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	0	0
	Oils - Used cooking oil "yellow"	3,385	
	Oils - Grease trap waste "brown"	405	
	Subtotal	***3,790***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	5	13
	Dairy Cows	0	0
	Equine	445	3,938
	Sheep	8	24
	Goats	8	23
	Swine	730	5,388
	Poultry (layers)	36	427
	Turkeys	0	0
	Wastewater treatment plant biosolids	6,059	72,709
	Subtotal (other wastes - solid)	***7,290***	***82,523***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	322	199,307
	Landfill Gas	1,194	604,247
	Subtotal (other wastes - gaseous)	***1,516***	***803,553***
	Sutotal (other waste - all)	***65,289***	***886,076***
	TOTAL BIOMASS	**608,707**	

Rutgers
New Jersey Agricultural Experiment Station

Appendix I: Burlington County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	503	NA
	Rye	1,788	NA
	Corn for Grain	24,917	NA
	Wheat	4,883	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***32,090***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	1,057	13,297
	Rye	5,954	0
	Corn for Grain	15,128	202,293
	Corn for Silage	4,747	56,010
	Alfalfa Hay	4,420	0
	Other Hay	6,510	50,776
	Wheat	4,544	0
	Forestry Residues	127,223	992,339
	Processing Residues (lignocellulosic)	14	222
	Yard waste		
	Brush/Tree Parts	27,441	485,703
	Grass Clippings	301	4,691
	Leaves	16,737	261,099
	Stumps	736	13,024
	Subtotal	***214,810***	***2,079,453***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	12,652	121,456
	Waste paper, Landfilled	46,664	542,126
	Other Biomass, Landfilled	35,894	375,307
	C&D (Non-recycled wood)	39,479	447,215
	Recycled Products		
	Food Waste	3,203	51,251
	Wood Scraps	5,112	45,238
	Corrugated	37,134	0
	Mixed Office Paper	5,304	0
	Newspaper	24,812	0
	Other Paper/Mag/JunkMail	2,397	34,806
	Subtotal	***212,651***	***1,617,400***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	19,214	0
	Oils - Used cooking oil "yellow"	1,678	
	Oils - Grease trap waste "brown"	201	
	Subtotal	***21,093***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	1,098	3,242
	Dairy Cows	1,896	16,800
	Equine	13,248	117,360
	Sheep	240	710
	Goats	231	681
	Swine	730	5,388
	Poultry (layers)	48	577
	Turkeys	7	103
	Wastewater treatment plant biosolids	1,095	13,136
	Subtotal (other wastes - solid)	***18,594***	***157,997***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	72	44,433
	Landfill Gas	1,658	839,133
	Subtotal (other wastes - gaseous)	***1,730***	***883,565***
	Sutotal (other waste - all)	***86,409***	***1,041,562***
	TOTAL BIOMASS	**567,054**	

Appendix I: Camden County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	389	NA
	Rye	376	NA
	Corn for Grain	1,439	NA
	Wheat	240	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***2,444***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	377	4,739
	Rye	1,264	0
	Corn for Grain	873	11,679
	Corn for Silage	92	1,084
	Alfalfa Hay	1,646	0
	Other Hay	1,026	8,002
	Wheat	238	0
	Forestry Residues	23,350	182,126
	Processing Residues (lignocellulosic)	21	338
	Yard waste		
	Brush/Tree Parts	14,495	256,555
	Grass Clippings	6,088	94,966
	Leaves	22,191	346,184
	Stumps	1,611	28,517
	Subtotal	***73,270***	***934,191***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	4,017	38,560
	Waste paper, Landfilled	14,815	172,112
	Other Biomass, Landfilled	11,396	119,151
	C&D (Non-recycled wood)	50,597	573,164
	Recycled Products		
	Food Waste	475	7,597
	Wood Scraps	3,016	26,695
	Corrugated	43,736	0
	Mixed Office Paper	6,068	0
	Newspaper	12,367	0
	Other Paper/Mag/JunkMail	10,165	147,610
	Subtotal	***156,651***	***1,084,889***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	186	0
	Oils - Used cooking oil "yellow"	1,921	
	Oils - Grease trap waste "brown"	230	
	Subtotal	***2,337***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	139	411
	Dairy Cows	18	160
	Equine	1,723	15,265
	Sheep	25	74
	Goats	46	137
	Swine	7	51
	Poultry (layers)	11	128
	Turkeys	0	6
	Wastewater treatment plant biosolids	5,855	70,263
	Subtotal (other wastes - solid)	***7,825***	***86,495***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	192	118,619
	Landfill Gas	23	11,570
	Subtotal (other wastes - gaseous)	***214***	***130,189***
	Sutotal (other waste - all)	***15,225***	***216,684***
	TOTAL BIOMASS	**249,928**	

Appendix I: Cape May County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	49	NA
	Rye	116	NA
	Corn for Grain	319	NA
	Wheat	288	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***772***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	99	1,252
	Rye	383	0
	Corn for Grain	193	2,586
	Corn for Silage	40	474
	Alfalfa Hay	558	0
	Other Hay	958	7,473
	Wheat	265	0
	Forestry Residues	26,538	206,993
	Processing Residues (lignocellulosic)	47,428	774,780
	Yard waste		
	Brush/Tree Parts	8,671	153,479
	Grass Clippings	1,717	26,783
	Leaves	2,906	45,330
	Stumps	412	7,291
	Subtotal	***90,167***	***1,226,439***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	4,319	41,465
	Waste paper, Landfilled	15,931	185,082
	Other Biomass, Landfilled	12,254	128,130
	C&D (Non-recycled wood)	29,662	336,016
	Recycled Products		
	Food Waste	258	4,122
	Wood Scraps	3,860	34,163
	Corrugated	11,403	0
	Mixed Office Paper	107	0
	Newspaper	6,902	0
	Other Paper/Mag/JunkMail	9	135
	Subtotal	***84,706***	***729,113***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	0	0
	Oils - Used cooking oil "yellow"	364	
	Oils - Grease trap waste "brown"	44	
	Subtotal	***407***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	56	164
	Dairy Cows	0	0
	Equine	820	7,266
	Sheep	38	113
	Goats	31	92
	Swine	233	1,722
	Poultry (layers)	11	128
	Turkeys	2	27
	Wastewater treatment plant biosolids	1	13
	Subtotal (other wastes - solid)	***1,192***	***9,525***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	54	33,323
	Landfill Gas	732	370,601
	Subtotal (other wastes - gaseous)	***786***	***403,924***
	Sutotal (other waste - all)	***31,893***	***413,449***
	TOTAL BIOMASS	**207,946**	

Appendix I: Cumberland County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	766	NA
	Rye	445	NA
	Corn for Grain	17,626	NA
	Wheat	8,445	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***27,282***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	251	3,156
	Rye	1,341	0
	Corn for Grain	10,702	143,103
	Corn for Silage	4,167	49,169
	Alfalfa Hay	4,472	0
	Other Hay	6,003	46,820
	Wheat	7,754	0
	Forestry Residues	73,756	575,293
	Processing Residues (lignocellulosic)	3,757	61,372
	Yard waste		
	Brush/Tree Parts	9,258	163,864
	Grass Clippings	259	4,048
	Leaves	5,903	92,093
	Stumps	866	15,321
	Subtotal	***128,487***	***1,154,238***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	5,400	51,842
	Waste paper, Landfilled	19,918	231,400
	Other Biomass, Landfilled	15,321	160,196
	C&D (Non-recycled wood)	16,453	186,381
	Recycled Products		
	Food Waste	5,611	89,778
	Wood Scraps	6,329	56,011
	Corrugated	15,047	0
	Mixed Office Paper	2,524	0
	Newspaper	4,099	0
	Other Paper/Mag/JunkMail	1,162	16,873
	Subtotal	***91,865***	***792,481***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	8,220	0
	Oils - Used cooking oil "yellow"	587	
	Oils - Grease trap waste "brown"	70	
	Subtotal	***8,877***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	657	1,940
	Dairy Cows	1,451	12,850
	Equine	3,033	26,867
	Sheep	22	65
	Goats	100	296
	Swine	233	1,722
	Poultry (layers)	377	4,527
	Turkeys	2	27
	Wastewater treatment plant biosolids	1,018	12,217
	Subtotal (other wastes - solid)	***6,894***	***60,512***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	41	25,110
	Landfill Gas	190	96,243
	Subtotal (other wastes - gaseous)	***231***	***121,353***
	Sutotal (other waste - all)	***15,768***	***181,865***
	TOTAL BIOMASS	**272,279**	

Appendix I: Essex County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	0	NA
	Rye	0	NA
	Corn for Grain	0	NA
	Wheat	0	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***0***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	9	107
	Rye	0	0
	Corn for Grain	0	0
	Corn for Silage	0	0
	Alfalfa Hay	0	0
	Other Hay	0	0
	Wheat	0	0
	Forestry Residues	0	0
	Processing Residues (lignocellulosic)	586	9,576
	Yard waste		
	Brush/Tree Parts	14,731	260,735
	Grass Clippings	1,136	17,714
	Leaves	23,644	368,849
	Stumps	554	9,809
	Subtotal	***40,659***	***666,791***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	4,806	46,142
	Waste paper, Landfilled	17,728	205,955
	Other Biomass, Landfilled	13,636	142,580
	C&D (Non-recycled wood)	86,970	985,199
	Recycled Products		
	Food Waste	32,922	526,759
	Wood Scraps	4,557	40,333
	Corrugated	43,115	0
	Mixed Office Paper	14,268	0
	Newspaper	12,153	0
	Other Paper/Mag/JunkMail	5,214	75,710
	Subtotal	***235,370***	***2,022,677***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	0	0
	Oils - Used cooking oil "yellow"	2,932	
	Oils - Grease trap waste "brown"	351	
	Subtotal	***3,283***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	0	0
	Dairy Cows	0	0
	Equine	110	977
	Sheep	0	0
	Goats	1	2
	Swine	0	0
	Poultry (layers)	2	21
	Turkeys	0	0
	Wastewater treatment plant biosolids	8,771	105,248
	Subtotal (other wastes - solid)	***8,883***	***106,248***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	881	545,545
	Landfill Gas	0	0
	Subtotal (other wastes - gaseous)	***881***	***545,545***
	Sutotal (other waste - all)	***38,772***	***651,792***
	TOTAL BIOMASS	**318,084**	

Appendix I: Gloucester County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	644	NA
	Rye	569	NA
	Corn for Grain	10,213	NA
	Wheat	6,846	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***18,272***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	398	5,007
	Rye	2,033	0
	Corn for Grain	6,201	82,918
	Corn for Silage	4,603	54,316
	Alfalfa Hay	4,760	0
	Other Hay	4,254	33,182
	Wheat	6,291	0
	Forestry Residues	14,687	114,555
	Processing Residues (lignocellulosic)	3,846	62,827
	Yard waste		
	Brush/Tree Parts	16,932	299,698
	Grass Clippings	5,752	89,733
	Leaves	11,537	179,975
	Stumps	514	9,092
	Subtotal	***81,807***	***931,301***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	1,204	11,563
	Waste paper, Landfilled	4,443	51,613
	Other Biomass, Landfilled	3,417	35,731
	C&D (Non-recycled wood)	24,269	274,924
	Recycled Products		
	Food Waste	7,703	123,245
	Wood Scraps	5,034	44,552
	Corrugated	40,630	0
	Mixed Office Paper	5,063	0
	Newspaper	11,438	0
	Other Paper/Mag/JunkMail	6,978	101,329
	Subtotal	***110,179***	***642,957***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	8,231	0
	Oils - Used cooking oil "yellow"	1,078	
	Oils - Grease trap waste "brown"	129	
	Subtotal	***9,438***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	945	2,790
	Dairy Cows	4,979	44,110
	Equine	5,687	50,375
	Sheep	233	688
	Goats	245	722
	Swine	403	2,973
	Poultry (layers)	68	811
	Turkeys	18	262
	Wastewater treatment plant biosolids	10,267	123,208
	Subtotal (other wastes - solid)	***22,844***	***225,941***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	57	35,043
	Landfill Gas	2,710	1,371,051
	Subtotal (other wastes - gaseous)	***2,766***	***1,406,094***
	Sutotal (other waste - all)	***131,590***	***1,632,035***
	TOTAL BIOMASS	**351,287**	

Appendix I: Hudson County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	0	NA
	Rye	0	NA
	Corn for Grain	0	NA
	Wheat	0	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***0***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	0	0
	Rye	0	0
	Corn for Grain	0	0
	Corn for Silage	0	0
	Alfalfa Hay	0	0
	Other Hay	0	0
	Wheat	0	0
	Forestry Residues	2,017	15,733
	Processing Residues (lignocellulosic)	0	0
	Yard waste		
	Brush/Tree Parts	782	13,845
	Grass Clippings	17	261
	Leaves	1,150	17,938
	Stumps	163	2,881
	Subtotal	***4,129***	***50,658***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	17,510	168,098
	Waste paper, Landfilled	64,584	750,312
	Other Biomass, Landfilled	49,679	519,432
	C&D (Non-recycled wood)	50,472	571,743
	Recycled Products		
	Food Waste	435	6,957
	Wood Scraps	21,999	194,687
	Corrugated	37,196	0
	Mixed Office Paper	21,370	0
	Newspaper	8,931	0
	Other Paper/Mag/JunkMail	25,009	363,181
	Subtotal	***297,185***	***2,574,411***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	0	0
	Oils - Used cooking oil "yellow"	2,372	
	Oils - Grease trap waste "brown"	284	
	Subtotal	***2,656***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	0	0
	Dairy Cows	0	0
	Equine	0	0
	Sheep	0	0
	Goats	0	0
	Swine	0	0
	Poultry (layers)	0	0
	Turkeys	0	0
	Wastewater treatment plant biosolids	1,010	12,119
	Subtotal (other wastes - solid)	***1,010***	***12,119***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	129	80,004
	Landfill Gas	0	0
	Subtotal (other wastes - gaseous)	***129***	***80,004***
	Sutotal (other waste - all)	***5,393***	***92,123***
	TOTAL BIOMASS	**309,362**	

Appendix I: Hunterdon County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	570	NA
	Rye	481	NA
	Corn for Grain	23,555	NA
	Wheat	3,319	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***27,926***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	274	3,445
	Rye	1,524	0
	Corn for Grain	14,301	191,239
	Corn for Silage	7,077	83,506
	Alfalfa Hay	14,027	0
	Other Hay	38,009	296,472
	Wheat	3,058	0
	Forestry Residues	51,261	399,836
	Processing Residues (lignocellulosic)	0	0
	Yard waste		
	Brush/Tree Parts	3,013	53,327
	Grass Clippings	0	0
	Leaves	1,891	29,501
	Stumps	502	8,885
	Subtotal	***134,938***	***1,066,212***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	2,329	22,356
	Waste paper, Landfilled	8,589	99,785
	Other Biomass, Landfilled	6,607	69,080
	C&D (Non-recycled wood)	69,074	782,473
	Recycled Products		
	Food Waste	28	456
	Wood Scraps	1,364	12,072
	Corrugated	7,380	0
	Mixed Office Paper	2,014	0
	Newspaper	4,167	0
	Other Paper/Mag/JunkMail	1,216	17,652
	Subtotal	***102,767***	***1,003,874***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	4,189	0
	Oils - Used cooking oil "yellow"	480	
	Oils - Grease trap waste "brown"	57	
	Subtotal	***4,727***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	4,249	12,545
	Dairy Cows	3,462	30,665
	Equine	15,609	138,273
	Sheep	717	2,116
	Goats	386	1,140
	Swine	122	899
	Poultry (layers)	151	1,815
	Turkeys	37	549
	Wastewater treatment plant biosolids	1,808	21,696
	Subtotal (other wastes - solid)	***26,541***	***209,698***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	11	6,646
	Landfill Gas	0	0
	Subtotal (other wastes - gaseous)	***11***	***6,646***
	Sutotal (other waste - all)	***26,905***	***216,344***
	TOTAL BIOMASS	**297,263**	

Appendix I: Mercer County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	133	NA
	Rye	343	NA
	Corn for Grain	7,319	NA
	Wheat	716	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***8,511***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	247	3,113
	Rye	1,488	0
	Corn for Grain	4,443	59,418
	Corn for Silage	0	0
	Alfalfa Hay	1,937	0
	Other Hay	3,675	28,662
	Wheat	657	0
	Forestry Residues	21,617	168,613
	Processing Residues (lignocellulosic)	52,681	860,594
	Yard waste		
	Brush/Tree Parts	20,448	361,934
	Grass Clippings	508	7,928
	Leaves	10,535	164,350
	Stumps	1,472	26,049
	Subtotal	***119,709***	***1,680,660***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	11,190	107,420
	Waste paper, Landfilled	41,271	479,474
	Other Biomass, Landfilled	31,746	331,934
	C&D (Non-recycled wood)	31,373	355,398
	Recycled Products		
	Food Waste	1,304	20,860
	Wood Scraps	18,525	163,945
	Corrugated	28,732	0
	Mixed Office Paper	6,689	0
	Newspaper	10,190	0
	Other Paper/Mag/JunkMail	4,641	67,403
	Subtotal	***185,662***	***1,526,434***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	3,842	0
	Oils - Used cooking oil "yellow"	1,371	
	Oils - Grease trap waste "brown"	164	
	Subtotal	***5,377***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	428	1,265
	Dairy Cows	111	984
	Equine	3,154	27,935
	Sheep	228	674
	Goats	22	65
	Swine	1	6
	Poultry (layers)	30	363
	Turkeys	0	4
	Wastewater treatment plant biosolids	13,427	161,128
	Subtotal (other wastes - solid)	***17,402***	***192,425***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	149	92,499
	Landfill Gas	0	0
	Subtotal (other wastes - gaseous)	***149***	***92,499***
	Sutotal (other waste - all)	***22,470***	***284,924***
	TOTAL BIOMASS	**341,728**	

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Appendix I: Middlesex County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	165	NA
	Rye	476	NA
	Corn for Grain	8,694	NA
	Wheat	178	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***9,513***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	219	2,760
	Rye	1,490	0
	Corn for Grain	5,279	70,585
	Corn for Silage	1,079	12,733
	Alfalfa Hay	476	0
	Other Hay	922	7,191
	Wheat	171	0
	Forestry Residues	25,339	197,644
	Processing Residues (lignocellulosic)	0	0
	Yard waste		
	Brush/Tree Parts	25,678	454,502
	Grass Clippings	2,035	31,747
	Leaves	6,292	98,150
	Stumps	4,409	78,037
	Subtotal	***73,388***	***953,350***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	25,374	243,591
	Waste paper, Landfilled	93,589	1,087,277
	Other Biomass, Landfilled	71,989	752,709
	C&D (Non-recycled wood)	98,235	1,112,808
	Recycled Products		
	Food Waste	1,534	24,540
	Wood Scraps	11,780	104,254
	Corrugated	115,498	0
	Mixed Office Paper	26,848	0
	Newspaper	23,087	0
	Other Paper/Mag/JunkMail	18,387	267,011
	Subtotal	***486,320***	***3,592,189***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	3,491	0
	Oils - Used cooking oil "yellow"	3,029	
	Oils - Grease trap waste "brown"	362	
	Subtotal	***6,882***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	146	432
	Dairy Cows	30	262
	Equine	1,885	16,700
	Sheep	64	188
	Goats	84	248
	Swine	114	839
	Poultry (layers)	20	235
	Turkeys	6	90
	Wastewater treatment plant biosolids	40,304	483,644
	Subtotal (other wastes - solid)	***42,651***	***502,637***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	435	269,123
	Landfill Gas	786	397,648
	Subtotal (other wastes - gaseous)	***1,221***	***666,771***
	Sutotal (other waste - all)	***88,379***	***1,169,408***
	TOTAL BIOMASS	**664,482**	

Appendix I: Monmouth County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	746	NA
	Rye	1,653	NA
	Corn for Grain	5,849	NA
	Wheat	1,181	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***9,428***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	320	4,033
	Rye	5,946	0
	Corn for Grain	4,594	61,435
	Corn for Silage	1,131	13,342
	Alfalfa Hay	4,967	0
	Other Hay	4,620	36,033
	Wheat	1,084	0
	Forestry Residues	39,486	307,987
	Processing Residues (lignocellulosic)	8	136
	Yard waste		
	Brush/Tree Parts	30,612	541,831
	Grass Clippings	31	482
	Leaves	30,994	483,510
	Stumps	1,490	26,374
	Subtotal	***125,283***	***1,475,163***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	20,396	195,799
	Waste paper, Landfilled	75,227	873,955
	Other Biomass, Landfilled	57,865	605,028
	C&D (Non-recycled wood)	60,214	682,105
	Recycled Products		
	Food Waste	637	10,192
	Wood Scraps	13,349	118,141
	Corrugated	44,155	0
	Mixed Office Paper	14,193	0
	Newspaper	17,430	0
	Other Paper/Mag/JunkMail	10,213	148,309
	Subtotal	***313,679***	***2,633,529***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	4,921	0
	Oils - Used cooking oil "yellow"	2,358	
	Oils - Grease trap waste "brown"	282	
	Subtotal	***7,561***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	821	2,425
	Dairy Cows	58	510
	Equine	25,546	226,293
	Sheep	226	666
	Goats	324	956
	Swine	38	282
	Poultry (layers)	1,418	17,018
	Turkeys	316	4,667
	Wastewater treatment plant biosolids	7,740	92,877
	Subtotal (other wastes - solid)	***36,486***	***345,693***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	175	108,434
	Landfill Gas	222	112,459
	Subtotal (other wastes - gaseous)	***397***	***220,893***
	Sutotal (other waste - all)	***51,189***	***566,586***
	TOTAL BIOMASS	**507,140**	

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Appendix I: Morris County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	0	NA
	Rye	102	NA
	Corn for Grain	3,122	NA
	Wheat	73	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***3,297***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	349	4,397
	Rye	398	0
	Corn for Grain	1,896	25,347
	Corn for Silage	1,435	16,932
	Alfalfa Hay	2,698	0
	Other Hay	4,464	34,816
	Wheat	67	0
	Forestry Residues	66,066	515,315
	Processing Residues (lignocellulosic)	479	7,832
	Yard waste		
	Brush/Tree Parts	12,408	219,620
	Grass Clippings	4,115	64,196
	Leaves	17,198	268,283
	Stumps	1,679	29,713
	Subtotal	***113,251***	***1,186,449***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	13,442	129,038
	Waste paper, Landfilled	49,577	575,968
	Other Biomass, Landfilled	38,135	398,736
	C&D (Non-recycled wood)	46,903	531,314
	Recycled Products		
	Food Waste	915	14,635
	Wood Scraps	3,166	28,017
	Corrugated	55,764	0
	Mixed Office Paper	13,187	0
	Newspaper	16,772	0
	Other Paper/Mag/JunkMail	11,674	169,526
	Subtotal	***249,535***	***1,847,235***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	233	0
	Oils - Used cooking oil "yellow"	1,841	
	Oils - Grease trap waste "brown"	220	
	Subtotal	***2,295***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	577	1,703
	Dairy Cows	283	2,508
	Equine	4,835	42,834
	Sheep	401	1,183
	Goats	176	520
	Swine	30	218
	Poultry (layers)	37	448
	Turkeys	331	4,884
	Wastewater treatment plant biosolids	10,761	129,129
	Subtotal (other wastes - solid)	***17,431***	***183,428***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	147	90,812
	Landfill Gas	447	226,119
	Subtotal (other wastes - gaseous)	***594***	***316,931***
	Sutotal (other waste - all)	***40,024***	***500,359***
	TOTAL BIOMASS	**408,401**	

Appendix I: Ocean County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	128	NA
	Rye	206	NA
	Corn for Grain	592	NA
	Wheat	81	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***1,007***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	53	663
	Rye	943	0
	Corn for Grain	359	4,802
	Corn for Silage	901	10,633
	Alfalfa Hay	424	0
	Other Hay	863	6,729
	Wheat	74	0
	Forestry Residues	111,710	871,338
	Processing Residues (lignocellulosic)	1	13
	Yard waste		
	Brush/Tree Parts	19,954	353,194
	Grass Clippings	186	2,897
	Leaves	15,754	245,758
	Stumps	6,851	121,271
	Subtotal	***158,073***	***1,617,298***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	18,585	178,411
	Waste paper, Landfilled	68,547	796,347
	Other Biomass, Landfilled	52,727	551,301
	C&D (Non-recycled wood)	52,131	590,535
	Recycled Products		
	Food Waste	811	12,971
	Wood Scraps	6,459	57,166
	Corrugated	49,935	0
	Mixed Office Paper	6,351	0
	Newspaper	20,557	0
	Other Paper/Mag/JunkMail	7,818	113,528
	Subtotal	***283,919***	***2,300,260***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	260	0
	Oils - Used cooking oil "yellow"	2,156	
	Oils - Grease trap waste "brown"	258	
	Subtotal	***2,675***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	225	666
	Dairy Cows	1,794	15,888
	Equine	2,606	23,081
	Sheep	37	109
	Goats	54	160
	Swine	37	275
	Poultry (layers)	46	555
	Turkeys	3	37
	Wastewater treatment plant biosolids	3	36
	Subtotal (other wastes - solid)	***4,805***	***40,807***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	179	110,506
	Landfill Gas	911	460,898
	Subtotal (other wastes - gaseous)	***1,089***	***571,404***
	Sutotal (other waste - all)	***46,770***	***612,211***
	TOTAL BIOMASS	492,444	

Appendix I: Passaic County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	0	NA
	Rye	0	NA
	Corn for Grain	4	NA
	Wheat	0	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***4***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	15	193
	Rye	2	0
	Corn for Grain	0	0
	Corn for Silage	0	0
	Alfalfa Hay	19	0
	Other Hay	52	406
	Wheat	0	0
	Forestry Residues	35,198	274,544
	Processing Residues (lignocellulosic)	207	3,377
	Yard waste		
	Brush/Tree Parts	8,909	157,682
	Grass Clippings	3,918	61,125
	Leaves	9,043	141,063
	Stumps	607	10,739
	Subtotal	***57,969***	***649,129***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	15,943	153,052
	Waste paper, Landfilled	58,803	683,153
	Other Biomass, Landfilled	45,232	472,938
	C&D (Non-recycled wood)	46,260	524,028
	Recycled Products		
	Food Waste	3,071	49,130
	Wood Scraps	3,144	27,827
	Corrugated	56,671	0
	Mixed Office Paper	13,529	0
	Newspaper	19,031	0
	Other Paper/Mag/JunkMail	8,602	124,922
	Subtotal	***270,286***	***2,035,050***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	0	0
	Oils - Used cooking oil "yellow"	1,875	
	Oils - Grease trap waste "brown"	224	
	Subtotal	***2,099***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	20	60
	Dairy Cows	49	432
	Equine	1,472	13,037
	Sheep	11	33
	Goats	25	73
	Swine	7	54
	Poultry (layers)	9	107
	Turkeys	3	37
	Wastewater treatment plant biosolids	1,749	20,990
	Subtotal (other wastes - solid)	***3,344***	***34,822***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	28	17,514
	Landfill Gas	0	0
	Subtotal (other wastes - gaseous)	***28***	***17,514***
	Sutotal (other waste - all)	***4,304***	***52,336***
	TOTAL BIOMASS	**334,662**	

Appendix I: Salem County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	2,278	NA
	Rye	521	NA
	Corn for Grain	48,797	NA
	Wheat	11,674	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***63,270***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	745	9,382
	Rye	2,006	0
	Corn for Grain	29,627	396,175
	Corn for Silage	14,913	175,953
	Alfalfa Hay	11,952	0
	Other Hay	11,996	93,572
	Wheat	10,921	0
	Forestry Residues	32,043	249,935
	Processing Residues (lignocellulosic)	194	3,169
	Yard waste		
	Brush/Tree Parts	3,307	58,538
	Grass Clippings	143	2,236
	Leaves	612	9,549
	Stumps	66	1,160
	Subtotal	***118,525***	***999,668***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	1,900	18,243
	Waste paper, Landfilled	7,009	81,428
	Other Biomass, Landfilled	5,391	56,372
	C&D (Non-recycled wood)	17,727	200,808
	Recycled Products		
	Food Waste	5	74
	Wood Scraps	589	5,215
	Corrugated	3,808	0
	Mixed Office Paper	671	0
	Newspaper	1,545	0
	Other Paper/Mag/JunkMail	888	12,898
	Subtotal	***39,534***	***375,037***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	20,320	0
	Oils - Used cooking oil "yellow"	247	
	Oils - Grease trap waste "brown"	30	
	Subtotal	***20,597***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	3,662	10,812
	Dairy Cows	11,581	102,588
	Equine	7,220	63,962
	Sheep	191	565
	Goats	228	673
	Swine	78	579
	Poultry (layers)	43	512
	Turkeys	2	31
	Wastewater treatment plant biosolids	293	3,515
	Subtotal (other wastes - solid)	***23,298***	***183,237***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	0	0
	Landfill Gas	309	156,426
	Subtotal (other wastes - gaseous)	***309***	***156,426***
	Sutotal (other waste - all)	***35,486***	***339,663***
	TOTAL BIOMASS	277,413	

Appendix I: Somerset County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	192	NA
	Rye	450	NA
	Corn for Grain	5,527	NA
	Wheat	1,920	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***8,088***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	19	235
	Rye	1,180	0
	Corn for Grain	3,355	44,869
	Corn for Silage	1,693	19,979
	Alfalfa Hay	4,910	0
	Other Hay	12,537	97,787
	Wheat	1,659	0
	Forestry Residues	17,952	140,026
	Processing Residues (lignocellulosic)	11	187
	Yard waste		
	Brush/Tree Parts	4,519	79,994
	Grass Clippings	205	3,202
	Leaves	2,692	42,001
	Stumps	266	4,714
	Subtotal	***50,999***	***432,995***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	9,471	90,924
	Waste paper, Landfilled	34,934	405,845
	Other Biomass, Landfilled	26,871	280,962
	C&D (Non-recycled wood)	1,797	20,354
	Recycled Products		
	Food Waste	216	3,448
	Wood Scraps	4,694	41,544
	Corrugated	18,564	0
	Mixed Office Paper	3,352	0
	Newspaper	15,975	0
	Other Paper/Mag/JunkMail	3,472	50,417
	Subtotal	***119,346***	***893,494***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	1,092	0
	Oils - Used cooking oil "yellow"	1,210	
	Oils - Grease trap waste "brown"	145	
	Subtotal	***2,447***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	1,718	5,072
	Dairy Cows	370	3,281
	Equine	4,791	42,438
	Sheep	245	723
	Goats	228	673
	Swine	72	535
	Poultry (layers)	1,151	13,815
	Turkeys	111	1,634
	Wastewater treatment plant biosolids	5,931	71,169
	Subtotal (other wastes - solid)	***14,616***	***139,339***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	70	43,031
	Landfill Gas	0	0
	Subtotal (other wastes - gaseous)	***70***	***43,031***
	Sutotal (other waste - all)	***16,974***	***182,370***
	TOTAL BIOMASS	197,855	

Appendix I: Sussex County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	146	NA
	Rye	130	NA
	Corn for Grain	9,058	NA
	Wheat	79	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***9,414***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	279	3,509
	Rye	486	0
	Corn for Grain	5,500	73,540
	Corn for Silage	13,891	163,898
	Alfalfa Hay	15,382	0
	Other Hay	21,480	167,543
	Wheat	73	0
	Forestry Residues	89,546	698,459
	Processing Residues (lignocellulosic)	48	785
	Yard waste		
	Brush/Tree Parts	2,214	39,192
	Grass Clippings	49	766
	Leaves	817	12,752
	Stumps	1,317	23,305
	Subtotal	***151,081***	***1,183,749***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	3,574	34,310
	Waste paper, Landfilled	13,182	153,145
	Other Biomass, Landfilled	10,140	106,020
	C&D (Non-recycled wood)	13,595	154,006
	Recycled Products		
	Food Waste	226	3,621
	Wood Scraps	662	5,855
	Corrugated	7,276	0
	Mixed Office Paper	1,778	0
	Newspaper	3,881	0
	Other Paper/Mag/JunkMail	1,789	25,974
	Subtotal	***56,102***	***482,931***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	35	0
	Oils - Used cooking oil "yellow"	558	
	Oils - Grease trap waste "brown"	67	
	Subtotal	***660***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	3,144	9,283
	Dairy Cows	12,125	107,409
	Equine	10,950	96,996
	Sheep	431	1,272
	Goats	316	933
	Swine	80	589
	Poultry (layers)	132	1,580
	Turkeys	24	348
	Wastewater treatment plant biosolids	210	2,520
	Subtotal (other wastes - solid)	***27,411***	***220,931***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	0	0
	Landfill Gas	18	8,989
	Subtotal (other wastes - gaseous)	***18***	***8,989***
	Sutotal (other waste - all)	***28,111***	***229,920***
	TOTAL BIOMASS	**245,367**	

Appendix I: Union County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	0	NA
	Rye	0	NA
	Corn for Grain	0	NA
	Wheat	0	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***0***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	1	11
	Rye	4	0
	Corn for Grain	0	0
	Corn for Silage	0	0
	Alfalfa Hay	0	0
	Other Hay	0	0
	Wheat	0	0
	Forestry Residues	0	0
	Processing Residues (lignocellulosic)	6,591	107,669
	Yard waste		
	Brush/Tree Parts	11,171	197,719
	Grass Clippings	3,864	60,275
	Leaves	14,198	221,494
	Stumps	194	3,439
	Subtotal	***36,023***	***590,606***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	1,356	13,014
	Waste paper, Landfilled	5,000	58,088
	Other Biomass, Landfilled	3,846	40,213
	C&D (Non-recycled wood)	58,380	661,330
	Recycled Products		
	Food Waste	1,239	19,829
	Wood Scraps	2,479	21,941
	Corrugated	21,050	0
	Mixed Office Paper	5,025	0
	Newspaper	10,996	0
	Other Paper/Mag/JunkMail	2,810	40,809
	Subtotal	***112,181***	***855,223***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	0	0
	Oils - Used cooking oil "yellow"	2,007	
	Oils - Grease trap waste "brown"	240	
	Subtotal	***2,247***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	0	0
	Dairy Cows	0	0
	Equine	7	61
	Sheep	0	0
	Goats	0	0
	Swine	0	0
	Poultry (layers)	0	0
	Turkeys	0	0
	Wastewater treatment plant biosolids	1,085	13,017
	Subtotal (other wastes - solid)	***1,092***	***13,078***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	365	225,854
	Landfill Gas	0	0
	Subtotal (other wastes - gaseous)	***365***	***225,854***
	Sutotal (other waste - all)	***13,466***	***238,933***
	TOTAL BIOMASS	**163,916**	

Appendix I: Warren County Data

FEEDSTOCK CATEGORIES	FEEDSTOCKS	Current Gross Quantity (Dry Tons)	Current Net Energy Available (MMBtu)
SUGARS/STARCHES	Energy crops - starch/sugar based		
	Sorghum	585	NA
	Rye	100	NA
	Corn for Grain	48,888	NA
	Wheat	1,806	NA
	Processing Residues (waste sugars)		NA
	Subtotal	***51,380***	***0***
LIGNOCELLULOSIC BIOMASS	Energy crops - lignocellulosic	0	0
	Agricultual crop residuals		
	Sweet Corn	283	3,562
	Rye	555	0
	Corn for Grain	29,682	396,914
	Corn for Silage	13,018	153,603
	Alfalfa Hay	11,231	0
	Other Hay	17,015	132,716
	Wheat	1,659	0
	Forestry Residues	53,840	419,948
	Processing Residues (lignocellulosic)	7,931	129,557
	Yard waste		
	Brush/Tree Parts	3,456	61,179
	Grass Clippings	275	4,286
	Leaves	754	11,760
	Stumps	60	1,054
	Subtotal	***139,757***	***1,314,579***
SOLID WASTES	Solid wastes - Landfilled		
	Food waste, Landfilled	709	6,806
	Waste paper, Landfilled	2,615	30,377
	Other Biomass, Landfilled	2,011	21,030
	C&D (Non-recycled wood)	9,481	107,400
	Recycled Products		
	Food Waste	555	8,873
	Wood Scraps	703	6,226
	Corrugated	5,836	0
	Mixed Office Paper	680	0
	Newspaper	1,733	0
	Other Paper/Mag/JunkMail	1,786	25,938
	Subtotal	***26,109***	***206,650***
BIO-OILS	Oils - field crop or virgin		
	Soybeans	4,508	0
	Oils - Used cooking oil "yellow"	407	
	Oils - Grease trap waste "brown"	49	
	Subtotal	***4,963***	***0***
OTHER WASTES	Agricultural livestock waste		
	Beef Cattle	2,908	8,588
	Dairy Cows	13,416	118,847
	Equine	6,517	57,733
	Sheep	430	1,268
	Goats	284	837
	Swine	288	2,128
	Poultry (layers)	9,464	113,574
	Turkeys	0	0
	Wastewater treatment plant biosolids	156	1,873
	Subtotal (other wastes - solid)	***33,464***	***304,848***
	Waste Methane Sources	**MMSCF**	
	Wastewater treatment plant biogas	8	4,865
	Landfill Gas	94	47,378
	Subtotal (other wastes - gaseous)	***101***	***52,243***
	Sutotal (other waste - all)	***37,422***	***357,092***
	TOTAL BIOMASS	**259,631**	

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Appendix II- Example GHG Emission Calculations

Landfill Gas to Power CO_2 Calculations:

Electricity Generation Potential (EGP) equation
EGP =
C5*1000000*(506/3412)*0.2916239/1000
1000000 - conversion from mmscf to scf
(multiply)
(506/3412) - conversion of the energy content of LFG (assumed to be 506 Btu/scf) to kWh/scf by dividing by 3412 Btu/kWh (multiply)
0.2916239 - weighted average efficiency for engines, gas turbines, and boiler/steam turbines[1] (attained by dividing 3412 Btu/kWh by the given 11,700 Btu/kWh) (multiply)
1000 - conversion kWh to MWh (divide)

Potential CO_2 Produced: EPA (CO2EPA) equation*
CO2EPA = C5*0.9*1000000*0.5*(1012/1050)*0.12059/2000
0.9 - gross capacity factor (multiply)
1000000 - conversion from mmscf to scf (multiply)
0.5 - fraction of methane in scf of LFG in scf (multiply)
(1012/1050) - energy content ratio between methane (1012 Btu/scf) and natural gas (1050 Btu/scf) (multiply)
0.12059 - pounds of carbon dioxide per scf of natural gas (multiply)
2000 - converting lbs to tons (divide)