



**RENEWABLE FUELS ROADMAP  
AND SUSTAINABLE BIOMASS  
FEEDSTOCK SUPPLY FOR NEW YORK**

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**NEW YORK STATE  
ENERGY RESEARCH AND  
DEVELOPMENT AUTHORITY**





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# **RENEWABLE FUELS ROADMAP AND SUSTAINABLE BIOMASS FEEDSTOCK SUPPLY FOR NEW YORK**

Final Report

Prepared for the  
**NEW YORK STATE  
ENERGY RESEARCH AND  
DEVELOPMENT AUTHORITY**

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## **ABSTRACT**

The need for a Renewable Fuels Roadmap was identified in the February 2008 Report of the Governor's Renewable Energy Task Force, which called for a Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply Study for New York (Roadmap). The Roadmap assesses the prospects for the expansion of biofuel production in New York State, focusing on resource availability and economic and environmental impacts. In addition, the Roadmap solicited input from New York stakeholders to identify the most important social, economic and environmental issues to make a renewable fuels industry socially, economically, and environmentally sustainable in the State. Assigned with the task of looking into the future for impacts from an industry that almost entirely does not exist at this writing, the Roadmap Team devised and implemented three scenario analyses. The scenario analyses were coordinated using an integrated set of computer models based on the best available data, combined with a set of expert judgments and assumptions where quantitative data were not available. These integrated computer models collectively provide feedstock, energy, economic, and environmental analyses of the three Roadmap scenarios. The Roadmap presents possibilities, identifies potential challenges, and outlines important technology and policy options that may be used to ensure that any expansion of a renewable fuels industry serves the social, economic and environmental goals for New York.

## **KEY WORDS**

Biodiesel  
Biofuels  
Cellulosic ethanol  
Competing uses  
Conversion technology  
Feedstock  
Greenhouse gas emissions  
Life cycle analysis  
Renewable energy  
Sustainability  
Transportation fuels

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**RENEWABLE FUELS ROADMAP**

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## *EXECUTIVE SUMMARY*

### 1 PURPOSE OF STUDY

The February 2008 Report of the Governor’s Renewable Energy Task Force identified the need for a Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply Study for New York (Roadmap). In response, the New York Energy Research and Development Authority (NYSERDA), in collaboration with the New York State Department of Agriculture and Markets and the New York State Department of Environmental Conservation (NYSDEC), jointly funded the development of the Roadmap through a competitive grant process. Pace Law School’s Energy and Climate Center (Pace) led a team of more than 40 experts in renewable fuels from academia, industry, and government in the project. A select group of advisors and public stakeholder groups was consulted and surveyed for input.

The key components identified by the Governor's Renewable Energy Task Force included an evaluation of “critical environmental, capacity, technology, efficiency, and economic issues for renewable fuels.” In particular, the Roadmap was to provide policymakers with the positive and negative impacts associated with the increased use and production of renewable fuels in the State, with particular attention to environmental issues and public health. Because the analysis was to be performed with respect to an industry that does not exist at this writing, three future industry scenarios were developed.

A goal of the Roadmap is to inform the Climate Action Council (CAC), which is currently developing a plan to assess how New York can best address climate change by examining how “all economic sectors can reduce greenhouse gas (GHG) emissions and adapt to climate change” (New York State Climate Action Council 2010). The recommendations found in New York’s 2009 State Energy Plan also rely on the Roadmap to inform how the State will “[d]etermine the optimal fuel(s) for a substantial replacement of petroleum, considering environmental, economic and energy benefits” (State Energy Planning Board 2009).

### 2 APPROACH

The Roadmap considered 11 key issues (called *Strategic Priority Tasks*) for a renewable fuels future in New York State. The 11 *Tasks* were addressed by the respective Roadmap Task Teams. The reports written by these Teams are attached as Appendices to the Roadmap:

- Stakeholder Input: Vision Document and Stakeholder Input Workshops (Appendices C and D)
- Analysis of Sustainable Feedstock Production Potential in New York State (Appendix E)
- Feedstock Transportation and Logistics (Appendix F)

- Life Cycle Analysis and Public Health Assessment of Biofuel Production, Transportation, and Use in New York State (Appendix G)
- Technologies for Biofuels Production (Appendix H)
- Biofuel Industry Economic Impacts and Analysis (Appendix I)
- Worker Training and Business Research Infrastructure for a Biofuel Industry in New York (Appendix J)
- Sustainability Criteria (Appendix K)
- Selected Future Production Pathways in New York (Appendix L)
- Policy Analysis and Inventory of Existing Relevant State and Federal Policies (Appendices M and N)
- Biofuels Markets in New York State & Integration in the Northeast Region and Competition for Biomass Resources (Appendices O and P)

### 3 STAKEHOLDER INPUT

#### 3.1 VISIONING MEETING

NYSERDA sponsored a one-day Visioning Meeting in Albany, New York on January 29, 2009. The goal of the meeting was to create a cohesive, unified vision for biofuels in New York State that could serve as a realistic, vetted guide to the development and design of the Roadmap’s future scenario analyses. A cross-section of 48 experts representing key stakeholder groups, institutional organizations, environmental organizations, and end-users of renewable fuels participated in the development of the following Vision Statement for the year 2030.

*By 2030, New York State will have a vibrant, world-class biofuels industry that*

- *Uses its highly diverse state and regional biomass feedstocks in the most sustainable manner possible;*
- *Cost-effectively and significantly reduces New York State greenhouse gas (GHG) emissions and petroleum imports while improving environmental quality;*
- *Establishes New York State as the leader in education and technology research, development, and deployment (RD&D), making ongoing contributions to enhanced sustainability and the development of fuels that are almost chemically identical to conventional fuels but are significantly cleaner to use and that release minimal CO<sub>2</sub>. (These fuels are commonly termed ‘next generation’ fuels.);*
- *Significantly contributes to economic revitalization throughout New York State, ensuring stable and secure communities; and*
- *Employs an efficient supply and distribution infrastructure to provide an economical, reliable fuel supply for all New Yorkers.*

### 3.2 STAKEHOLDER MEETINGS

Eleven workshops were held throughout the State (see Figure ES-1) to provide information to the general public and stakeholders about the Roadmap, to discuss the project’s approach, to obtain feedback, and to distribute a written Sustainability Criteria survey. There were approximately 30 participants per meeting. Participants represented the agricultural industry, forest industry, renewable fuels industry, environmental groups, local governments, State and federal research organizations, and academia. Based on workshop feedback and written comments submitted at the end of the workshops, some common themes emerged: property owner rights, food security, environment, decentralized industry structure, cost of production, need for technology improvement, new ways to integrate energy into farming, new business and technology concepts, and use of greener fuels.



**Figure ES-1. Map Showing Locations of Roadmap Stakeholder Workshops.**

### 3.3 SUSTAINABILITY CRITERIA SURVEY

Approximately 400 New Yorkers completed the sustainability criteria survey, distributed at the stakeholder workshops and through other channels. Discussing sustainability for a complex system like biofuels is complicated in that it consists of different components such as feedstock production, conversion technology, fuel distribution, and end use, with each component engaging different groups with diverse worldviews and values. Survey results underscore the need to refine and prioritize criteria for biofuel sustainability in New York and the importance of a participatory process in continuing the development of a system for monitoring, assessing and improving a biofuels industry.

Defining and measuring sustainability is difficult because it is based on many worldviews rooted in human values and is subject to many scientific uncertainties. Social norms as well as science are subject to frequent changes across time and space. Sustainability therefore needs to be understood as a process that has to be pursued and adapted over time. Biofuel sustainability criteria need to be identified, monitored

and reviewed periodically on their performance to detect trends, compare outcomes to desired conditions, and initiate modifications to the system. Applicable criteria need to be identified through a public process (norm creation), need to be science-based and quantifiable (knowledge production), and need to be relevant to biofuels. A biofuel stakeholder survey on criteria for potential biofuels sustainability yielded highly variable results across New York. Meanwhile, a range of potentially applicable biofuel sustainability criteria is already monitored independently across multiple agencies (Appendix K). Collecting baseline data and monitoring ongoing data on a range of biofuels sustainability criteria would be a good start to track biofuel sustainability in New York. Providing a means for ongoing public input on a biofuel sustainability assessment framework for New York is also valuable.

#### 4 SCENARIO ANALYSIS

In order to frame the analysis around potential biofuel industry impacts, the Roadmap conducted scenario-based analyses. In particular, the Roadmap created three possible future (~year 2020) scenarios related to an expanding biofuels industry in New York State. The three scenario analyses are not meant to provide side-by-side comparison for the “best” possible pathway to the future, but rather to allow a broad but realistic consideration of the primary issues and impacts that arise under three different possible futures, based on where the emphasis is placed. All scenarios assume that existing and planned corn grain-to-ethanol production systems in New York (totaling 154 million gallons per year [MGY]) will continue, and that new production for liquid biofuels comes predominantly from lignocellulosic to ethanol pathways.<sup>1</sup> Land use change impacts are mitigated by design of the assessment (see discussion below). It is assumed that New York forests will stay forests, and that areas in crop production will remain in agricultural production to support current agricultural industry capacity in the State. The assessment assumes no future growth of the New York dairy industry, but assumes that current dairy industry capacity remains. Additional land is brought into energy crop production in Scenarios 2 and 3 through the assumption that current trends in crop and milk production efficiency (higher yields on less land) continue, allowing today’s crop and dairy production levels to be achieved on less total land. New York transportation infrastructure (rail, roads, and waterways) are assumed to provide the same transportation system coverage and capacity in 2020 as today. Further, each scenario was evaluated under two price cases: \$3/gallon gas equivalents [gge] and \$4/gge prices.

- **Scenario 1 - “Big Step Forward”** This scenario places strong emphasis on maintaining current New York agricultural food and feed production as well as current forest production, with focus on large (average 90 MGY) biofuel production plants. For this scenario, rapid development of lignocellulosic feedstock resources is assumed on a portion of suitable and available rural lands. The available land base excludes all land currently in food production. It is assumed that first generation lignocellulosic biorefineries (biochemical and thermochemical systems) are performing

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<sup>1</sup> Biodiesel was considered, but provides a smaller contribution to overall production volumes than ethanol.

at their optimum potential. Total New York production of renewable gasoline substitutes would reach 508 MGY. Under this scenario, New York meets about 5.6% of its projected transportation gasoline consumption with home grown biofuels.

- **Scenario 2 - “Giant Leap Forward”** In this scenario, in addition to the land estimated available in Scenario 1, some cropland is used for biofuel feedstock production. This applies only to cropland estimated to become available due to increases in crop yield and milk yield per cow such that crop and milk production could be maintained at 2007 levels. Furthermore, second generation lignocellulosic biorefineries (biochemical and thermochemical systems) are assumed ready for commercial deployment. Here, large lignocellulosic biorefinery clusters (average capacity 354 MGY) exist in a centralized collection and distribution system. Total New York liquid biofuel production including grain derived ethanol would reach 1,449 MGY. In the Scenario 2 base case, New York could meet about 16% of its projected transportation gasoline consumption with home grown biofuels.
- **Scenario 3 - “Distributed Production”** This scenario envisions the same feedstock production and similar conversion technology as in Scenario 2. However, this scenario reflects a more decentralized fuel production industry with no individual biorefinery capacity exceeding 60 MGY, except for the existing grain ethanol biorefineries. Total New York liquid biofuel production including grain-derived ethanol would reach 1,449 MGY. In the Scenario 3 base case, New York could meet about 16% of its projected transportation gasoline consumption with home grown biofuels.

The three scenario analyses were coordinated using an integrated set of computer models that collectively provided feedstock, energy, economic, and environmental data. A set of coordinated assumptions that were incorporated into the scenario analyses is presented in Table ES-1.

**Table ES-1. Key Scenario Assumptions and Inputs.**

Attributes	Scenario 1	Scenario 2	Scenario 3
<i>Human Values Emphasized</i>			
Natural resources used in a sustainable manner	x	x	x
No conversion of cropland to bioenergy feedstock production	x		
Land use change effects minimized (especially food crops)		x	x
Centralized, larger scale production	x	x	
Distributed, smaller scale production as a goal			x
<i>State of Conversion Technology</i>			
Ready in near term	x		

Advanced technologies (ready in mid-term)		x	x
<b>Land Resources (million acres)</b>			
[Non-forest] land used for lignocellulosic feedstocks	0.98	1.68 <sup>a</sup>	1.68 <sup>a</sup>
<b>Biomass Feedstock Resource Inputs (Mdt)</b>			
Lignocellulosic feedstocks (at \$3 wholesale gge)	4.2	14.5	14.5
Lignocellulosic feedstocks (at \$4 wholesale gge)	9.4	14.6	14.6
Total production of corn grain, soybean, and yellow grease (current baseline) <sup>b</sup>	1.9	1.9	1.9
<b>Lignocellulosic Feedstock Types (Mdt)<sup>c</sup></b>			
Hardwood and softwood chips	4.8	6.4	6.4
Warm season grasses	2.3	4.6	4.6
Short-rotation willow	2.1	3.3	3.3
Corn stover	0.3	0.3	0.3
<b>Capacity of Existing Biorefineries in Year 2020 (MGY)</b>			
Two grain ethanol plants (current nameplate capacity)	154	154	154
Biodiesel production (\$4 wholesale gge case)	30	30	30
<b>New Biorefineries and Feedstock Sheds</b>			
Number of lignocellulosic feedstock sheds	4	4	4
Number of lignocellulosic biorefineries	4	12	22-24
Average lignocellulosic biorefinery unit capacity (MGY)	90	354	60
Total state production capacity ethanol (MGY)	508	1,449	1,449
Percentage of New York gasoline consumption in 2020	5.6 %	16%	16%
<b>Economic Factors</b>			
Investment capital from investors	60%	60%	50%
<b>Transportation Factors</b>			
Average distance fuel is transported to blending terminals (miles)	28.1	27.0	24.5

<sup>a</sup> Additional land becomes available due to increased crop and milk yields such that the same amount of crops and milk can be produced as in 2007, but on less land, freeing some current crop land for production of lignocellulosic feedstocks.

<sup>b</sup> Corn grain and soy are measured in dry tons. Yellow grease is measured in tons.

<sup>c</sup> Scenario 1 lignocellulosic feedstock type production levels correspond to \$4 wholesale gge.

<sup>d</sup> Percentage of total biorefinery capital costs that are supplied by private investment.

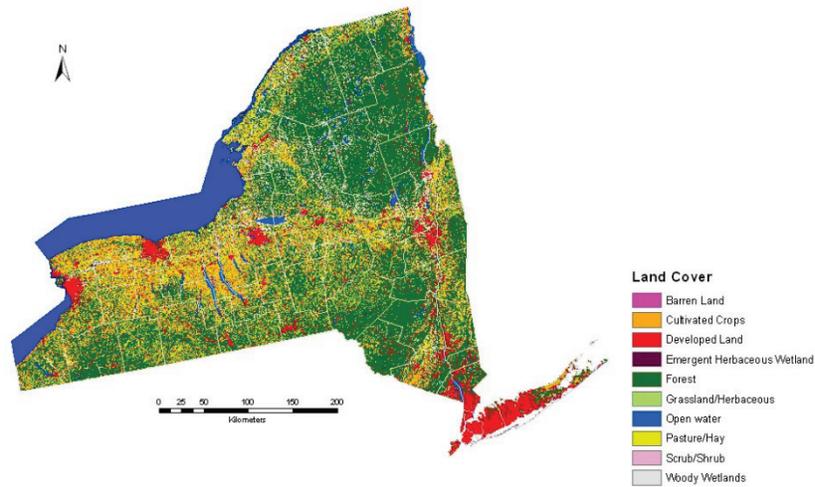
## 5 EXISTING CONDITIONS

An analysis of New York's ability to play a role in the renewable fuels industry began with an assessment of current resources and conditions, including how the land is currently being used in the State; the amount of biomass on those lands; how that biomass is currently being used; the current road, rail and waterway

transport systems that might serve a biofuels production industry; the current and potential competing uses of biomass by State and regional markets; and the current status of biomass-to-liquid fuel conversion technologies.

## 5.1 LAND AVAILABILITY AND BIOMASS CAPACITY

The analysis of current land cover shows that forests cover more than half of the State, and nearly 25% of the State is in agricultural land cover, primarily hay and pastureland (see Figure ES-2). There is the potential for between one million and 1.68 million acres of non-forest land to be used for bioenergy feedstock production in New York. Of the State's forest lands, there are almost 18.5 million acres, of which nearly 15.8 million acres is producing or is capable of producing woody biomass (excluding areas in the State such as the forest preserves in the Adirondacks and Catskills where harvesting is restricted).



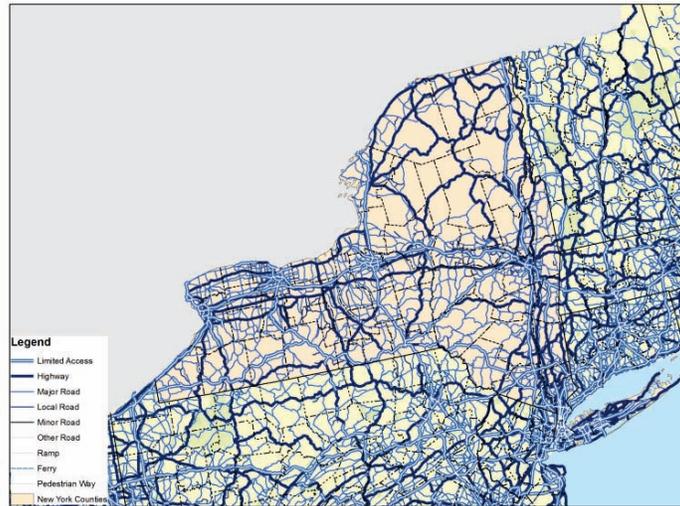
**Figure ES-2. Land Cover in New York State.**

The biomass assessment estimated that the New York agricultural industry currently produces approximately 12 million dry tons annually (Mdt/year) of biomass and New York forests grow at a rate that produces another 9.5 Mdt/year of biomass. Much of this biomass is already being used by other industries. The current forest products industry uses 2.5 Mdt/year. Corn provides the greatest amount of biomass from a single agricultural crop in the State (60%) and much of this is used by the New York dairy industry.

## 5.2 TRANSPORT

The capacity and condition of transport modes (truck, train, and barge) and New York's existing transportation and distribution (T&D) network will have a bearing on the development of the biofuels industry in the short term. The road network is the most extensive transportation system connecting feedstocks, processing facilities, blending facilities, and distribution facilities with end users. The New York road network consists of ~115,000 miles of road. Figure ES-3 shows that the highway network in the

State extends into all feedstock counties in the State. In contrast, the State waterway and rail networks (Figures ES-4 and ES-5, respectively) do not reach into several northeastern and southwestern counties in the State where potential feedstock production is plentiful, so in many cases truck transportation is the only currently existing option for feedstock transport. Nevertheless, there may be opportunities for a New York biofuel industry to take advantage of railway and waterway networks.



**Figure ES-3. Map of New York State Highway Networks**



**Figure ES-4 Map of New York State Waterways**



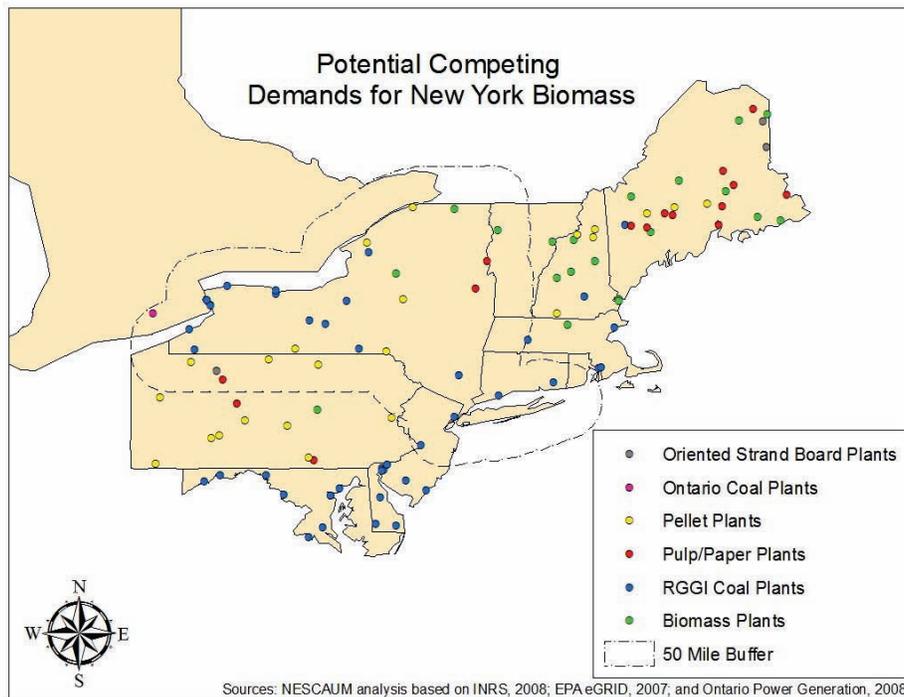
**Figure ES-5. Map of New York State Railways**

### 5.3 COMPETING USES

An analysis of competing uses for biomass resources focused on woody biomass, a key input to both existing and future users of biomass. Figure ES-6 displays existing facilities in and near New York that are

either current users of New York’s woody biomass resources (biomass electricity plants, pulp/paper plants, pellet plants, sawmills and manufacturing board plants) or are candidates for using New York biomass in the future (new wood pellet facilities, coal-fired power plants regulated under the Regional Greenhouse Gas Initiative (RGGI),<sup>2</sup> nearby Canadian coal-fired power plants that will convert to biomass co-firing as part of Ontario’s GHG-reduction action plan, and plants that choose to participate in New York’s Renewable Portfolio Standard by co-firing with biomass). A considerable potential exists for biomass needs associated with all of the RGGI coal plants in New York<sup>3</sup> and in surrounding states.

**Figure ES-6. Potential Competing Demands for New York’s Woody Biomass from Electric and Thermal Users. (Sawmills and firewood producers not shown.)**



Another probable growth area for New York biomass demand is for producing heating fuels. New York’s production of firewood, a traditional wood heating fuel, is estimated to be more than 60% of industrial needs and a relatively steady and significant use of wood. Wood pellets, used extensively in Europe for many years, are a relatively new type of heating fuel in the U.S., and pellet stoves are gaining popularity as an alternative to oil heating in the Northeast. Because the region’s heavy dependence on oil as a heating fuel exposes consumers to the volatility of prices for a commodity the cost of which is controlled by global

<sup>2</sup> RGGI is a regulatory initiative of ten Northeast and Mid-Atlantic States of the U.S. whose goal is to achieve a 10% reduction in GHG emissions from electric generation by 2018.

<sup>3</sup> The definition of eligible biomass as it pertains to sustainable harvesting will affect the likelihood of New York’s 12 coal-fired RGGI plants to co-fire with woody biomass. Guidance on this matter in New York is under development by the NYSDEC. To ensure RGGI facilities are achieving CO<sub>2</sub> reduction benefits, NYSDEC’s preliminary guidance includes requirements that could substantially limit the quantity of woody biomass used as a CO<sub>2</sub> compliance mechanism for co-firing in New York’s RGGI facilities.

markets, wood is increasingly seen as an option that increases the Northeast's energy security, though air emissions from wood combustion must be considered.

#### 5.4 CONVERSION TECHNOLOGIES

Fifteen current technologies were evaluated for converting solid biomass to liquid fuels. The Roadmap summarized process descriptions, current development status, and estimated economic and performance attributes for the year 2020. Only three of the technologies described are currently in commercial use, all based on grain-to-ethanol processes (for example, corn and sugar cane). Lignocellulosic material (such as wood or perennial grasses) generally requires a greater degree of pretreatment in preparation for the conversion process. Lignocellulosic technologies may be moving beyond the pilot phase into the demonstration stage ("near-term" technologies), or may be expected to move into the demonstration phase around the 2015 to 2025 period ("advanced" technologies). Biomass conversion processes require water, the amount of which varies depending on the technology. Biogas was not evaluated in the Roadmap.

## 6 SCENARIO ANALYSIS FINDINGS

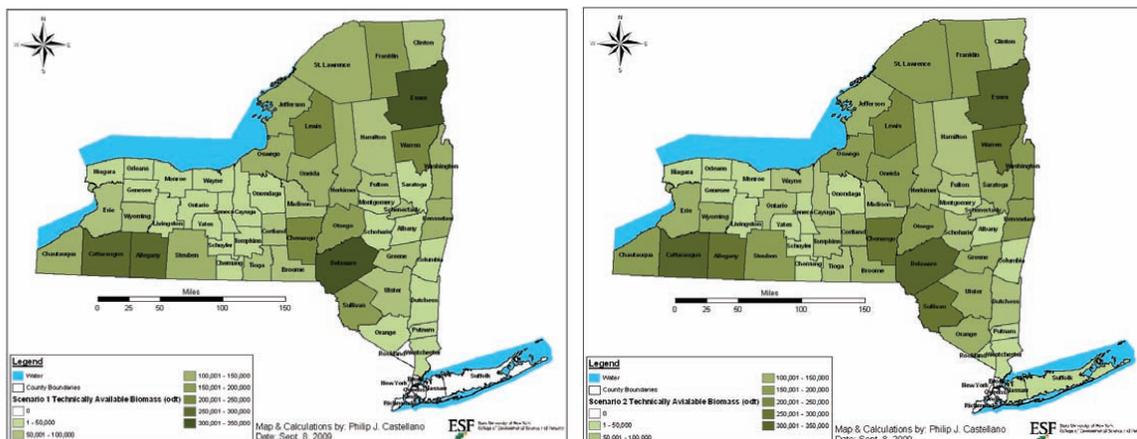
Table ES-3 summarizes key findings from the Roadmap scenario analysis. A discussion of the findings follows.

### 6.1 NEW YORK BIOMASS CAPACITY

New York State could produce enough biomass to support a lignocellulosic ethanol industry. The Roadmap finds that New York could sustainably produce between 4.2 - 14.6 million dry tons of cellulosic biomass per year (which includes 6.4 Mdt from forests) (see Figures ES-7 and ES-8). Assuming that the technological barriers to commercial scale production of lignocellulosic ethanol are overcome by the year 2020, the total State capacity for lignocellulosic ethanol is estimated to be between 508 and 1,449 million gallons, representing 5.6% to 16%, respectively, of projected 2020 gasoline consumption in New York State. This estimate makes an assumption that all of the sustainably available biomass in New York is sold for lignocellulosic ethanol production.<sup>4</sup> In reality, there will be competing uses and competing markets for that biomass (such as heating and electricity). The upper end of this range is intended as an estimate of the "upper boundary" of feasible and sustainable New York biomass and biofuel production. Achieving this level of annual production would require substantial investments in R&D and very rapid deployment that may be difficult to achieve by 2020 or even 2030.

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<sup>4</sup> These estimates are in addition to current agriculture and forest production volumes.



**Figures ES 7 and ES 8. Potentially available woody biomass from timberland in each county in New York for Scenario 1 (on left) and Scenarios 2 and 3 (on right).**

## 6.2 DIRECT AND INDIRECT LAND USE CHANGE

Growing dedicated biofuels feedstocks may result in both direct and indirect land use change. Direct land use change refers to the change in the use of a parcel of land from one type, such as forest, to another type, such as farming of perennial bioenergy feedstocks. Indirect land use change (iLUC) refers to the indirect impacts that occur due to market changes. Using corn grain for bioenergy instead of feed, for example, may indirectly cause other land to be planted in corn to meet the demand for corn. Similarly, legislated preservation of forested areas that were previously harvested may create a need for wood products that must be met elsewhere in the world. Such indirect changes can occur locally, regionally, or globally, but much of the controversy about iLUC involves shifts of production from one country to another. Such changes in land use may cause large emissions of GHG, especially if forests are cleared by burning, which releases most of the stored CO<sub>2</sub> into the atmosphere. Changes can also occur in soil carbon, especially if lands that were not previously cultivated are plowed, causing a substantial release of stored soil carbon to the atmosphere. Indirect land use change is a complex and controversial topic with respect to biofuels, and is currently centered around carbon/GHG emissions accounting.

The scientific debate connecting iLUC to biofuels has received increased attention since 2008 when research papers were published in the journal *Science* connecting increased demand for corn used for biofuel production with global, indirect land use changes in rainforests, peat lands, savannas and grasslands, thereby resulting in an increase of global carbon/GHG emissions when these specific lands are converted to meet food and feed demand. (Fargione et al. 2008; Searchinger et al. 2008). Criticism of the two studies states that neither paper provides any data correlating increased U.S. grain ethanol production to global land use change. Some view the papers as highly speculative scenarios with several flawed assumptions (Wang 2008, Dale 2008). While such iLUC effects are possible, and may be significant in

scale, it is very difficult to accurately quantify the degree to which land use change in one country causes specific changes in land use in another country because there are multiple causes of land use change (Liska and Perrin 2009). The point made by this debate is that the studies and responses demonstrate *indirect* land use change to be much more difficult to model than *direct* land use change and that new, more adequate global models are urgently needed so that biofuels policy is not misguided.

As discussed here and in Section 4 and Appendix E, incorporating iLUC emissions into life cycle GHG analysis is challenging. The EPA has recently issued regulations implementing the second renewable fuel standard, known as RFS2, as required under the Energy Independence and Security Act of 2007 (EISA). Under RFS2, four renewable fuel categories are created, and the EPA must develop life cycle GHG emission thresholds that each type of fuel must meet in order to qualify under the RFS. Notably, these life cycle emissions must include significant emissions from iLUC. In recognition of the fact that the science behind assessing GHG emissions, especially those from iLUC, is ever-changing,<sup>5</sup> the EPA will be updating its methods as appropriate. California's low carbon fuel standard (LCFS) requires the incorporation of iLUC emissions into life cycle analyses as well because the California Air Resources Board (CARB) concluded that these impacts are significant enough to be included. In order to address iLUC concerns and other technical issues, CARB created an Expert Workgroup comprising various experts that will meet publicly to develop policy recommendations on these matters (California Air Resources Board 2009). CARB will also continue working with universities to ensure that their methodologies are accurate and up-to-date. In light of the ongoing debate and research surrounding the area of iLUC emissions, the Roadmap team will continue to follow this issue and update its findings as appropriate during its annual updates.

Without adequate global models for iLUC at this writing, the impacts of New York-specific iLUC are very difficult to quantify, and it was not feasible to conduct the required global scale analysis to attempt to quantify such findings. However, the Roadmap analysis was conducted so as to greatly reduce the likelihood of iLUC impacts from each of the three Roadmap Scenarios. Specifically, for each of the three Roadmap Scenarios, total food, feed, and forest production in 2007 was maintained even as production of feedstock for biofuels increases.

By maintaining current levels of agricultural and forest production, the need to use new additional land outside New York State to meet the State's needs was avoided or substantially mitigated. There were differences, however, among the three scenarios in how much land use change was allowed. In all Scenarios, forest land producing wood products is maintained. In Scenario 1, all lands currently in food and feed production remain in food and feed production. In Scenarios 2 and 3, agricultural production is

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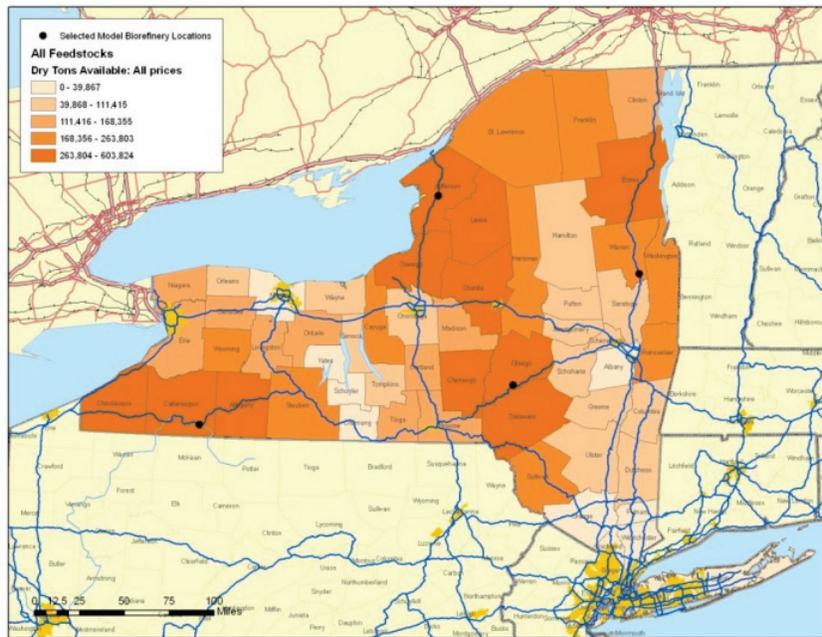
<sup>5</sup> A recent study combines ecological data with a global economic commodity and trade model to project the effects of U.S. corn ethanol production on CO<sub>2</sub> emissions resulting from land-use changes in 18 regions across the globe. This analysis adapts the model developed by Searchinger et al., and incorporates changes which may lessen land-use conversion impacts. Although the results are approximately a quarter of the Searchinger estimates of GHG releases attributable to iLUC, the authors conclude that these indirect, market-mediated effects on GHG emissions are enough to cancel out the benefits corn ethanol has on global warming, thereby limiting its potential contribution in the context of California's LCFS (Hertel et al. 2010).

maintained at current levels, but it is assumed that some additional land will become available due to increased crop yield and milk yield per cow. That is, in Scenarios 2 and 3 the same amount of food is produced on less land than was needed in 2007, due to projected increases in crop yields and milk yields per cow. Specifically, 27% of cropland and 6% of hay land becomes available in Scenarios 2 and 3.

It should be noted that in recent decades, New York State has not usually produced enough grain to meet the needs of livestock in the State, not to mention the food needs of the people of the State. Additionally, population growth or decline in the State and any other changes in food or feed demand were not modeled. If greater amounts of food or feed are desired due to human population increases or changes in diet, additional land could, of course, be required to meet those needs either from within New York State or outside it.

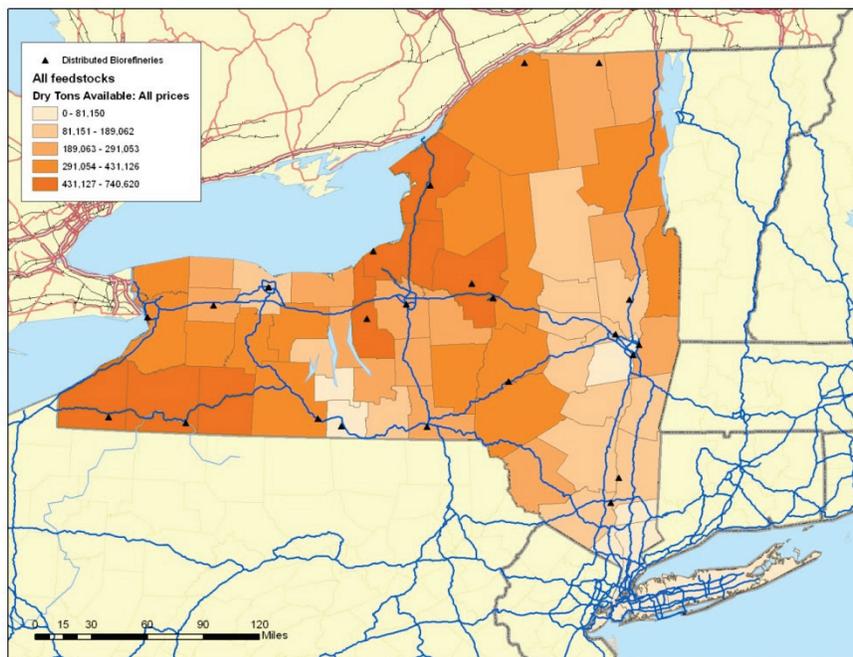
### 6.3 PRODUCTION CAPACITY

The number of lignocellulosic biorefineries that could be profitably built changes according to Scenario inputs. In Scenario 1, four biorefineries could produce ethanol at a total State-wide production capacity of 354 MGY of lignocellulosic ethanol. The four sites selected by the National Biorefinery Siting Model (NBSM) place the biorefineries in locations central to four biomass resource producing regions of New York (see Figure ES-9).



**Figure ES-9. Siting Map for four lignocellulosic biorefineries projected in Scenarios 1 and 2. Scenario 1 biorefineries have an average capacity of 90 MGY. Scenario 2 average site capacity is 354 MGY with multiple biorefineries at each indicated site.**

Average capacity for the four sites in Scenario 1 is 90 MGY. Scenarios 2 and 3 have the same biomass input and same lignocellulosic ethanol production capacity, but under two very different industry structures. Scenario 2 describes large-scale, centralized production. Scenario 3 has smaller-scale, distributed production (see Figure ES-10). While smaller facilities are usually disadvantaged by both the economies of scale in physical plant and development costs, they represent less financial risk and tend to have proportionately lower impacts, such as road traffic congestion, on local communities. Scenario 2 used four sites identified in Scenario 1 but increased capacity by building four clusters of three biorefineries at each site, for an average site capacity of 354 MGY and a total statewide production capacity of 1,449 MGY. In Scenario 3, the same level of production is achieved by smaller scale plants (average capacity constrained to 60 MGY for the analysis). Twenty-two individual sites around the State house a total of 24 biorefineries. (Two of the 22 sites modeled had two 60 MGY biorefineries at the same site. All others had one 60 MGY plant).



**Figure ES-10. Siting Map for 24 Lignocellulosic Biorefineries Projected in Scenario 3 (Distributed Production Scenario). Scenario 3 biorefineries have an average capacity of 60 MGY.**

Siting maps (Figures ES-9 and ES-10) show locations at the county-scale for resource collection and transportation infrastructure. Combining existing grain ethanol capacity with projected lignocellulosic ethanol, in Scenario 1 New York could produce approximately 508 MGY/year. Assuming that transportation gasoline consumption will be approximately six billion gallons per year (BGY) in 2020, New York could meet 5.6%<sup>6</sup> of its transportation gasoline consumption in Scenario 1, and could produce 1,449 MGY and meet ~16%<sup>7</sup> of year 2020 gasoline consumption in Scenarios 2 and 3.

*Caveat to Scenarios 2 and 3 production capacity: For Scenarios 2 and 3, the computer model predicts that with the advanced conversion technologies, all of the environmentally and sustainably available resources would be consumed in production. This level of production is very unlikely if the model were to incorporate competition for those resources and accounted for the time it would take to build the infrastructure to supply these facilities. For this reason, Scenarios 2 and 3 would take much longer to actually implement even if the technology improvements were achieved by 2020. Furthermore, constraints for site permitting, competition for resources and logistical issues would further limit the actual capacity built by this time. This level of production is modeled as an upper bound for purposes of evaluating issues and impacts that emerge at this quantity of production.*

<sup>6</sup> 508 MGY ethanol \* 0.657 gasoline equivalents / 6,048 MGY (projected 2020 consumption) = 334 MGY gasoline equivalents, which is 5.6% of 2020 forecast consumption. See Appendix L for discussion.

<sup>7</sup> 1,449 MGY ethanol \* 0.657 gasoline equivalents / 6,048 MGY = 952 MGY gasoline equivalents, which is 16% of 2020 forecast consumption. See Appendix L for discussion.

## 6.4 ECONOMIC IMPACTS

The wholesale price paid for ethanol in the year 2020 will influence the inputs available and quantity of production. Two price-points (\$3 and \$4 per gallon of gasoline equivalent) were evaluated for each scenario.

- *Job creation* As shown in Table ES-2, in Scenario 1, an estimated 3,800 jobs are created at the \$3 price point, and 7,700 jobs are created at the \$4 price point. In Scenarios 2 and 3, because the model allows all of the sustainable biomass to be used for biofuel production, increasing the price paid for this input did not increase the amount available. The model is feedstock-limited at the \$4 price point in Scenarios 2 and 3. In both Scenarios 2 and 3, ~14,000 thousand jobs are created.

**Table ES-2. Estimates of Jobs Created by Biofuel Refinery Growth, Statewide, at \$3 price point.**

Job Sector	Scenario #1	Scenario #2	Scenario #3
<b>Agriculture and Forestry Based</b>	1,675 (43%)	6,525 (45%)	6,959 (49%)
<b>Transportation Based</b>	912 (23%)	3,830 (26%)	1,864 (13%)
<b>Miscellaneous Jobs</b>	753 (19%)	2,525 (17%)	2,727 (19%)
<b>Subtotal – Input Sector Jobs</b>	<b>3,340 (86%)</b>	<b>12,880 (88%)</b>	<b>11,550 (82%)</b>
<b>Direct Jobs at Refinery</b>	275 (7%)	798 (6%)	1,320 (9%)
<b>Induced Jobs (due to direct worker and investor spending)</b>	276 (7%)	925 (6%)	1,317 (9%)
<b>TOTAL JOBS</b>	<b>3,891 (100%)</b>	<b>14,604 (100%)</b>	<b>14,189 (100%)</b>

*Estimates include direct and induced job growth resulting from biofuel refinery expansion*

- *Estimated labor income* In Scenario 1 at the \$3/gge price point, labor income (wages and salaries paid statewide) are approximately \$172.6 million, climbing to \$350.4 million at the \$4/gge wholesale price point. In Scenario 2, \$640.4 million is paid in wages and salaries at the \$3 price point and in Scenario 3, with smaller scale plants (less efficient scale), the estimated statewide labor income is \$608.3 million.
- *Value added/Gross domestic product (GDP)* In Scenario 1, the GDP of the industry is an estimated \$0.46 billion (in the \$3/gge wholesale price case) and \$0.93 billion (in the \$4/gge wholesale price case). In Scenarios 2 and 3, GDP is approximately \$1.7 billion.

## 6.5 WORKFORCE AND WORKER TRAINING NEEDS IN NEW YORK

Workforce training needs were evaluated and compared to the training capacity within the State. The analysis concluded that workforce training programs have a good foundation in existing New York institutions (public and private colleges, universities, and technical training programs). However, specific programs such as in biofuels industry research or business support may be needed. Program development would benefit from a research consortium that would focus specifically on issues posed by deployment of a next generation biofuel industry in New York and the Northeast.

## 6.6 ENVIRONMENTAL IMPACTS OF INFRASTRUCTURE

The scenario analyses also provide estimates on the amount of fossil energy consumed, emissions produced, and impacts to transportation flows in the State.<sup>8</sup> Although rail and barge have lower freight costs by weight, the additional fees associated with loading and unloading makes trucking the most cost-effective option in the three Scenarios. The decentralized industry (Scenario 3) measurably decreases required ton-miles<sup>9</sup> of feedstock transport. Although Scenarios 2 and 3 generate equivalent quantities of feedstock and ethanol, the quantity of ton-miles in Scenario 3 is roughly half that in Scenario 2. This is especially important from an emissions standpoint, because ton-miles are directly associated with energy use, emissions, and economics of transport. The scenario results show that energy and emissions associated with transportation and distribution in Scenario 2 are approximately twice those in Scenario 3, even though nearly identical quantities of feedstock and ethanol are produced.

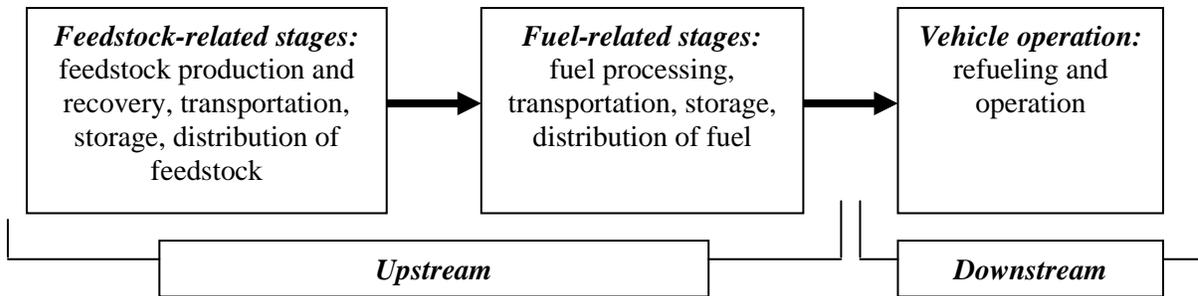
## 6.7 ENVIRONMENTAL LIFE CYCLE ANALYSIS

A life cycle analysis (LCA) was performed to evaluate both upstream and downstream emissions, as shown in Figure ES-11).

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<sup>8</sup> This analysis was not designed to find the pathway that would have the least impact to transportation as it relates to biofuels production, but to quantify and describe the impacts of such development on transportation. The transportation model took the outputs from the biorefinery siting model (Appendix L) and constructed the transportation emissions and energy use calculations based on those outputs. No preference was given for selecting one mode of transportation over another – truck vs. barge, vs. rail -- in creating the biorefinery siting model; instead, the economic model employed in siting the biorefineries was a cost minimization model that identified only the private costs of feedstock production, transportation, and fuel production. This model does not include potential social costs from biofuels production. In the future, this analysis could form part of a baseline for developing a social costs model that values the environmental and health impacts from the transportation and distribution of biofuels.

<sup>9</sup> A measure of output for freight transportation; reflects weight of shipment and the distance it is hauled; a multiplication of tons hauled by the distance traveled.



**Figure ES-11. Components of a Total Fuel-Cycle from Winebrake, Wang, et al. (2001).**

Health and public safety were considered in LCA findings. Compared to fossil fuels, in a total life cycle analysis, certain emitted air pollutants will be reduced, while others will be increased. Lignocellulosic ethanol (LCE) production and use will reduce life-cycle emissions of sulfur oxides (SO<sub>x</sub>), with reductions ranging from 90 metric tons to more than 1,000 metric tons. The tradeoffs associated with biofuels production include increased emissions of some air pollutants that may lead to increased public health concerns in locations where feedstock expansion and fuel production occur.

Emissions may occur either at the farm or fuel production facilities (upstream emissions) or at the tailpipe of the vehicle (downstream emissions). Detailed quantitative modeling of the atmospheric fate and transport of such pollutants is beyond the scope of this project. Instead, the public health impacts are discussed through a presentation of the literature on this topic, which is then connected with the Roadmap life cycle analysis results. The net effects of biofuels' use on public health are uncertain, since the scale, location of emissions, and affected populations are unknown—as are future regulations of air pollutants and toxics. In addition, it is important to note that competing uses of biomass for energy are also associated with negative health impacts. For instance, residential use of firewood produces emissions of particulate matter (PM) and volatile organic compounds (VOCs), and potentially carcinogenic pollutants. These pollutants are linked to respiratory problems, lung damage, and cancer.

Because the sources of the upstream emissions from a biofuels industry will be located in New York, whereas upstream emissions sources for conventional fuels often are located out-of-state, New York may observe increases in upstream emissions as a biofuel industry emerges. Downstream (tailpipe of the vehicle) emissions often occur in areas with high population density, and therefore the impacts to human health may be proportionately greater.

As an example of the complexity of assessing public health risk, the literature indicates that replacing gasoline with ethanol results in a decrease in toxic emissions from benzene and butadiene. This would be a positive sign with respect to cancer impacts. This is tempered, however, by the likely increase in formaldehyde and acetaldehyde, which are associated with other health impacts. The relative toxicity of

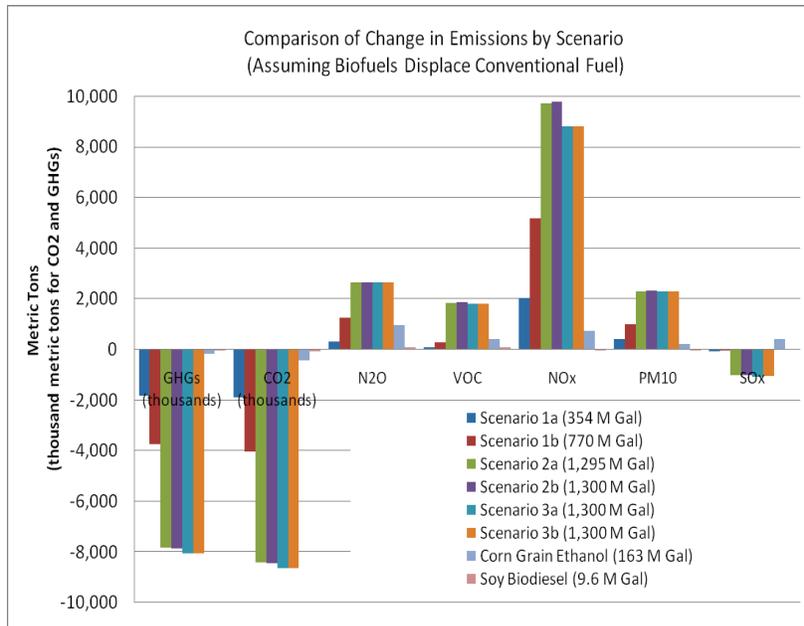
pollutants is important to consider; benzene and butadiene are considered much more toxic (with respect to cancer risk) than formaldehyde and acetaldehyde by EPA’s CURE (Cancer Unit Risk Estimate) scale.

## 6.8 GREENHOUSE GAS EMISSIONS

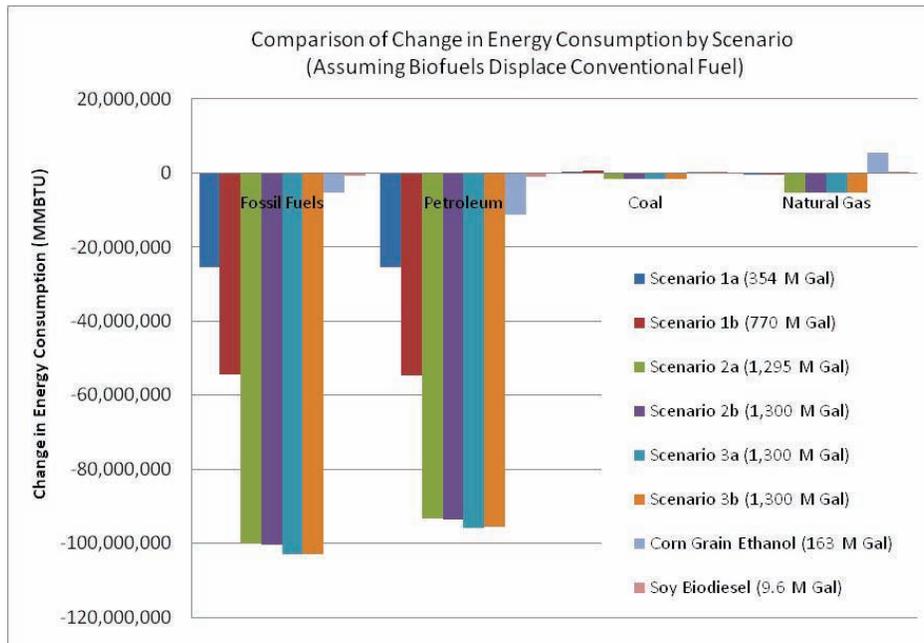
Overall, LCA results suggest that a shift from conventional gasoline to lignocellulosic ethanol will reduce GHG emissions by 67% to 85% compared to equivalent energy content of petroleum fuel (Figure ES-12). Results indicate that displacing gasoline with lignocellulosic ethanol produced in the State will reduce GHG emissions by 1.8 million metric tons per year (Mmt/yr) in Scenario 1, to 8 Mmt/year in Scenario 3. The model did not address indirect land use change and its effects on GHG emissions.

LCA results also demonstrate that displacing petroleum fuels with LCE will reduce life-cycle consumption of fossil fuels, with reductions ranging from more than 20 million MMBtu in Scenario 1 to more than 100 million MMBtu in Scenario 3 cases (Figure ES-13).

**Figure ES-12. Comparison of Change in Emissions by Scenario.**



**Figure ES-13. Comparison of Change in Energy Consumption by Scenario.**



## 6.9 POLICY ANALYSIS

The policy section of the Roadmap includes findings from interviews with industry experts from both in and outside of New York State; interviews with representatives of seven different identified biofuel industry sectors; modeling; and reviews of both federal and State biofuel/biomass policies. The report identifies policies that, if implemented, could lead to the development and expansion of a significant, sustainable biofuels industry within New York State.

The establishment of a successful biofuels production industry in New York State requires diligent analysis of policy options and consideration of the impact on existing environmental and social protections that exist in the State. Establishing a sustainable biofuels industry in New York will require the adoption of a well-crafted suite of policies that provide flexibility, balance and opportunity to the entire spectrum of stakeholders in this industry's development.

**Table ES-3. Key Findings of Roadmap Scenarios**

<b>Attributes</b>	<b>Scenario 1</b>	<b>Scenario 2</b>	<b>Scenario 3</b>
<b><i>Biofuels Statewide Capacity (MGY/year)</i></b>			
Lignocellulosic, \$3/wholesale gge price point case	354	1295	1300
Lignocellulosic, \$4/wholesale gge price point case	700	1300	1300
Grain ethanol production in Scenarios	154	154	154
<b><i>New Biorefineries and Feedstock Sheds</i></b>			
Number of lignocellulosic feedstock sheds	4	4	4
Number of lignocellulosic biorefineries	4	12	22-24
Average lignocellulosic biorefinery site capacity (MGY)	90	354	60
Total state production capacity ethanol (MGY)	508	1449	1449
Percentage of New York gasoline consumption	5.6 %	16%	16%
<b><i>Energy Use (MMBTU/year) to Transport Lignocellulosic Feedstock and Fuel</i></b>			
Transport energy used for moving lignocellulosics at \$3/ gge case	0.39	1.80	0.86
Transport energy used for moving lignocellulosics at \$4/gge case	1.12	1.81	0.86
Transport energy used for moving corn grain and fuel	0.25	0.25	0.25
Transport energy used for moving soybean and biodiesel	0.04	0.04	0.04
<b><i>Road Capacity Issues</i></b>			
Total ton-miles for moving feedstock (million ton-miles) \$3 gge case	313	1,470	663
Total ton-miles for moving feedstock (million ton-miles) \$4 gge case	905	1,478	663
Average number of trucks entering each biorefinery/day \$3 gge case	240	720	130
Average number of trucks entering each biorefinery/day \$4 gge case	480	720	130
Average number of trucks entering each biorefinery/year \$3 gge case	87,430	262,920	47,950
Average number of trucks entering each biorefinery/year \$4 gge case	174,910	263,720	47,950
<b><i>Statewide Economic Impacts</i></b>			
Number of jobs created \$3 gge case	3,891	14,604	14,189
Number of jobs created \$4 gge case	7,780	14,019	14,236
Estimate of annual labor income (wage & salary) \$3 gge case (\$ million)	\$172.6	\$640.6	\$608.3
Estimate of annual labor income (wage & salary) \$4 gge case (\$ million)	\$350.4	\$614.7	\$616.9
Gross domestic product \$3 gge case (\$ billion)	\$0.46	\$1.73	\$1.78
Gross domestic product \$4 gge case (\$ billion)	\$0.93	\$1.66	\$1.79

Attributes	Scenario 1	Scenario 2	Scenario 3
<b><i>Change in Total Fuel Cycle Emissions, Biofuels vs. Energy Equivalent of Petroleum Fuel (Ethanol vs. Gasoline; Biodiesel vs. Low-Sulfur Diesel)</i></b>			
<b><i>Thousand Metric tons/year</i></b>			
GHG <sup>10</sup> \$3 gge wholesale price case (lignocellulosic ethanol) <sup>11</sup>	(1,843)	(7,839)	(8,065)
GHG \$4 gge wholesale price case (lignocellulosic ethanol)	(3,756)	(7,874)	(8,063)
GHG (Corn and soy, all scenarios & price cases)	(218)	(218)	(218)
CO <sub>2</sub> \$3 gge wholesale price case (lignocellulosic ethanol)	(1,888)	(8,419)	(8,643)
CO <sub>2</sub> \$4 gge wholesale price case (lignocellulosic ethanol)	(4,020)	(8,459)	(8,642)
CO <sub>2</sub> (Corn and soy, all scenarios & price cases)	(531)	(531)	(531)
<b><i>Metric tons/year</i></b>			
NO <sub>x</sub> \$3 gge wholesale price case (lignocellulosic ethanol)	2,028	9,701	8,786
NO <sub>x</sub> \$4 gge wholesale price case (lignocellulosic ethanol)	5,174	9,758	8,811
NO <sub>x</sub> (Corn and soy, all scenarios & price cases)	720	720	720
PM <sub>10</sub> \$3 gge wholesale price case (lignocellulosic ethanol)	416	2,279	2,293
PM <sub>10</sub> \$4 gge wholesale price case (lignocellulosic ethanol)	980	2,321	2,294
PM <sub>10</sub> (Corn and soy, all scenarios & price cases)	209	209	209
SO <sub>x</sub> \$3 gge wholesale price case (lignocellulosic ethanol)	(90)	(1,029)	(1,071)
SO <sub>x</sub> \$4 gge wholesale price case (lignocellulosic ethanol)	(57)	(1,029)	(1,067)
SO <sub>x</sub> (Corn and soy, all scenarios & price cases)	435	435	435
VOC \$3 gge wholesale price case (lignocellulosic ethanol)	89	1,830	1,790
VOC \$4 gge wholesale price case (lignocellulosic ethanol)	289	1,865	1,791
VOC (Corn and soy, all scenarios & price cases)	460	460	460

<sup>10</sup> GHG includes CO<sub>2</sub>, N<sub>2</sub>O, and CH<sub>4</sub>, and is reported as CO<sub>2</sub> equivalent.

<sup>11</sup> Parentheses indicate negative values.

## 7 CONCLUSIONS

1. New York State could produce enough biomass to support a lignocellulosic ethanol industry: there is the potential for between one million and 1.68 million acres of non-forest land to be used for bioenergy feedstock production in New York. There are also 15.8 million acres of available timberland where woody biomass could be harvested (which excludes forest areas in parks and preserves).
2. New York could sustainably produce between 4.2 and 14.6 million dry tons (Mdt) of cellulosic biomass per year (this includes 6.4 Mdt from forests).
3. New York biofuels could provide 5.6% to 16% of estimated 2020 in-State gasoline consumption.
4. A comprehensive biofuels sustainability framework does not yet exist for New York. Development of ecologically sustainable practices for producing biofuel feedstock is a crucial first step. Sustainability criteria need to be identified through a public process, and must be science-based, quantifiable, and relevant to biofuels.
5. Ethanol was compared to gasoline in a total life cycle analysis of ethanol. The modeling showed that certain emitted air pollutants will be reduced, while others will be increased. The tradeoffs associated with biofuels production include increased emissions of some air pollutants that may lead to increased public health concerns in locations where feedstock expansion and fuel production occur.
6. Lignocellulosic ethanol (LCE) production shows potential to decrease greenhouse gas (GHG) emissions by millions of tons annually compared to gasoline.<sup>12</sup> Moreover, these benefits are even greater under a distributed, localized biofuels industry. Corn ethanol and soy biodiesel production also reduce GHGs and petroleum consumption, though to a lesser degree than LCE.
7. In addition to air impacts, other potentially negative environmental impacts of increased feedstock production, biofuels production, and biofuels use in the State include: soil erosion, impaired water quality, acidification of water and soil, eutrophication of bodies of water, damage to plants and animals, reduced biodiversity, and loss of habitat. Proper implementation of best management practices could mitigate negative effects.
8. New York-specific indirect land use change (iLUC) impacts are possible and potentially significant in scale. Generally, iLUC impacts are very difficult to quantify, and global models to

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<sup>12</sup> This does not take into account indirect land use effects.

measure potential impacts are still under development. At the time of this writing (March 2010) it was not feasible to conduct the global-scale analysis necessary to quantify potential New York-specific adverse effects.<sup>13</sup> However, the scenarios included in the Roadmap analyses were selected to minimize the likelihood of significant iLUC impacts. As global iLUC models are developed, it would be appropriate to integrate them into future New York biofuels life cycle analyses.

9. Based on modeling that used least-cost inputs, biofuel production facilities will rely on road transport. An examination of social costs such as projected congestion patterns on roadways leads to the conclusion that feedstock movement via rail or barge may be more desirable than via truck transport.
10. Four large-scale centralized lignocellulosic biorefineries (capacity range 90-354 million gallons per year) using New York biomass could operate in the State. Alternatively, up to 24 smaller-capacity (60 million gallons per year) biorefineries could be built.
11. The estimated GDP of a biofuels industry producing 5.6% of New York transportation fuels is \$0.5 to \$0.9 billion. The estimated GDP of a biofuels industry producing 16% of New York transportation fuels is \$1.8 to \$1.9 billion.
12. There is potential for robust job growth in the New York economy for a biofuels industry. For Scenario 1, approximately 3,900 jobs would be created; for Scenario 2, approximately 14,600 jobs would be created; and for Scenario 3, approximately 14,200 jobs would be created.
13. Workforce training programs have a good foundation in existing institutions. Specific programs such as in biofuels industry research or business support may be needed. Program development would benefit from a research consortium that would focus specifically on issues posed by next generation biofuel industry deployment in New York and the Northeast.
14. A variety of biofuel technologies exist, but they will need to improve until they have similar or better yields and similar or lower production costs than the technologies evaluated in this report.
15. Over the next five to ten years, there may be considerable competition between liquid biofuel producers and other users of lignocellulosic biomass feedstock in the region, including thermal fuel production (e.g., wood chips, pellets, and firewood), biomass electricity (e.g., utility-scale co-

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<sup>13</sup> The Roadmap analysis of iLUC was conducted in November 2009. The body of knowledge is rapidly evolving. New information will be provided in the 2011 annual update of the Roadmap.

firing and stand-alone wood-fired power plants), and combined heat and power (CHP). There will continue to be multiple uses of biomass, but the Roadmap does not conclude that any one use should be given priority over the others. A key consideration in evaluating the potential competition between current and emerging users of New York's woody biomass is that some biomass resources are less appropriate for certain production processes and end-uses than others. Overall, supplies of biomass may increase in response to market prices.

16. The distribution of land ownership in New York (and throughout the Northeast) is dominated by many landowners with relatively small parcels of land (i.e., under 100 acres). It is difficult to anticipate how and whether these owners might want to produce bioenergy crops. Additional research on landowner preferences could help to refine the understanding of biomass availability.
17. A number of laws enacted by local governments may overly restrict harvesting, and these governments should be provided with information on how these laws can be amended to minimize their impact on sustainable forest practices.
18. Financing for biofuels production facilities is essentially unavailable in the current economic climate (late 2009 and early 2010).
19. The establishment of a successful biofuels production industry in New York State requires diligent analysis of policy options and consideration of the impact on existing environmental and social protections in the State. Establishing a sustainable biofuels industry in New York will require the adoption of a well-crafted suite of policies that provide flexibility, balance and opportunity to the entire spectrum of stakeholders in this industry's development.

# ***Renewable Fuels Roadmap***

## 1 DESCRIPTION OF STUDY

### 1.1 PURPOSE OF THIS STUDY

The need for a Renewable Fuels Roadmap was identified in the February 2008 Report of the New York Governor’s Renewable Energy Task Force, which called for a Renewable Fuels Roadmap and Sustainable Biomass Feedstock Study for New York (Roadmap). The key components identified by the Task Force included an evaluation of “critical environmental, capacity, technology, efficiency, and economic issues for renewable fuels.” In particular, the Roadmap was to provide policymakers with the positive and negative impacts associated with the increased use and production of renewable fuels in the State, paying particular attention to environmental issues and public health.

The Roadmap evaluates the future of liquid biofuel production and feedstock supplies for transportation purposes in New York State in order to address increasing greenhouse gas (GHG) and local pollutant emissions as well as independence from petroleum usage. For the foreseeable future, biofuels like ethanol will be a necessary part of the State’s transportation fuels mix. Based on current and projected demand, as well as vehicle technology and fleet turnover, New York residents will continue to primarily consume gasoline to meet their transportation needs. Even if a move toward grid-connected electric vehicles gains in popularity and affordability, it will take decades to convert the entire New York residential vehicle fleet to electricity and to build the electrical grid-infrastructure necessary to power such a fleet. Grid-independent hybrid vehicles are a more likely future, with grid-connected (i.e., “plug-in”) hybrids possibly gaining traction in the next decade or two. In both cases, liquid fuels, especially ethanol-gasoline mixtures, will still be necessary.

### 1.2 APPROACH AND SOURCES OF INFORMATION

The approach followed by the Roadmap Team in this study brings together aspects of both *visioning* and *analysis* to produce a Sustainable Renewable Fuels Roadmap for New York, intended to be visionary and meaningfully well-grounded in its scientific, economic, and environmental analysis.

The Roadmap considers eleven key issues (or *Strategic Priority Tasks* as they were structured during the research, analysis, and writing phases of the Roadmap project) for a renewable fuels future in New York State. The eleven *Tasks* were addressed by the respective Roadmap Task Teams. The reports written by these Teams are attached as Appendices to the Roadmap:

- Stakeholder Input: Vision Document and Stakeholder Input Workshops (Appendices C and D)
- Analysis of Sustainable Feedstock Production Potential in New York State (Appendix E)

- Feedstock Transportation and Logistics (Appendix F)
- Life Cycle Analysis and Public Health Assessment of Biofuel Production, Transportation, and Use in New York State (Appendix G)
- Technologies for Biofuels Production (Appendix H)
- Biofuel Industry Economic Impacts and Analysis (Appendix I)
- Worker Training and Business Research Infrastructure Biofuel Industry in New York (Appendix J)
- Sustainability Criteria (Appendix K)
- Selected Future Production Pathways in New York (Appendix L)
- Policy Analysis and Inventory of Existing Relevant State and Federal Policies (Appendices M and N)
- Biofuels Markets in New York State & Integration in the Northeast Region and Competition for Biomass Resources (Appendices O and P)

The Roadmap considers the future of renewable fuel production in New York State from the perspective of these 11 *Tasks*. The analysis of these 11 priorities provides a framework for addressing the potential size and impact of the development of a renewable fuels industry in New York, considering the quantity of required and sustainably-produced feedstock resources, the environmental and economic impacts, and the relationship of the new industry to the larger New York State and regional economies. Each of the 11 *Tasks* has its own specific methodology, depending on the task. These individual methodologies are detailed in the Appendix Reports.

In order to frame the analysis around potential biofuel industry impacts, the Roadmap conducts scenario-based analyses. In particular, the Roadmap creates three possible future (~year 2020) scenarios related to an expanding biofuels industry in New York State. The three scenario analyses are not meant to provide side-by-side comparison for the “best” possible pathway to the future, but rather allow a broad but realistic consideration of the primary issues and impacts that arise under three different possible futures, based on where the emphasis is placed. All scenarios assume that existing and planned corn grain-to-ethanol production systems (totaling 154 million gallons per year [MGY]) will continue, and that new production for liquid biofuels comes predominantly from lignocellulosic to ethanol pathways.<sup>14</sup> Further, each scenario was evaluated under two price cases: \$3/gallon gas equivalents [gge] and \$4/gge.

- **Scenario 1 - “Big Step Forward”** This scenario places strong emphasis on maintaining current New York agricultural food and feed production as well as current forest production, with focus on large (average 90 MGY) biofuel production plants. For this scenario, rapid development of lignocellulosic feedstock resources is assumed on a portion of suitable and available rural lands. The available land base excludes all land currently in food production. It is assumed that first

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<sup>14</sup> Biodiesel was considered, but provides a smaller contribution to overall production volumes than ethanol.

generation lignocellulosic biorefineries (biochemical and thermochemical systems) are performing at their optimum potential. Total New York production of renewable gasoline substitutes would reach 508 MGY. Under this scenario, New York meets about 5-6% of its projected transportation gasoline consumption with home grown biofuels.

- **Scenario 2 - “Giant Leap Forward”** In this scenario, in addition to the land estimated available in Scenario 1, some cropland is used for biofuel feedstock production (specifically, the cropland estimated to become available due to increases in crop yield and milk yield per cow such that crop and milk production could be maintained at 2007 levels). Furthermore, second generation lignocellulosic biorefineries (biochemical and thermochemical systems) are assumed ready for commercial deployment. Here, large lignocellulosic biorefinery clusters (average capacity 354 MGY) exist in a centralized collection and distribution system. Total New York liquid biofuel production including the grain derived ethanol would reach 1,449 MGY. In the Scenario 2 base case, New York could meet about 16% of its projected transportation gasoline consumption with home grown biofuels.
- **Scenario 3 - “Distributed Production”** This scenario envisions the same feedstock production and similar conversion technology as in Scenario 2. However, this scenario reflects a more decentralized fuel production industry with no individual biorefinery capacity exceeding 60 MGY, except for the existing grain ethanol biorefineries. Total New York liquid biofuel production including the grain derived ethanol would reach 1,449 MGY. In the Scenario 3 base case, New York could meet about 16% of its projected transportation gasoline consumption with home grown biofuels.

The three scenario analyses were coordinated using a well integrated set of computer models based on the best available data, combined with a set of expert judgments and assumptions where quantitative data were not available. These integrated computer models collectively provide feedstock, energy, economic, and environmental analyses of the three Roadmap scenarios.

## 2 EXISTING CONDITIONS

Assessing the State's future biofuels production potential in a strategic way requires an assessment of the current situation. This section of the Roadmap presents a current (2007-2009) snapshot of New York's current biomass production, including agricultural products and forest products. Included in this section of the Roadmap are sub-sections addressing: biomass feedstock inventory; land uses; transportation and distribution infrastructure; competing uses for biomass; and biofuel conversion technologies. In this document, "biomass" is defined as any plant-derived organic matter. Biomass available for energy on a sustainable basis includes herbaceous and woody energy crops, agricultural food and feed crops, agricultural crop residues, and wood residues.

### 2.1 CURRENT BIOMASS FEEDSTOCK INVENTORY (2007 – 2009)

#### **2.1.1 Current New York Agricultural Biomass**

According to the 2007 Census of Agriculture, more than 10.3 million dry tons per year (Mdt/yr) of agricultural products were harvested from 3.67 million acres in New York State. If estimated corn stover<sup>15</sup> is added to this estimate, more than 12 Mdt/yr are currently produced in New York. Current agricultural land use and production of selected crops are summarized in Table 2-1.

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<sup>15</sup> Corn stover is the above ground portion of the plant that is not grain.

**TABLE 2-1. Current Agricultural Production (Derived from the 2007 Census of Agriculture\*)**

Commodity	Area Harvested	Average Yield	Average Yield Unit	Production Wet Weight	Moisture Content	Production Dry Weight	Percentage of Total biomass contributed (dry weight basis)
	<i>acres</i>		<i>per acre</i>	<i>short tons/year</i>	<i>% moisture</i>	<i>short tons/year</i>	<i>%</i>
Corn (grain, stover and silage)*						<b>7,268,611</b>	60.6%
<i>Corn Grain</i>	551,629	129.5	<i>bu</i>	2,000,720	15.5%	1,690,608	
<i>Corn Stover</i> *	<i>*Stover estimated to be approximately equal to corn grain dry weight.</i>					*1,690,000	
<i>Corn Silage</i>	507,568	17.0	<i>tons</i>	8,640,006	55.0%	3,888,003	
All Forage + Hay	1,962,620	2.5	<i>tons</i>	4,981,812	13.0%	<b>4,334,176</b>	36.1%
Soybeans	199,775	37.3	<i>bu</i>	223,700	13.0%	<b>194,619</b>	1.6%
Vegetable/Orchard	264,495						
Wheat	84,955	53.5	<i>bu</i>	136,321	13.5 %	<b>117,918</b>	1%
Oats	60,999	58.3	<i>bu</i>	56,900	14.0%	<b>48,934</b>	0.4%
Sorghum (grain and silage)						<b>11,030</b>	0.1%
<i>Sorghum Grain</i>	717	49.9	<i>bu</i>	1,003	13.0%	873	
<i>Sorghum Silage</i>	3,192	7.1	<i>tons</i>	22,571	55.0%	10,157	
Barley	10,793	49.1	<i>bu</i>	12,730	14.5%	<b>10,844</b>	0.1%
All other Edible Beans	16,218	15.3	<i>cwt</i>	12,388	13.0%	<b>10,778</b>	0.1%
Rye	6,879	32.7	<i>bu</i>	6,303	14.0%	<b>5,421</b>	0.05%
Sunflower seed	357	1,030	<i>lbs</i>	184	10.0%	<b>166</b>	0.001%
TOTAL (no stover)	3,670,197					<b>10,312,497</b>	
<b>TOTAL*</b>	<b>3,670,197</b>					<b>12,002,497</b>	100 %

\*Corn stover (above ground portion of the plant that is not grain) is approximately equal to the dry weight of the grain but is not included in the Census of Agriculture. Corn stover weight is estimated here from corn grain data. The amount of corn stover shown here does not consider amounts that would be left behind to replenish soil in actual practice.

Corn provides the greatest amount of biomass from a single agricultural crop in the State (60%). An estimated 7.2 Mdt/yr (when corn silage, corn grain, and corn stover are combined) are produced from 1.1 million acres. Currently, the corn stover is not a product, so it is not included in the 2007 Census of Agriculture statistical summaries, but is estimated here based on grain weight. To harvest corn stover in a sustainable manner, some portion of this estimated total stover production would be returned to the soil in actual practice. Therefore, in our analysis, only 25% of stover is estimated to be available from any field, with a further restriction that stover is harvested only from half of all fields. All forage and hay in the State contributes 4.3 Mdt/yr of biomass from 1.9 million acres. Soybean production is nearly 0.2 Mdt/yr from

nearly 0.2 million acres. Sorghum and sunflower are potential bioenergy feedstocks that are grown in the State, but only small quantities are produced currently.

### **2.1.2 Current New York Forest Biomass**

The amount of New York land defined as forest area varies depending on the classification system used. Values for forest land from the U.S. Forest Service and forest cover from the National Land Cover Database (NLCD) differ due to their classification systems. Based on forest inventory data from the United States Department of Agriculture (USDA) Forest Service, there are over 18.4 million acres of forest land in the State. Removing the forest area in parks and preserves leaves 15.8 million acres of timberland where woody biomass could be harvested. There are over 991 Mdt of standing biomass on the timberland across the State. The State-wide net annual growth rate on New York timberland (i.e., amount of biomass added to New York forests each year through tree growth less the amount lost to mortality) is 9.6 million oven dry tons (odt/yr). Total annual forest production (i.e., amount of biomass removed from New York forests for industrial production) in 2007 was 161 million cubic feet, equivalent to 2.5 million odt. The types of trees harvested for 635 million board feet/yr of wood products in New York are approximately 22% Sugar maple, 13% Red maple, 13% White pine, 11% Northern red oak, 10% Black cherry, 9% Ash, and 16% other. In addition, the 2.5 million odt also includes wood chips and wood pulp (New York State Department of Environmental Conservation, NYSDEC 2008).

In addition, substantial quantities of firewood are harvested from New York Forests, estimated to be an additional 1.3 million oven odt/yr (personal communication -- Sloane Crawford, NYSDEC). Since 1999, the annual harvest of logs has decreased from 900 million board feet to 635 million board feet, while pulpwood and chip harvest have been variable with no strong trends. Modeled estimates of forest biomass based on the 2002-2006 Forest Inventory and Analysis Database and 2007 Timber Products database of the USDA Forest Service show that New York forest biomass is growing approximately three times faster than it is being harvested. Some of this harvested wood later becomes residue after milling or manufacturing, and the use of such residues as a bioenergy feedstock is discussed in Appendix E. Other information on bioenergy feedstocks is also provided in Appendix E.

### **2.1.3 Current New York Biomass Feedstocks for Liquid Biofuels**

The dominant biomass feedstock used currently to produce biofuels in New York State is corn grain, at a single ethanol production facility in Shelby, NY. This facility reports that it processes 18.5 million bushels per year (Mbu/yr) of corn grain. This amount is equivalent to 26% of current corn grain production in New York State, although not all of the grain used by the plant is necessarily grown in New York State. Another corn ethanol facility has been constructed in Volney, but is not operating at this writing (March 2010). At its nameplate capacity (i.e., the facility's rated production capacity), the Volney facility would use 35.8 Mbu of corn grain per year, equivalent to 50% of current State production. Thus, it is expected that in the near future, the equivalent of 76% of corn grain production in New York State will likely be used for

ethanol production. Nevertheless, not all of this corn would necessarily come from New York State for logistical and economic reasons. Even so, New York would need to import additional corn to maintain other existing uses of the product in the State, particularly livestock feed.

When corn ethanol is produced, a by-product is “dry distiller’s grains with solubles” (DDGS), which has value as livestock feed and other high-value bioproducts industry uses. The amount of DDGS produced is approximately 30% of the weight of the corn grain. Because DDGS has a different nutrient content than corn grain, it must be added to livestock diets in limited amounts (which vary by type of livestock) and balanced with other feeds. On the other hand, it has higher protein content than corn grain. With a recommended milking cow diet of six pounds of DDGS per day (13.2% of the total diet), 58% of the New York State dairy herd potentially could use all of the DDGS resulting from the two ethanol plants. Assuming continued current corn grain import levels, this amount of DDGS would displace the need for 238,659 New York acres used for producing a fraction of the current milking cow feed, amounting to 43% of the area currently used for corn grain production in New York State. Thus, the two corn ethanol plants operating at nameplate capacity would use the equivalent of 32% of current (2007) corn grain acreage in New York State, after accounting for the acreage represented by the potential feed value of the DDGS for dairy cattle. It should be noted that these calculations are overall net values for the State; in reality, the corn ethanol facilities are unlikely to obtain all of their corn from within New York State. This issue is discussed further in Appendix E.

## 2.2 LAND USE INVENTORY

Forests cover more than half (54%) of the State and nearly 25% of the State is in agricultural land cover, primarily hay and pastureland (Table 2-3). Most of New York forest land is in private ownership, and most of it is classified as “timberland,” meaning that it is suitable for sustainable harvest management. The next largest land use in the State is agriculture.

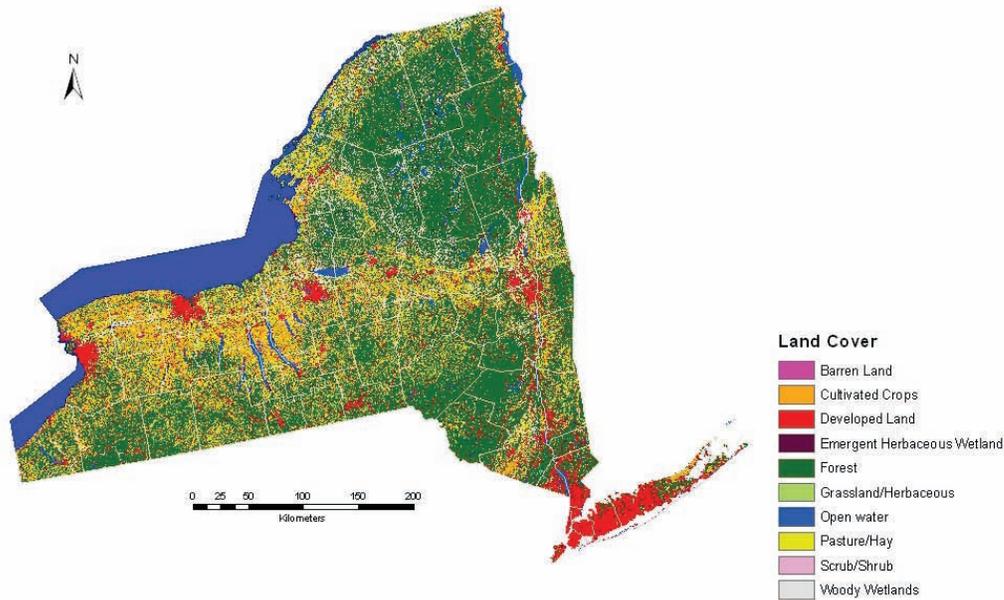
**TABLE 2-3. Land Cover and Land Use in New York State, and Potential Area for New Bioenergy Feedstocks**

Land Cover Type (from NLCD) <sup>1</sup>	Land Area acres	Suitable Area (not Federal, slope < 15%, field > 5 acres) acres	Current Crop, Forage, and Hay Land Acres	Current Equine Land Use acres	Unavailable <sup>3</sup> due to owner preferences acres	Available Area (our calculation) acres
Crop Land	2,641,314	2,427,554	1,707,577	0	719,977	0
Pasture, Hay & Grass Land	4,612,554	4,144,010	1,962,620	987,000	585,454	608,936
Shrub & Scrub Land	878,170	704,458	0	0	331,822	372,637
Forest Land <sup>2</sup>	16,702,133	15,775,600	0	0	n/a	n/a
Developed land	2,708,501	0	0	0		0
Barren land	58,608	0	0	0		0
Wetlands	2,453,891	0	0	0		0
Open water	1,017,873	0	0	0		0
Other	6,044	0	0	0		0
<b>TOTAL</b>	<b>31,079,087</b>	<b>23,051,623</b>	<b>3,670,197</b>	<b>987,000</b>	<b>1,637,253</b>	<b>981,572</b>

<sup>1</sup> NLCD is the National Land Cover Database, derived from remote sensing imagery circa 2001.

<sup>2</sup> NLCD data shown here. The amount of New York land defined as forest area varies depending on the classification system used. Values for forest land from the U.S. Forest Service and forest cover from the NLCD differ due to their classification systems. Based on forest inventory data from the USDA Forest Service, there are more than 18.4 million acres of forest land in the state. Based on data from the NLCD there are more than 16.7 million acres of forest land in the State.

<sup>3</sup> The amount of land "unavailable" due to owner preferences is estimated based on modeling owner-willingness to harvest as a function of population density.



Source: National Land Cover Database (NLCD) 2001 (<http://www.mrlc.gov>)

**Figure 2-1. Land cover in New York State. More than half of the State is covered by forest lands and nearly one-fourth of the State is used for agricultural crops, pasture and hay.**

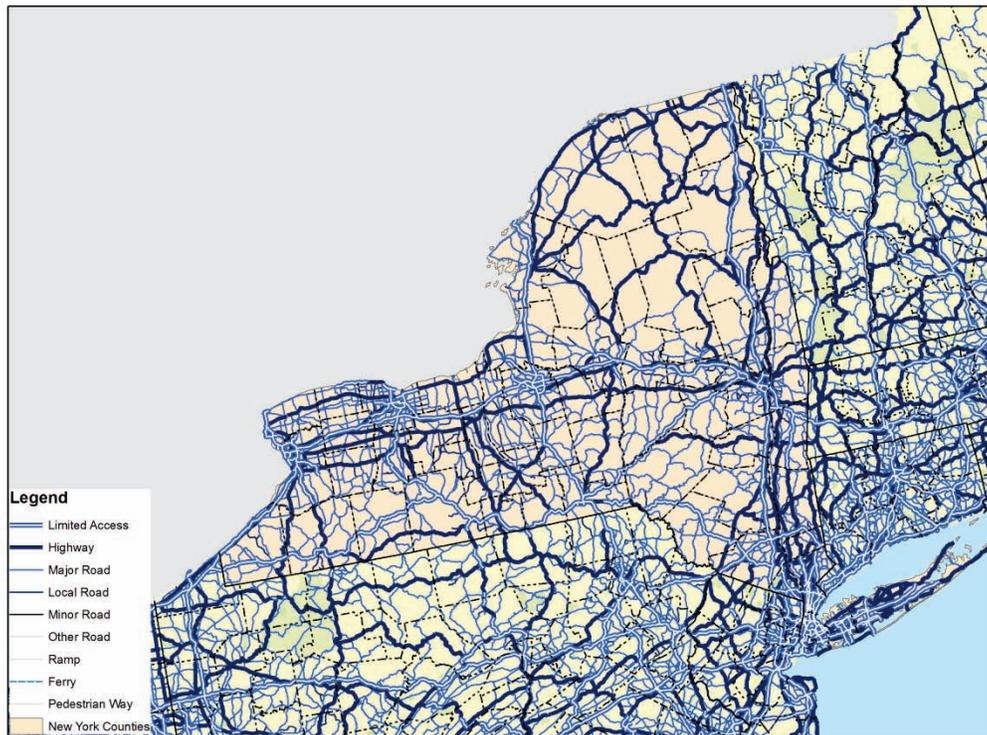
Pasture, hay, and grasslands comprise about 15% of the land, and cropland occupies nearly 9%. Land that has been developed comprises nearly 9%, wetlands represent approximately 8%, and open water accounts for 3%. Shrub and scrub land accounts for about the same amount of land as open water, approximately 3%. Figure 2-1 shows a land cover map of New York State based on the 2001 National Land Cover Database dataset. Further information is provided in Appendix E.

## 2.3 CURRENT TRANSPORT INFRASTRUCTURE INVENTORY (2007 – 2009)

The existing capacity of transport modes (including truck, train, and barge) and New York’s existing transportation and distribution (T&D) network will have a bearing on the development of the biofuels industry in the short term.

### **2.3.1 Current New York Roads Network**

The New York road network, shown in Figure 2-2, consists of minor and major roads, highways, freeways, and limited access interstate highways, including some toll roads. The road network is the most extensive transportation system connecting feedstocks, processing facilities, blending facilities, and distribution facilities with end users. The New York road network consists of ~115,000 miles of road (NYSDOT 2008). According to interviews with New York biofuel industry stakeholders, the road network is by far the most used mode in New York for biofuels feedstock and fuel T&D. Therefore, the road network is considered the baseline for estimating T&D impacts and opportunities. As shown in Figure 2-2, the highway network in the State extends into all feedstock origin counties.



**Figure 2-2. Map of New York State Highway Networks**

In contrast, the State waterway and rail networks (Figure 2-3 and Figure 2-4) do not reach into several northeastern and southwestern counties in the State where potential feedstock production is plentiful, so in many cases truck transportation is the only currently existing option for feedstock transport.

Nevertheless, there may be opportunities for the State to take advantage of railway and waterway networks, as will be discussed in a later section of this report (Future Scenarios, Section 4) and in Appendix F.

### **2.3.2 Current New York Waterway Transportation Network**

The State waterway network includes an inland canal system, Lake Ontario, Lake Erie, Finger Lakes access, and Atlantic coastal waters. The New York canal system is a 524-mile waterway network with locks and dams. Originally designed to connect crop production areas to processing and distribution centers, the current canal system is primarily dedicated to recreation, though commercial use is permitted according to a fee schedule. Many sections of the canal system have vertical clearance issues or shallow depths. Efforts are underway to return the canal system to a control depth of 14 feet between Waterford and Oswego and 12 feet elsewhere (NYS Canal Corporation 2009). Though impressive in length east to

west, the canal system does not reach extensively into many regions of the State, limiting the usefulness of the system for transport of feedstock from many counties to refining facilities modeled in this Roadmap.



**Figure 2-3. Map of New York State Waterway Transportation Network**

Waterway transport generally is less expensive and more energy efficient than truck transport on a marginal cost basis (per ton-mile); however, it tends to be less cost-effective over distances less than a few hundred miles as there are fixed transfer costs associated with waterway transport. These costs may increase the average costs of transport (per ton-mile) to be greater than truck transport for short distance hauls.

### **2.3.3 Current New York Rail Network and Intermodal Facilities**

The New York rail network includes approximately 3,600 miles excluding trackage<sup>16</sup> rights and 4,700 miles including trackage rights. The New York rail network is shown in Figure 2-4. In general, major railways are dedicated to long-haul service, as rail tends not to be cost-effective for shorter distances. Potential rail use for biofuels T&D will be limited to minor rail segments. According to leaders in the New

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<sup>16</sup> Trackage rights are determined through an agreement between two railroads. One railroad buys the right to run its trains on the tracks of the other railroad and pays a toll for the use of the tracks.

York biofuel industry, use of the rail network for biofuels feedstock and fuel transport within New York State is currently minimal.



**Figure 2-4. Map of New York State Rail Network and Intermodal Facilities**

Access to rail systems is also uncertain and will depend on the number of rail transfer facilities and their proximity to feedstock collection points. Figure 2-4 depicts five intermodal facilities where freight containers are moved between transportation modes (i.e. rail, truck, barge). These are located in: Buffalo (two), Syracuse, Albany and Staten Island. These facilities currently handle containers rather than bulk transfer operations. The New York State Rail Plan (NYSDOT 2009) envisions three new intermodal facilities or inland ports, at least two of which would be sited in upstate New York. If developed near areas of major feedstock production, and if they include bulk transfer operations, these new intermodal facilities might allow for use of rail transport where it is currently infeasible or uneconomical. However, like waterway transport, rail transport is generally less expensive than truck transport on a marginal cost basis (per ton-mile), but fixed transfer costs increase the average cost of rail transport to be greater than truck for short distance hauls.

## 2.4 CURRENT POTENTIAL COMPETING USES FOR NEW YORK BIOMASS

This section of the report provides a characterization of other markets for New York's woody biomass resources. These markets present feedstock competition for the State's emerging advanced liquid biofuels industry. Results from an on-line survey conducted in July 2009 by NESCAUM, the Pace Energy and Climate Center, and Farm Credit of Western New York found that ethanol industry stakeholders predicted that liquid biofuel producers in the region will compete considerably with other industries for New York's biomass resources (NESCAUM et al. 2009). In addition, many biomass market experts outside the ethanol industry predict substantial competition for New York's biomass from thermal fuel producers (i.e., pellets, wood chips, cordwood), biomass electricity producers, and traditional wood product industries, particularly over the next 5 to 10 years because advanced biofuel technologies are not yet commercially viable.

This section provides an empirical review or "snapshot" of current competing markets for New York's biomass resources and qualitative insights about key factors that are likely to influence future markets for biomass. Note that the focus of this analysis is primarily on woody biomass because these resources are a key input to both existing industries and for a number of advanced biofuel technologies under development (e.g., cellulosic ethanol fermentation or gasification). The following section provides a snapshot of competing uses for biomass resources by existing industries (e.g., wood products, electricity generation) and emerging or expanding applications (e.g., thermal fuels, biomass co-firing for GHG mitigation).

Figure 2-5 displays existing facilities in and near New York that are either current users of New York's woody biomass resources or are candidates for using New York biomass in the future. Current users include biomass electricity plants, pulp/paper plants, pellet plants, sawmills and manufacturing board plants, and firewood producers. Candidates for greater use of New York's biomass resource in the future include new wood pellet facilities, coal-fired power plants regulated under the Regional Greenhouse Gas Initiative (RGGI),<sup>17</sup> coal-fired power plants that will convert to biomass co-firing as part of Ontario's GHG-reduction action plan, and plants that choose to participate in New York's Renewable Portfolio Standard by co-firing with biomass. However, the actual use of woody biomass under RGGI will depend on the definition of sustainable eligible biomass that is adopted by New York State.

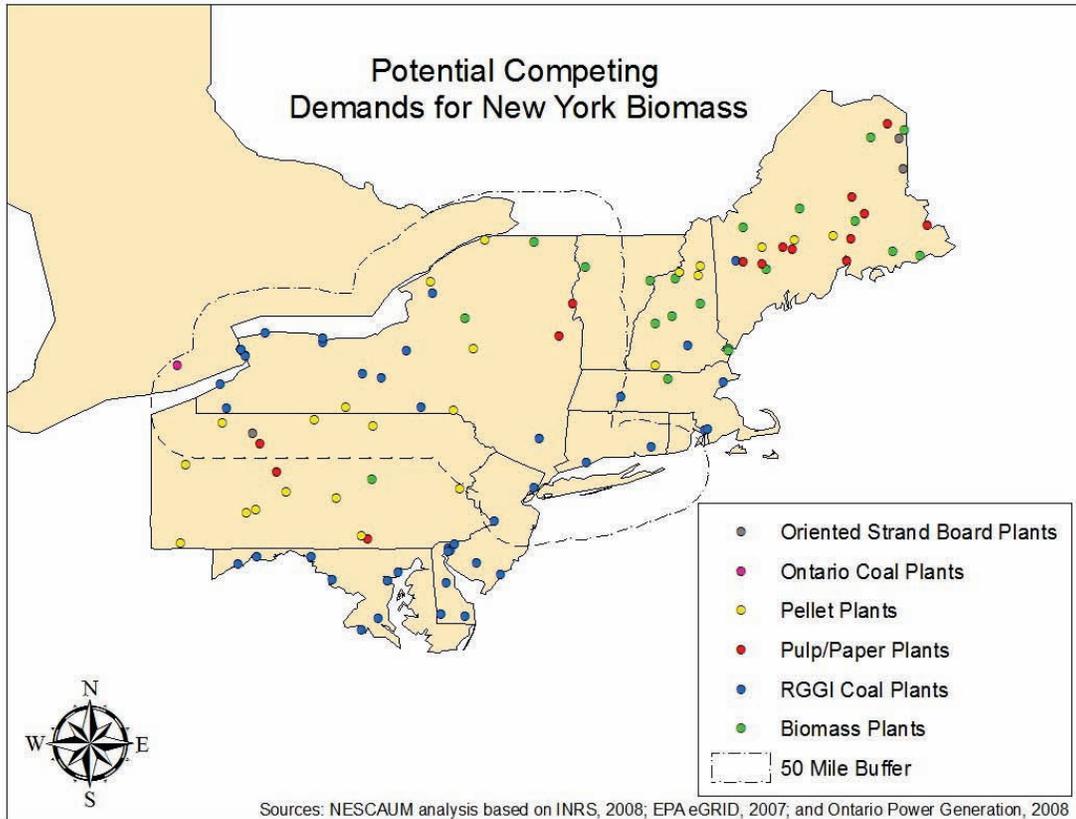
The dashed line in Figure 2-5 indicates an approximate 50-mile buffer from the New York border, which is assumed to be a reasonable limit for economic transport of New York wood and biomass products to facilities in neighboring states given current fuel and product prices.<sup>18</sup> If the distance for economic transport of New York biomass were to extend to 100 miles, for example, this would bring in many additional candidates, including additional biomass plants in Vermont, New Hampshire, Pennsylvania, and

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<sup>17</sup> RGGI is a regulatory initiative of ten Northeast and Mid-Atlantic States of the U.S. to achieve a 10% reduction in GHG emissions from electric generation by 2018.

<sup>18</sup> While this assumption is an oversimplification of the fact that actual export of biomass to neighboring states and countries will depend on a variety of factors in addition to geographic proximity, such as vendor reputation, product price, availability, and quality, among others, it is nonetheless helpful to note what facilities are likely candidates for importing New York biomass solely on the basis of their locations.

Ontario; additional pulp/paper and wood pellet facilities in Pennsylvania and New Hampshire; and a few additional coal-fired power plants in Massachusetts and possibly New Jersey as well. There may be additional competition from even more distant markets, such as wood and grass pellets from New York being shipped to Europe.



**Figure 2-5. Potential Competing Demands for New York’s Woody Biomass from Electric and Thermal Users. (Sawmills and firewood producers not shown.)**

A key consideration in evaluating the potential competition between existing and potential users of New York’s woody biomass is that some biomass resources are less appropriate than others for certain production processes and end-uses. Both traditional wood product manufacturers and some producers of advanced biofuels use only high-quality saw timber and wood chips in their production processes, whereas electricity generators, some pulp/paper manufacturers, and pellet producers are more flexible with respect to feedstock quality and thus are able to use lower quality biomass resources. Users that need high-quality feedstock for their production processes are not likely to compete for lower-quality feedstock (unless, for example, cellulosic ethanol producers improve their process). Producers that currently rely solely upon lower-grade biomass, however, could begin to compete for higher grade biomass if prices for their end-products were to increase substantially. Overall, supplies of biomass may increase in response to market prices. More information on biomass supply trends is provided in Appendix E.

### **2.4.1 Existing Users**

Existing users of New York's woody biomass resources include traditional wood product manufacturers such as sawmills, pulp/paper and wood chip producers, and firewood producers, as well as biomass electricity plants.

**2.4.1.1 Traditional Wood Products, Wood Exports, and Firewood.** Use of wood by New York's large and small sawmills, wood chip producers, pulp/paper producers, and for net wood exports, is significant, totaling 2.3 Mdt in 2007. Despite the general decline in recent years experienced by the Northeast's sawmill and pulp/paper industries from their highest levels of production,<sup>19</sup> these industries still make up the largest demand for woody biomass feedstock in New York. In addition to the wood that industrial wood product facilities use as feedstock for their products, many pulp mills and board facilities also have large multi-fuel boilers that can be significant consumers of biomass fuel. More information on competing uses for biomass in New York can be found in Appendix O and Appendix P.

The market for firewood is also a significant source of demand for New York woody biomass resources, although the informal nature of this market makes accurate estimates of firewood production quite difficult. The demand for wood from the firewood market is more than 60% of the market for industrial uses, or equal to approximately 1.6 Mdt in 2007 (personal communication -- Sloane Crawford, NYSDEC). In summary, New York's wood consumption by industrial users, and for firewood, totaled nearly 4 Mdt in 2007.

**2.4.1.2 Electricity Generation.** As shown in Table 2-4, there are two biomass electricity plants in New York and another plant in close proximity to the New York border in Burlington, Vermont. The two New York plants total nearly 40 MW in capacity, and require about 0.5 million green tons<sup>20</sup> (Mgt) of biomass annually. The McNeil plant in Burlington has a capacity of 50 MW, which is relatively large for a biomass electricity plant, and requires nearly 0.7 Mgt of biomass each year. A new, 9.6 MW biomass CHP system is expected to be operational at a business park in Rome, NY in early 2010. Together, biomass demand from these plants totals approximately 1.3 Mgt (equivalent to approximately 0.8 Mdt).

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<sup>19</sup> In 1999, New York produced 900 million board feet (mbf) of lumber; by 2003, lumber production had declined to 650 mbf (NYSDEC 2007).

<sup>20</sup> A term used in the forest products industry for a U.S. ton or metric ton (tonne) of freshly cut timber, bark mulch, i.e., undried biomass material. A dry ton weighs less than a green ton (conversion used in the Roadmap: dry tons are calculated as 60% of green tons).

**Table 2-4. Biomass Electricity Plants In and Near New York State**

Location	Plant	Capacity (MW)	Woody Biomass Demand (green tons)
Chateaugay, NY	Boralex	20	268,000
Lyonsdale, NY	Catalyst Renewables	19	254,600
Burlington, VT	McNeil/Burlington Electric	50	670,000
Rome, NY*	Griffiss Business Park CHP	9.6	140,000
<b>Totals</b>		<b>98.6</b>	<b>1,332,600 green tons (0.8 Mdt)</b>

Sources: INRS 2008.

\*This plant is scheduled to come on-line in early 2010.

In addition to the plants shown in Table 2-4, a few additional biomass electricity plants are under development in the region. Currently, it can be difficult for biomass plant developers to secure the long-term contracts for biomass supply that are necessary to obtain capital financing for plant construction. In addition, when compared to coal on a current cost per unit of energy basis, biomass fuel is still more expensive, although incentives provided by state renewable energy programs in some cases counterbalance the cost disadvantages of biomass.

Although large-scale biomass electricity plants in the region face some challenges, a growing opportunity for biomass generation is combined heat and power (CHP), which is an efficient use of biomass for heat and electricity and generally occurs at a smaller scale.

Within New York there is substantial growth potential for CHP systems. If a majority of future CHP systems are fueled by biomass, they could demand as much as 3-7 Mdt of feedstocks per year. Currently, only one percent of CHP systems in New York are fueled by biomass, so whether new CHP systems will use biomass is difficult to predict. However, future biomass CHP growth in the state warrants continued monitoring. For more detail see Appendix P.

## **2.4.2 Emerging Users**

**2.4.2.1 Electricity Generation.** Co-firing with biomass is currently the only low-cost opportunity for direct GHG reductions by RGGI coal plants.<sup>21</sup> For many of these plants, the capital costs to retrofit for co-firing are only a fraction of that required to fully convert a plant over to biomass-based generation. Table 2-5 shows the biomass needs associated with all New York RGGI coal plants and those within 50 miles of New York in surrounding states and Ontario, at levels of co-firing of 2.5%, 5%, and 10%.<sup>22</sup> Two of these

<sup>21</sup>Compliance with the RGGI program can also be achieved through the use of credits from GHG offset projects.

<sup>22</sup> Biomass demand levels in Table 2-5 assume 13,400 green tons of biomass per MW, and a 95% plant capacity.

plants, AES Greenidge and Niagara Generating Facility, are in fact already co-firing with biomass.<sup>23</sup> Demand for biomass to support co-firing at all of these plants even at a 2.5% level would be formidable, equaling 4.3 million green tons (or 2.6 Mdt), roughly equal to the volumes used by the entire New York wood products industry. Co-firing at a level of 10% is much less likely due to engineering constraints, but would require even higher levels of biomass, nearly 17 million green tons (or 10 Mdt) if all RGGI plants listed were to shift to co-firing.

As explained earlier in this report, current fuel prices and GHG policy drivers alone are probably not yet compelling enough for many of these plants to invest in co-firing. As it is one of the few GHG-reduction opportunities for coal-fired plants, however, some plant owners are likely to invest in co-firing capabilities as a hedge against more stringent GHG requirements in the future. Thus, demand for biomass co-firing as a GHG mitigation strategy for coal-fired power plants could be a significant source of growth in demand for New York's woody biomass in coming years. Additional discussion of electricity generation as a competing use of biomass in New York can be found in Appendix O and Appendix P.

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<sup>23</sup> The Niagara plant also co-fires with tires in addition to woody biomass.

**Table 2-5. Northeast RGGI and Ontario Coal Plants**

State	RGGI Coal Plants	Capacity (MW)	Biomass Demand 2.5% co-fire (green tons) <sup>a</sup>	Biomass Demand 5.0% co-fire (green tons)	Biomass Demand 10% co-fire (green tons)
Connecticut	AES Thames	214	71,657	143,313	286,626
	Bridgeport Station	582	194,836	389,672	779,344
Massachusetts	Brayton Point	1,611	539,652	1,079,303	2,158,606
	Mount Tom	136	45,560	91,120	182,240
	Somerset Station	199	66,665	133,330	266,660
New Jersey	PSEG Hudson Generating Station	1,114	373,324	746,648	1,493,296
	PSEG Mercer Generating Station	768	257,280	514,560	1,029,120
New York <sup>b</sup>	AES Cayuga	323	108,038	216,075	432,150
	AES Greenidge	163	54,605	109,210	218,420
	AES Somerset LLC	655	219,459	438,917	877,834
	AES Westover	119	39,798	79,596	159,192
	Black River Generation	56	18,593	37,185	74,370
	C R Huntley Generating Station	816	273,360	546,720	1,093,440
	Danskammer Generating Station	537	180,029	360,058	720,116
	Dunkirk Generating Station	627	210,112	420,224	840,448
	Kodak Park Site	201	67,168	134,335	268,670
	Niagara Generating Facility	56	18,760	37,520	75,040
	S A Carlson	101	33,835	67,670	135,340
	Trigen Syracuse Energy	101	33,869	67,737	135,474
Ontario	Nanticoke Generating Station	3,640	1,219,400	2,438,800	4,877,600
<b>TOTALS</b>		<b>12,018</b>	<b>4,025,996</b>	<b>8,051,993</b>	<b>16,103,986</b>
	<b>Dry tons</b>		<b>2,415,598</b>	<b>4,831,196</b>	<b>9,662,392</b>

Sources: EPA EGrid database, Regional Greenhouse Gas Initiative, and NESCAUM analysis, 2009.

<sup>a</sup> Dry tons are calculated as 60% of green tons.

<sup>b</sup> The definition of eligible biomass as it pertains to sustainable harvesting will affect the likelihood of New York's 12 coal-fired RGGI plants to co-fire with woody biomass. Guidance on this matter in New York is under development by the NYSDEC. To ensure RGGI facilities are achieving CO<sub>2</sub> reduction benefits, NYSDEC's preliminary guidance includes requirements that could substantially limit the quantity of woody biomass used as a CO<sub>2</sub> compliance mechanism for co-firing in New York's RGGI facilities.

**2.4.2.2 Heating Fuels.** In addition to biomass electricity, another probable growth area for New York biomass demand is as a feedstock for producing heating fuels. As mentioned earlier, New York's production of firewood, a traditional wood heating fuel, is estimated to be more than 60% of industrial needs and a relatively steady and significant use of wood. Wood pellets, used extensively in Europe for many years, are a relatively new type of heating fuel in the U.S., and pellet stoves are gaining popularity as an alternative to oil heating in the Northeast. Demand for wood as a heating fuel, either as firewood or in pellet form, historically has been highly sensitive to the price of heating oil in the Northeast. Because the

region's heavy dependence on oil as a heating fuel exposes consumers to the volatility of prices for a commodity the cost of which is controlled by global markets, wood is increasingly seen as an option that increases the Northeast's energy security.

Another reason that pellet fuels are a likely growth area for New York's biomass sector is that new pellet plants are relatively simple manufacturing operations, and do not require large capital investments to establish. In addition, in this region pellet plants are generally built at a scale (e.g., 100,000 green tons per year or less) that does not require biomass supplies at the levels required by even small biomass electricity plants. Therefore, they are generally relatively easy to finance and as yet have not been prone to substantial community opposition.

Table 2.6 shows existing and pending pellet facilities in New York and nearby in Pennsylvania. In total, these 12 facilities require less than 0.6 Mgt/yr.<sup>24</sup> In 2009, New England Wood Pellet announced the addition of another pellet facility in Deposit, New York (Delaware County), which will be a 100,000-ton/yr facility. In addition, a very large pellet plant (more than one million green tons per year) has been proposed for Cornwall, Ontario. If this plant is eventually built, it could seek as much as one-third of its biomass requirements from New York (NYSDEC 2009). Additional discussion of pellet facilities as a competing use of biomass in New York can be found in Appendix O and Appendix P.

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<sup>24</sup> A few of the pellet facilities in Pennsylvania are currently using sawmill residues as feedstocks, but could shift to virgin biomass if mill residues become more scarce.

**Table 2-6. Woody Biomass Demand from Wood Pellet Facilities In and Near New York State.**

<b>State</b>	<b>Location</b>	<b>Company</b>	<b>Biomass Consumption (green tons)</b>
New York	Lafargeville	Associated Harvest Co.	10,000
	Arcade	Dry Creek Products	50,000
	Schuyler	Schuyler Wood Pellet	100,000
	Massena	Curran Renewable Energy LLC	10,000
	Addison	InstantHeat Wood Pellets, Inc.	50,000
	Stamford	Hearthside Wood Pellets	10,000
	Deposit*	New England Wood Pellet	100,000
		<b>NY Total</b>	<b>330,000</b>
Pennsylvania	Nazareth	Treecycle	145,000
	Marion	AJ Stoves & Pellets	n/a
	Ulysses	PA Pellets, LLC	80,000
	Troy	Barefoot Pellet	70,000
	Youngsville	Allegheny Pellet Corp.	60,000
<b>PA Total</b>			<b>355,000</b>
<b>PA and NY Totals (green tons)</b>			<b>685,000</b>
<b>PA and NY Totals (dry tons)</b>			<b>411,000</b>

Source: Sloane Crawford, NYSDEC -- personal communication; various pellet manufacturers, 2009; INRS 2008.

Note: Dry tons are calculated as 60% of green tons.

\* Anticipated opening last quarter 2010

## 2.5 CURRENT STATUS OF BIOMASS-TO-LIQUID FUEL CONVERSION TECHNOLOGIES

This sub-section focuses on technologies that convert solid biomass to liquid fuels and are most likely to be available for commercial scale production in the 2015 to 2025 time period. Fifteen biofuel conversion technologies are evaluated here (for more detail see Appendix H). The sheer number of technologies under development suggests a high level of interest and diversity of approaches being taken to commercialize biofuels. Many of the technologies also require some degree of pretreatment of the biomass feedstock in preparation for the conversion process. Table 2-7 describes pretreatment requirements for selected conversion technologies.

**Table 2-7. Pretreatment Requirements for Selected Biofuel Conversion Technologies**

Conversion Technology	Pretreatment Description	Required Moisture Content (% by weight)	Required Biomass Material Size
Grain to ethanol - dry mill	Milling to a fine flour	--	fine
Grain to ethanol - wet mill	Steeping	--	--
Fatty acid to methyl ester (FAME)	Filtering, dewatering	~ 0%	--
Lignocellulosics to ethanol - fermentation/hydrolysis <sup>1</sup>	Cleaning <sup>2</sup> , sizing and milling, dilute acid hydrolysis	--	1-3 mm
	Cleaning <sup>2</sup> , sizing, steam explosion	--	19 mm
	Cleaning <sup>2</sup> , sizing, liquid hot water	--	19 mm
Lignocellulosics to middle distillates - Fischer Tropsch <sup>3</sup>	Sizing, drying	10-15 %	6-13 mm
Lignocellulosics to gasoline - upgrading/ pyrolysis	Sizing, drying	5-10 %	2 mm
Fatty acids to hydrocarbon-hydrotreatment	Combination of filtering, dewatering, acid-washing, deionizing, desalting	~ 0%	--

1) This process has a dryer to remove moisture from solid residuals before used for heat – usually available at moisture content of 60%, dried to 15%.

2) Cleaning is not required for all feedstocks. For example, debarked forest residues generally do not need to be cleaned, while agricultural residues such as corn stover need to be washed.

3) The required material for gasification depends on the gasifier type and the feedstock.

Brief explanations, process descriptions, estimated cost, performance, benefits and challenges for each of these conversion technologies are provided in Table 2-8. Three of the technologies shown in Table 2-8 (grain ethanol dry mill, grain ethanol wet mill, and sugar-to-ethanol fermentation) are currently in commercial use. Technologies that are already moving beyond the pilot phase into the demonstration stage are designated as “near-term” technologies. Those technologies that are expected to be moving into the

demonstration phase around the 2015 to 2025 time period are designated as “advanced” technologies. The costs are given based on capacity of the system; due to economies of scale, larger systems tend to have lower average costs of production.

**Table 2-8. Conversion Technology Status Matrix- Gasoline Fuels Market** (for additional details see Appendix H: Technologies for Biofuels Production)

Name	Feedstock	Conversion Technology	Fuel Type Produced	Status	Year 2020- non feedstock cost and performance analysis model result <sup>25</sup>	Benefits	Key challenges
<b>PRODUCTION OF BIOFUELS FOR THE GASOLINE FUELS MARKET</b>							
Grain ethanol - Dry mill	Grains/starches	Enzymatic fermentation	Ethanol	Commercial	50,000 ton/y \$0.58/gal  1,000,000 ton/y \$0.36/gal	Commercial technology- many facilities already operational and in construction	Feedstock competition with food products, net energy balance lower than cellulosic ethanol, limited opportunity for improvements
Grain ethanol - Wet mill	Grains/starches	Separation & fermentation	Ethanol	Commercial	560,000 ton/y \$0.33/gal  3,360,000 ton/y \$0.12/gal		
Sugar to ethanol fermentation	Sugars	Fermentation	Ethanol	Commercial	Not modeled	Commercial technology; more efficient than conversion of starches	Limited feedstock availability in North America
Lignocellulosics to ethanol- Hydrolysis/Fermentation	Lignocellulosic biomass	Enzymatic hydrolysis & fermentation	Ethanol	Demonstration - pilot plants operating, more planned in 5 years	Not modeled	Relatively low maintenance cost, potentially high yield	Cellulase cost must be reduced. Enzymes sensitive to poisoning
	Lignocellulosic biomass	Acid hydrolysis & fermentation	Ethanol	Demonstration plants planned for operation within 5 years	700,000 ton/y \$0.68/gal  1,160,000 ton/y \$0.63/gal	Technically mature -dilute acid process is oldest cellulosic ethanol technology	Expensive vessels, high maintenance (corrosion). Needs large amounts of gypsum for disposal. Requires improved acid recovery
Lignocellulosics to ethanol - gasification/fermentation	Lignocellulosic biomass	Gasification & fermentation	Ethanol	Demonstration plants planned for operation within 5 years	Not modeled	Higher yield/ton than direct fermentation (Note 1)	See Note 2

Table continued next page

<sup>25</sup> The costs are given based on capacity of the system and due to economies of scale, larger systems tend to have lower average costs of production.

Table 2-8 (Continued)

Name	Feedstock	Conversion Technology	Fuel type produced	Status	Year 2020- non feedstock cost and performance analysis model result	Benefits	Key challenges
Lignocellulosics to mixed alcohol- gasification/ thermocatalysis	Lignocellulosic biomass	Gasification & thermochemical conversion	Mixed Alcohols	Demonstration plants planned for operation within 5 years	185,000 ton/y \$1.04/gal  1,500,000 ton/y \$0.28/gal	Mixed alcohols are easily blended with gasoline. See note 1.	See note 2, catalysts sensitive to deactivation from sintering. Process requires improved yields. Potential groundwater contamination from mixed alcohols usage
Lignocellulosics to butanol-hydrolysis/fermentation	Lignocellulosic biomass (e.g., Wheat straw)	Thermochemical conversion or multistage fermentation	N-butanol, Iso-butanol	Demonstration operating. Commercial plants by late 2009.	442,478 ton/y \$1.86/gal  1,327,434 ton/y \$0.94/gal	Butanol is high-octane, pipeline-transportable, and energy-dense.	Compatibility with existing motors not proven beyond 16% blends. Toxicity to humans
Hemicellulose to ethanol: pulp and paper application	Hard and soft woods	Hot water extraction hydrolysis & fermentation	Ethanol	Not yet to pilot phase	2,539,683 ton/y \$3.17/gal  634,921 ton/y \$3.99/gal	Increases value of hemicellulose as a feedstock	Fermentation studies not performed. Probable high water use. High purity water is a by-product
Lignocellulosics to gasoline-Pyrolysis/hydrotreating	Lignocellulosic biomass	Pyrolysis oil production & upgrading via hydrotreatment-hydrocracking	Bio-oil, diesel, gasoline	Development of process chain began in June 2006, concept develop. by 2011	30,000 ton/y \$6.20/gal  800,000 ton/y \$2.90/gal	Using refinery technologies already in place, ease of adoption into current infrastructure	In early development stages. Refinery integration issues
High moisture biomass: biorefinery heat & power	Biorefinery byproducts and Ag. wastes	Digestion or gasification	Methane, syngas	Digesters commercially operating. Gasification still at bench scale.	Not modeled	Averts disposal costs, allows integration of animal farms and food processing plants with biorefineries.	Significant purification costs for turbine-combustible gas Gasification technology not well demonstrated

Table continued next page

Table 2-8 (Continued)

Name	Feedstock	Conversion Technology	Fuel type produced	Status	Year 2020 – non feedstock cost and performance analysis model result	Benefits	Key challenges
<b>PRODUCTION OF BIOFUELS FOR THE DIESEL FUELS MARKET</b>							
Fatty acid methyl ester	Seed oil, waste oil, animal fats	Esterification	Methyl esters	Commercial	5,000 ton/y Virgin oil - \$0.78/gal Waste oil - \$1.47/gal  310,000 ton/y Virgin oil - \$0.31/gal Waste oil - \$0.76/gal	Ease of conversion, can be used in diesel engines, significant heating oil market	Relatively small scale. Limited opportunity for process improvements Cold weather technical issues
Lignocellulosics to middle distillates Fischer Tropsch	Lignocellulosic biomass	Gasification and Fischer Tropsch synthesis	Middle distillates gasoline	Pilot facilities in operation, and demonstration facilities planned for 2009.	185,000 ton/y \$4.12/gal  1,500,000 ton/y \$2.07/gal	FT diesel can be substituted directly for conventional diesel with lower emissions. Note 1	See note #2. Catalysts sensitive to poisoning and sintering. Requires improved yields
Black liquor conversion to middle distillates or DME	Pulp mill byproducts	Gasification and synthesis	FT liquids (FTL) or, dimethyl ether (DME)	Pilot and demonstration facilities operating	250,000 ton/y FTL \$1.33 - 2.24 (3) DME \$0.58 - 1.31  750,000 tons/y FTL \$0.91 - 1.54 DME \$0.40 - 0.91	Involves no land conversion events; significant feedstock supply, leverages existing pulp mill equipment	Complex capital-intensive process Technology not well demonstrated Pulp industry has little free capital
Algae to biodiesel (methyl ester)	microalgae	Pressing and esterification	Renewable diesel	Several demonstration facilities operating, commercial facilities planned	Not modeled	High potential yields per acre could be integrated with power plants to sequester carbon	Technology not commercialized yet High production cost, high capital cost/productivity trade off
Fatty acids to diesel fuel-hydrotreatment (green diesel)	Seed oil, waste oil, animal fats	Upgrading via hydrotreatment	Renewable diesel	Pilot facilities in operation, others are planned	20,000 ton/y Skid-mount \$1.17/gal Co-process \$0.32/gal  785,000 ton/y Skid-mount \$0.28 800,000 ton/y Co-process \$0.18	Using refinery technologies already in place, ease of adoption into current infrastructure	In early development stages Refinery integration issues

1) High range of feedstock flexibility. Intermediate product from gasification can be used for broad slate of end-products (i.e., fuels, power, heat, etc.)

2) Gasification requires dried biomass. High level of syngas clean-up required.

3) Lower cost in range is based on using a retrofitted gasifier, while higher cost is based on building the entire plant.

Most of these biomass conversion technologies require water. Water use was estimated for selected conversion technologies based on the conversion technology models or available data in the literature, and are shown in Table 2-9.

**Table 2-9. Water Use for Various Biomass Conversion Technologies\***

<b>Technology</b>	<b>Feedstock</b>	<b>Water Use *** (gal / gal product)</b>
Grain to Ethanol (Dry Mill)	Grains	4.7
Grain to Ethanol (Wet Mill)	Grains	24.4
Fatty Acid Methyl Ester (FAME) Biodiesel	Virgin Oil	0.03
	Waste Oil	0.03
	Animal Fat	0.03
Lignocellulosic ethanol (LCEt) Fermentation / Enzymatic Hydrolysis (dilute acid pretreatment)	Wood Chips (hardwood)	6.2
	Wood Chips (softwood)	5.9
	Corn Stover / Ag Residues	6.6
	Wheat Straw / Ag Residues	7.0
	Switchgrass / HEC	6.9
Lignocellulosics to middle distillates Fischer Tropsch (LCMD) - Fischer Tropsch	Wood Chips (hardwood)	1.2
	Wood Chips (softwood)	1.1
	Corn Stover / Ag Residues	1.3
	Wheat Straw / Ag Residues	1.2
	Switchgrass / Herbaceous energy crops	1.3
Lignocellulosics to gasoline** (LCGa) - Upgrading/Pyrolysis	Clean Wood Chips	8.2
	Softwood	8.9
	Bark	9.8
Fatty acids to diesel** hydrotreatment (stand-alone) (co-processing)	Vegetable Oil or Animal Fat	0.0
	Vegetable Oil or Animal Fat	0.0

\* Antares (2008)

\*\* Sheehan et al. (1998).

\*\*\*While the total water embodied in a gallon of ethanol has decreased in recent years, this embodiment is largely driven by irrigation water use, rather than conversion facility process water use (Suh et al., 2009). According to Suh et al. (2009), average process water consumption for corn ethanol facilities (both wet and dry mills) in the U.S. is 3.3-4 gallons per gallon ethanol. This is a net, rather than absolute, value and does not distinguish between dry and wet mills, so the most recent value available that did differentiate mill types (Shapouri and Gallagher, 2005) was used. This may present an overestimate due to progress made in water consumption reductions over the past four years.

There is no guarantee that early demonstrations will be successful or that technologies that appear to be in early phases of development will not make a breakthrough earlier than expected. Further, other conversion technologies and fuels that do not strictly meet the product or timeline constraints of this assessment could potentially be incorporated in the transportation market in the future. For example, there is a potential for the use of compressed biogas as an alternative to natural gas for buses or specialized fleets. Biogas can be generated from manure and wastes via anaerobic digestion, and is also a by-product from landfills. For more detailed information on the conversion technologies described here, see Appendix H.

### 3.1 VISION STATEMENT FOR A RENEWABLE FUELS INDUSTRY IN NEW YORK STATE

#### **3.1.1 Purpose of Developing a Vision Statement**

The purpose of developing a vision for the Roadmap was to define the key conditions to be addressed by an analysis of a future biofuels industry path, including constraints on some approaches. The vision process included presentations on renewable fuels and biofuels in New York; discussion and prioritization of technology, market, policy, and institutional issues that affect renewable fuels and biofuels development in the State; and agreement on a vision for more robust market development and deployment of biofuels in New York.

#### **3.1.2 Achieving the Renewable Fuels Vision for 2030**

The Pace Energy and Climate Center and Energetics Incorporated coordinated a NYSERDA-sponsored one-day Renewable Fuels Vision Meeting in Albany, New York on January 29, 2009 (Appendix C). The goal of the vision meeting was to create a cohesive, unified vision for biofuels in New York State that could serve as a realistic, vetted, guide to the development and design of the Roadmap's Future-Scenario analyses. A cross-section of 48 experts representing key stakeholder groups, institutional organizations, and end-users of renewable fuels participated in the meeting. These individuals have the expertise and vision to help identify the long term goals of a successful, sustainable New York biofuels industry.

#### **3.1.3 Vision Statement**

In order to define key conditions for the Roadmap's Future-Scenario analyses, the following vision was crafted at the workshop, representing a shared view of the future for biofuels development in New York:

*By 2030, New York State will have a vibrant, world-class biofuels industry that*

- Uses its highly diverse state and regional biomass feedstocks in the most sustainable manner possible;
- Cost-effectively and significantly reduces New York State greenhouse gas (GHG) emissions and petroleum imports while improving environmental quality;
- Establishes New York State as the leader in education and technology research, development, and deployment (RD&D), making ongoing contributions to enhanced sustainability and the development of *fuels that are almost chemically identical to conventional fuels but are significantly cleaner to use and that release minimal CO<sub>2</sub>. (These fuels are commonly termed 'next generation' fuels.)*;
- Significantly contributes to economic revitalization throughout New York State, ensuring stable and secure communities; and
- Employs an efficient supply and distribution infrastructure to provide an economical, reliable fuel supply for all New Yorkers.

### **3.1.4 Challenges to Achieving This Vision**

Challenges to achieving this vision include:

- Overcoming the technological barriers to using cellulosic biomass at a commercial scale;
- Lowering the costs for biofuels through simple pre-treatment and technologies such as consolidated bio-processing;
- Building demonstration plants to test scaled-up technologies and to verify the environmental, economic, and technological benefits;
- Gaining public, political, and academic support; and
- Engaging the agricultural industry and forest community to produce feedstocks.

Achieving the 2030 biofuels vision for New York State will require attention to many priorities—both new initiatives and ongoing efforts that require additional resources—as identified by stakeholders across the industry. For more information and a listing of specific opportunities and challenges identified see the Vision Meeting Proceedings (Appendix C).

## **3.2 STAKEHOLDER AND PUBLIC INPUT MEETINGS SUMMARY**

### **3.2.1 Purpose of Stakeholder and Public Input Meetings**

The purpose of the stakeholder meetings was twofold. The meetings were used to provide information about the topics, considerations, and planned research approach to New York stakeholders and the general public in developing the Roadmap. The meetings also provided the opportunity to obtain feedback and data through a listening session, written general comments and a written Sustainability Criteria survey.

### **3.2.2 Approach and Format**

In order to inform stakeholders about the Roadmap topics and to obtain feedback on issues important to New York stakeholders, a series of 11 New York Stakeholder workshops were held from February 2009 to May 2009. The meetings were hosted through Cornell Cooperative Extension offices in the upstate, Southern Tier and Western New York region county offices (Oneida, Chautauqua, Washington, St. Lawrence, Tompkins, Steuben/Chemung/Schuyler, and Orange counties), two Pace University locations (White Plains and Manhattan), and one SUNY Stony Brook location on Long Island. Workshops were advertised by the hosting facility, through Cornell University and through Pace Energy and Climate Center Websites and flyers. An introduction to the Roadmap team and overview of the Roadmap approach was provided at all meetings. Following the informational session, participants were asked to complete a survey ranking sustainability criteria and to list the top five most important issues regarding biofuels, in their opinions. The results of this survey were needed to support the sustainability analysis conducted for the Roadmap (Appendix K).

### **3.2.3 Meetings Summary**

**3.2.3.1 Participants.** There were approximately 30 participants per meeting (range 20 to 42). Participants represented the agricultural industry, forest industry, renewable fuels industry, local governments, State and Federal research organizations, and academia. Additional details on participant background, (such as age, region of residence, and industry affiliation) were collected through the Sustainability Criteria survey.

**3.2.3.2 Issues of Concern (verbal and written comments).** Based on workshop feedback and written comments submitted at the end of the workshops, some common themes of concern emerged. The following topics were raised most frequently by participants:

- **Property owner rights** A number of participants were concerned about maintaining the right to use their private lands in a manner that they determine best. There was concern that the Roadmap might suggest a plan that would pose a threat to these rights. At each meeting, there was the need to emphasize the fact that the Roadmap sponsors and investigators were not advocating for a liquid biofuels industry, but rather were seeking information and input through the Roadmap project.
- **Food security** The concern of replacing food crops with fuel crops was expressed at each meeting, with one group summing up its priorities for New York biomass as follows, “First food, second heat, then...if there is anything remaining, we can consider liquid transportation fuels.”
- **Environment** There was strong concern that New York’s natural resources, especially biomass, soil and water, be used in an efficient manner with respect to choices of energy types (heat, power, liquid fuels). Among the energy use options, there was a strong preference for using solid biomass feedstocks for home heating needs as a priority over liquid transportation fuels.
- **Decentralized industry structure** In every workshop, participants strongly preferred a more locally distributed or decentralized industry structure over a large, centralized structure. In the Adirondacks region there was strong concern that biomass might be grown in the region, then shipped for use elsewhere as a result of much of the land in this region being owned by non-residents.
- **Cost of production and need for technology improvements** Participants expressed the view that biofuels in general “will not work” unless the technology could be advanced to the point that everyone along the production chain (feedstock to fuel pump) can achieve profitability without government subsidies.

**3.2.3.3 Stakeholder Input Espousing the Potential for a New York Biofuels Industry.** In addition to the concerns listed above, participants at the workshops also expressed interest in the potential for a New York biofuels industry. The following topics were raised most frequently by participants favoring the potential for a biofuels industry in their region:

- New ways to integrate energy into farming The farming community was well represented at most of the workshops and many individuals identified themselves as being present because of an interest in finding new ways to integrate energy systems into existing farming systems.
- New business and technology concepts The workshops also attracted participation of several small businesses. At one workshop, farmers lined up to speak with an industry representative describing a new feedstock collection business model. At another workshop the host organization arranged for a new combustion technology to be demonstrated. While interest in new concepts was high, so was the level of caution in adopting the new directions discussed.
- Greener fuels Many participants expressed strong interest in the concept of New York producing greener fuels as a new industry. Many participants also mentioned renewable energy projects, meetings and initiatives underway in their areas.

#### **3.2.4 Planned Follow-up with Stakeholders Over the Next Two Years (for Roadmap updates)**

Workshop participants were advised to follow up with the host-center for updates, such as public release of the Roadmap report and future opportunities to provide feedback and input through a Website format. For additional information on the stakeholder meetings and input, see Appendix D.

The following section describes the Sustainability Criteria survey taken at the stakeholder workshops and through internet-based systems.

### **3.3 IDENTIFYING AND ASSESSING BIOFUEL SUSTAINABILITY CRITERIA FOR NEW YORK**

#### **3.3.1 Understanding Sustainability as a Scientific and Social Process**

Sustainability is an idea that is widely discussed as being important by diverse groups of people. However, there is a lack of agreement on what is meant by sustainability. Much of this controversy occurs because sustainability is based on many worldviews rooted in human values. There is broad agreement that sustainability should include environmental, social and economic components, but there is often disagreement on how these components should be weighted. Also, the multiple perspectives encompassed in the concept of sustainability are subject to frequent changes across time and space. Moreover, the assessment of many of these aspects is subject to scientific uncertainties. Finally, there is often disagreement about knowing when a system is sustainable. One way to measure sustainability is to assess whether a future system will generate more benefits and have fewer negative impacts than its predecessor. This process focus requires that a cyclical and ongoing system of monitoring, assessment and modifications is implemented and maintained so that trends can be detected.

Discussing sustainability for a complex system such as biofuels is complicated in that the biofuels industry consists of different components. These components include feedstock production, conversion technology, fuel distribution, and end use, and each component engages different groups with diverse worldviews and

values. For instance, while feedstock producers are familiar with the challenges of their component of the whole process, they are generally less concerned and knowledgeable with issues related to conversion technology. In order to address the issue of sustainability of a New York biofuels industry, this broad array of views needs to be understood and orchestrated. The focus of this portion of the Roadmap was to (i) identify through a survey the components of sustainability that are important to New York biofuels stakeholders, (ii) determine the level of agreement among stakeholders on these components, (iii) assess what components currently are being addressed through federal, state or local laws and regulations, and (iv) analyze which sustainability issues identified as being important by New Yorkers can realistically be assessed.

One of the most common approaches to conducting a sustainability assessment is choosing criteria that reflect these values and identifying indicators that can measure those criteria with the latest scientific knowledge. This “Criteria and Indicator” approach has been developed and applied in forestry for over 15 years through organizations such as the Forest Stewardship Council (FSC) or the Sustainable Forestry Initiative (SFI). Experts around the world are developing similar sustainability assessment frameworks for bioenergy. The work of the Council on Sustainable Biomass Production (CSBP) is relevant to the U.S. The CSBP has undertaken an effort to develop a criterion-based certification system for biomass production (Appendix K). Such certification systems can be summarized in 35 criteria, which are proposed to adequately assess the sustainability of biofuel systems. Nevertheless, there is little consensus among experts on the importance of these criteria or how they should be applied in different contexts. Therefore, in order to develop a sustainable biofuels industry in New York it is critical, as a first step, to understand what issues are important to New York stakeholders. The selection and significance of these criteria can vary depending on individual values, geographical region, and attributes on spatial scale. For example, one sustainability criterion that has been in the news lately is the Food Security issue. With the current state of our knowledge, there is no single metric that can be applied to determine whether a given piece of land would be best used for food or fuel production, or some combination. Thus, efforts in planning a biofuels industry must seek input and consider the values of local stakeholders and assist in creating sustainability norms.

### **3.3.2 New York Biofuels Sustainability Survey**

Approximately 400 New York stakeholders, including 70 biofuel experts, were surveyed on their opinions regarding the relative importance of the 35 internationally recognized sustainability criteria as they relate to a New York biofuels industry. These criteria address the entire biofuel system including feedstock production, conversion technology, and energy distribution, and incorporate a range of environmental, economic and cultural aspects of biofuel sustainability. (For in-depth description and origin of these criteria see Appendix K). All New York regions were represented among the survey respondents, but the majority of respondents (281) identified themselves as rural residents. Participants were asked to rate

criteria on their importance. In addition, experts were asked to rate the practicality (or feasibility) of each criterion for measurement and monitoring with existing knowledge, tools and regulatory frameworks.

### **3.3.3 Ranking of Sustainability Criteria Among Groups in New York**

Overall, survey results indicated that all of the 35 sustainability criteria are important to the broad range of stakeholder respondents. The average importance rating for each of the 35 criteria was equal to or greater than 4.3 on a scale from 1-6 with 6 being “very important.” The criteria with the highest importance scores included *Natural Resource Efficiency*, *Soil Protection*, *Water Management*, *Support for Research and Development*, *Energy Balance*, and *Food Security*. However, each criterion received a score of 6 (highest importance) from at least 74 respondents. In other words, all the lowest rated criteria were heavily disputed, i.e., many respondents scored these criteria low, while a minority of respondents scored them very high. These disputed criteria included *Cultural Acceptability*, *Respecting Minorities*, *Social Cohesion*, *Use of Genetically Modified Organisms*, and *Local Nuisances*. The results suggest that all 35 criteria should be included in a biofuels sustainability framework for New York State.

### **3.3.4 Consensus on Criteria Importance**

Survey respondents were further categorized into subgroups based on several factors, including their stated level of knowledge about biofuels/renewable energy, area of residence in New York State, professional background, and scale of interest in biofuels (local, state, national). Among 18 of 20 subgroups, there were sets of criteria that were consistently ranked among the most important, including *Natural Resource Efficiency*, *Energy Balance*, *Support for Research and Development*, *Water Management*, and *Potentially Hazardous Atmospheric Emissions Other Than Greenhouse Gases*. Results also suggested significant differences in the criteria deemed important between stakeholders from a background in conservation or policy and those from a background in academia or project development and implementation. There was no significant discrepancy in the importance of sustainability criteria between urban, suburban and rural residents.

### **3.3.5 Practicality of Assessing Criteria**

In addition to indicating importance of a criterion, participants were also asked to rank the practicality of measuring that particular criterion. Results suggested that criteria with high importance ratings also had high practicality ratings, with the exception of *Participation*, *Monitoring of Criteria Performance*, *Food Security*, and *most notably*, *Property Rights and Rights of Use*. Although these criteria were ranked low in practicality, they are addressed to a certain extent by existing laws, regulations and/or guidelines for best management practices (Appendix K) and therefore may not be of primary concern to advanced biofuel sustainability assessments in New York. By contrast, several criteria rated low in terms of practicality – including *Respect for Human Rights*, *Standard of Living*, *Land Use Change*, and *Energy Balance* – lack an

existing legal and/or regulatory framework in New York. Developing guidelines for how to assess these criteria may be a priority to assess sustainability of biofuels in New York.

### **3.3.6 A Suggested Definition for Sustainable New York Liquid Biofuels**

Biomass systems can be sustainable only if they are able to perform effectively under changing conditions that can be either internal or external to the system, such as changing human needs or values, variations in climate, or shifts in the economy, or policy and regulations. The resulting inherent complexity under which these systems need to perform requires them to maintain a high resilience or adaptive capacity over time. Sustainability therefore needs to be understood as an ever-changing process rather than a single specific goal that can be decided upon once and for all. Broad examples of measures that strengthen adaptive capacity include increased diversity or access to information. These measures, in turn, increase the system's sustainability.

A liquid biofuel system includes feedstock production, conversion, and end use. The following suggested definition of sustainability is intended only for liquid biofuels that are produced in New York State:

*Sustainable liquid biofuels are developed, grown and produced through a deliberate planning and monitoring process that draws on extensive knowledge and current scientific understanding to maximize a mixture of environmental, economic, and social benefits. This process engages stakeholders, considers diverse feedstocks and technologies, and incorporates adaptive mechanisms necessary to respond to environmental, economic, and societal changes. The result of this process is a reliable source of liquid fuel that is supported by a range of stakeholder values throughout time.*

*Sustainable biomass production and its conversion to liquid fuels create new job opportunities, especially in rural areas; has a favorable energy balance; enhances New York's economy; maintains or improves desirable environmental conditions for future generations; contributes to resilient ecosystems that can adapt to changing external and internal forces; and can be produced in a sustained yield manner, i.e., no decrease in feedstock productivity is expected over time. Sustainable liquid biofuels use improves New York's overall soil, water and air quality, including greenhouse gas emissions, reduces dependence on outside sources of energy, and their consumption is tied into larger energy conservation and efficiency efforts that continuously improve end use technologies.*

### **3.3.7 The Need for a Comprehensive Framework to Assess Biofuel Sustainability on a New York State Scale**

Survey results underscore the need to refine and prioritize criteria for biofuel sustainability in New York. The importance of a participatory process in continuing the development of a system for monitoring,

assessing and improving a biofuels industry will be important to ensure the successful development of this industry. Once these criteria are identified, their application should be flexible and dynamic because the environmental, economic and cultural systems to which they apply are highly variable across New York and will inevitably change over time.

## 4 SCENARIO ANALYSES: THREE PICTURES OF A POSSIBLE FUTURE BIOFUELS INDUSTRY

No one can predict with certainty what combination of biomass feedstock, conversion technologies, and bio-based transportation fuels will be in place by 2020, or the scale of production. For this study, scenarios were used to allow analysts and policymakers the opportunity to envision different ways that a liquid biofuels industry might develop in New York. As will be discussed in greater detail below, the scenarios were informed by a careful analysis of existing trends and conditions, such as current uses of agricultural and forest land.

Each scenario is designed to represent a possible future for the biofuels industry and not just a “technical potential” that disregards economic, environmental, and societal constraints and impacts. Such constraints were addressed by making broad assumptions to bound the analysis. For example, the design of the scenarios includes the assumption that all New York lands currently in forest remain as forest and that all current levels and current types of New York agricultural products are maintained. This assumption is meant to allow analysis of the potential for new additional biomass production that is additional to current forest and agricultural production. However, landowners will make decisions about whether to use their land for production of agricultural or forest products, or bioenergy feedstocks, or for other purposes.

The scenarios are thus not intended to forecast exactly how the future will actually unfold, nor to provide side-by-side comparison for the “best” possible pathway to the future. Rather, the scenarios have been framed to consider a range of options that fall within bounds that will serve New York’s commitment to environmental protection, looking carefully at what may be possible within these bounds. Because these scenarios have been bounded in this manner, their outcomes represent nothing more than three potential futures that have been limited by the assumptions.

In the following section the scenarios are described, followed by details about the assumptions behind the scenario development.

### 4.1 SCENARIO DESCRIPTIONS

In order to frame the analysis around potential biofuel industry impacts, the Roadmap conducts scenario-based analyses using three possible future (circa year 2020) scenarios related to an expanding biofuels industry in New York State. As described above, the three scenario analyses are not meant to provide side-by-side comparison for the “best” possible pathway to the future, but rather allow a broad but realistic consideration of the primary issues and impacts that arise under three different possible futures. It should also be noted that none of these three scenarios represents a “business as usual” projection; instead, all scenarios would require rapid development of an expanded biofuels industry.

### 4.1.1 Scenario 1- “Big Step Forward”

This scenario represents rapid development of a lignocellulosic biofuels industry, circa 2020 to 2030. For this modeling exercise, rapid development of lignocellulosic feedstock resources is assumed on a portion of suitable and available rural lands. The available land base in this scenario excludes all land currently (2007-2009) in food production which, unlike the other two scenarios, limits the available feedstock. For this and other scenarios, estimated potential feedstock production is always additional to current production levels.

Potential feedstock production is estimated to be as follows (in millions of dry tons): hardwood chips 3.44, softwood chips 1.37, warm-season grasses 2.28, short-rotation willow 2.06, and corn stover 0.25 (Table 4-1). Wood chips would be primarily of lower-value wood from existing forests, assuming sustainable forest management practices were followed (as discussed in Appendix E). The grasses and willow would use 0.98 million acres of land currently in herbaceous cover that is not required to meet current agricultural needs. Conversion technologies are assumed to have met the cost and performance expectation for the first generation of lignocellulosic biorefineries (biochemical and thermochemical systems).

In Scenario 1, more than 4.8 million oven dry tons (odt) of woody biomass is available from within the State for biofuels or other applications on an annual basis. This material is in addition to current harvesting levels for traditional forest products (Figure 4-1). Because of the restrictions applied and the use of a sustainable yield model, this level of harvesting removes only 53.6% of the technically available woody biomass from forests defined as timberland by the USDA Forest Inventory and Analysis program. Hardwoods make up the majority of the material, accounting for 71.5% (Figure 4-1).

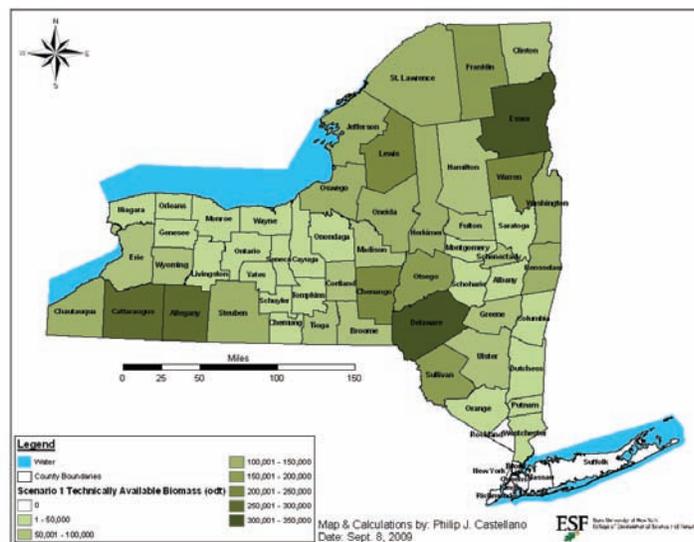


Figure 4-1. Potentially available woody biomass from timberland in each county in New York for Scenario 1. The total woody biomass potentially available is 4.8 million odt/yr.

In this Scenario, four lignocellulosic biorefineries could be profitably built, producing ethanol at a total State-wide production capacity of 354 million gallons per year (MGY) of lignocellulosic ethanol at four sites, selected to be central to each of four feedstock producing regions of New York. Average capacity at each of the four sites is near 90 MGY. In addition, in all scenarios the current corn ethanol capacity in New York should be able to continue to operate profitably, adding 154 MGY of grain ethanol. Total New York production of renewable gasoline substitutes would reach 508 MGY. Estimating transportation gasoline consumption to be approximately six billion gallons per year (BGY), New York could meet 5.6%<sup>26</sup> of this need with home grown biofuels.

#### **4.1.2 Scenario 2 – “Giant Leap Forward”**

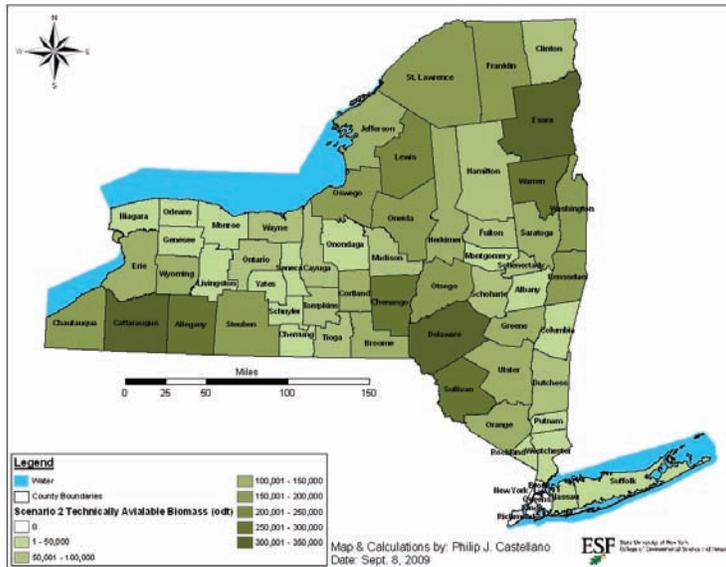
This scenario represents rapid development of a lignocellulosic biofuels industry, circa 2020-2030, requiring rapid advances in feedstock production and advanced conversion technologies. The land base for feedstock production is greater because of the use of some cropland made available due to increases in crop yield and milk yield per cow such that current crop and milk production could be maintained on less land than is required in 2009.

Potential feedstock production is estimated to be as follows (in millions of dry tons): hardwood chips 4.70, softwood chips 1.72, warm-season grasses 4.59, short-rotation willow 3.32, and corn stover 0.25. Wood chips would be from well-managed harvests primarily of lower-value wood from existing forests, with greater harvesting rates than in Scenario 1. The grasses and willow would use 1.68 million acres of land currently in herbaceous cover that is not required to meet current agricultural needs. While Scenario 1 uses first generation lignocellulosic technologies, Scenarios 2 and 3 use second generation technology.

Under the conditions outlined for Scenarios 2 and 3, it was assumed that a greater portion of the timberland would come under sustainable yield management and a greater proportion of the net growth and lower value forest biomass was available. The removal of biomass for biofuels and for traditional forest biomass products is still below the net annual growth rate for forests in any given county and across the entire State. Under these conditions, more than 6.4 million oven dry tons of woody biomass could be available on an annual basis for the production of biofuels or other bioenergy products. This is an increase of 33.5% over the amount of woody biomass under Scenario 1. Hardwoods were still the dominant source of biomass, making up 73.2% of the potential supply (Figure 4-2).

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<sup>26</sup> 508 MGY ethanol \* 0.657 gasoline equivalents / 6,048 MGY (projected 2020 consumption) = 334 MGY gasoline equivalents, which is 5.6% of 2020 forecast consumption. See Appendix L for discussion.



**Figure 4-2. Potentially available woody biomass from timberland in each county in New York for Scenarios 2 and 3. The total woody biomass potentially available is 6.4 million odt/yr.**

Lignocellulosic biorefineries producing ethanol at a total production capacity of 1,295 MGY could be profitably built and operated in this scenario’s “low price” case. This represents about four times the capacity projected for Scenario 1. The production units are modeled to be built at the same four sites as Scenario 1 and average capacity at each site is near 325 MGY. In effect, the biorefinery siting model predicts that with the advanced conversion technologies, all of the available resources would be consumed in production. *This level of production is very unlikely if we were to incorporate competition for those resources in the modeling and accounted for the time it would take to build the infrastructure to supply these facilities. For this reason, this is a scenario that would take much longer to actually implement even if the technology improvements were achieved by 2020. Furthermore, constraints for site permitting and logistical issues would further limit the actual capacity built by this time.* The production units could be very large conversion systems or more likely multiple units operating at the same site (e.g., two 150 MGY units providing 300 MGY of total capacity). Scenario 2 assumes high production with few biorefinery sites, and the distance the feedstock travels is therefore greater, on average, than in other scenarios. Total New York production of renewable gasoline substitutes, including the grain-derived ethanol, would reach 1,449 MGY. In the Scenario 2 “low price” case, New York could meet about 16%<sup>27</sup> of its transportation gasoline consumption with home grown biofuels.

#### **4.1.3 Scenario 3 - “Distributed Production”**

Scenario 3 envisions the same feedstock production and similar technology performance as for Scenario 2. This scenario assumes a distributed industry with no biorefinery capacity exceeding 60 MGY, except for the existing grain ethanol biorefineries. While ethanol facilities currently in the planning stages are reaching the 300 MGY mark, the plant size in this scenario was constrained to 20% of that scale in order to

<sup>27</sup> 1,449 MGY ethanol \* 0.657 gasoline equivalents / 6,048 MGY = 952 MGY gasoline equivalents, which is 16% of 2020 forecast consumption. See Appendix L for discussion.

draw upon local biomass resources and to serve local markets or blending terminals. While smaller facilities are usually disadvantaged by both the economies of scale in physical plant and development costs, these facilities represent less financial commitment and tend to have proportionately lower impacts on local communities, such as road traffic congestion. Nevertheless, the same caveat about resource demand described in Scenario 2 also applies to this scenario.

#### 4.2 SCENARIO DEVELOPMENT ASSUMPTIONS

The key assumptions and input values for the three Scenarios are shown in Table 4-1 below. Note that the available land and therefore the lignocellulosic feedstock supply is the same in Scenarios 2 and 3 at two price points: \$3/gallon gas equivalents (gge)<sup>28</sup> and \$4/gge (see Section 4.2.3 for further description). It would be expected that a higher wholesale price would bring additional biomass onto the market. Still, the amount of biomass available (due to land use constraints in the assumptions) reaches its maximum and acts as a limiting factor between the two price points in Scenarios 2 and 3.

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<sup>28</sup> Ethanol has two-thirds the energy value of an equivalent volume of unleaded gasoline. Accordingly it takes a gallon and a half of ethanol to produce the same amount of usable energy as a gallon of unleaded gasoline when burned in a typical motor vehicle engine. The transformation of the ethanol into a gallon of gasoline equivalency (gge) simply standardizes the ethanol on a price basis.

**Table 4-1. Key Scenario Assumptions and Inputs.**

<b>Attributes</b>	<b>Scenario 1</b>	<b>Scenario 2</b>	<b>Scenario 3</b>
<b><i>Human values emphasized</i></b>			
Natural resources used in a sustainable manner	x	x	x
No conversion of cropland to bioenergy feedstock production	x		
Land use change effects minimized (especially food crops)		x	x
Centralized, larger scale production	x	x	
Distributed, smaller scale production as a goal			x
<b><i>State of Conversion Technology</i></b>			
Ready in near term	X		
Advanced technologies (ready in mid-term)		x	x
<b><i>Land Resources (million acres)</i></b>			
[Non-forest] land used for lignocellulosic feedstocks	0.98	1.68 <sup>a</sup>	1.68 <sup>a</sup>
<b><i>Biomass Feedstock Resource Inputs (Mdt)</i></b>			
Lignocellulosic feedstocks (at \$3 wholesale gge)	4.2	14.5	14.5
Lignocellulosic feedstocks (at \$4 wholesale gge)	9.4	14.6	14.6
Total production of corn grain, soybean, and yellow grease (current baseline) <sup>b</sup>	1.9	1.9	1.9
<b><i>Lignocellulosic Feedstock Types (Mdt)<sup>c</sup></i></b>			
Hardwood and softwood chips	4.8	6.4	6.4
Warm season grasses	2.3	4.6	4.6
Short-rotation willow	2.1	3.3	3.3
Corn stover	0.3	0.3	0.3
<b><i>Capacity of Existing Biorefineries in Year 2020 (MGY)</i></b>			
Two grain ethanol plants (current nameplate capacity)	154	154	154
Biodiesel production (\$4 wholesale gge case)	30	30	30
<b><i>New Biorefineries and Feedstock Sheds</i></b>			
Number of lignocellulosic feedstock sheds	4	4	4
Number of lignocellulosic biorefineries	4	12	22-24
Average lignocellulosic biorefinery unit capacity (MGY)	90	354	60
Total state production capacity ethanol (MGY)	508	1,449	1,449
Percentage of New York gasoline consumption in 2020	5.6 %	16%	16%

<i>Economic Factors</i>			
Investment capital from investors	60%	60%	50%
<i>Transportation Factors</i>			
Average distance fuel is transported to blending terminals (miles)	28.1	27.0	24.5

<sup>a</sup> Additional land becomes available due to increased crop and milk yields such that the same amount of crops and milk can be produced as in 2007, but on less land, freeing some current crop land for production of lignocellulosic feedstocks.

<sup>b</sup> Corn grain and soy are measured in dry tons. Yellow grease is measured in tons.

<sup>c</sup> Scenario 1 lignocellulosic feedstock-type production levels correspond to \$4 wholesale gge.

<sup>d</sup> Percentage of total biorefinery capital costs that are supplied by private investment.

#### **4.2.1 Current Capacity for Biofuel Production in All Scenarios**

In all three scenarios, it was assumed that the two existing grain ethanol facilities in New York—which are capable of producing 154 MGY in total when operating at full capacity—will continue to produce biofuels in 2020. No growth beyond that current capability for grain-based ethanol was assumed in the scenarios. One of those facilities is not operating at this writing, but is scheduled to be refurbished and brought on line in the near future. For a production rate of 154 MGY, the equivalent of 76% <sup>29</sup>of the current New York corn grain crop would be required. Although in actual practice it may make better logistical sense (or better economic sense) to purchase out-of-state corn, the scenarios were designed with the assumption of using New York corn only. All of the scenarios (below) represent additional development of lignocellulosic fuels beyond the current capacity from grain ethanol.

#### **4.2.2 Sustainability Considerations for Scenario Development**

A number of scenario design choices were made about the types of land, types of feedstocks, and types of harvest. These choices and constraints are described in the following sections.

**4.2.2.1 Sustainability Considerations for Land Use.** To estimate of the area of land that was both suitable and potentially available for energy feedstock production, the following assumptions were made:

- Areas of land in federal ownership and State-protected lands were removed from consideration.
- Areas currently in equine use will remain in equine use and were removed from consideration.
- Current production levels of main agricultural products were maintained.
- Quantities of wood supplied to existing wood products industries were not impacted and all forest lands remain as forests.

<sup>29</sup> The two corn ethanol plants operating at nameplate capacity would use the equivalent of 32% of current (2007) corn grain acreage in New York State, after accounting for the acreage represented by the potential feed value of the DDGS for dairy cattle.

- Not all landowners will want to use their lands for energy feedstock production. The percentage of landowners potentially participating in feedstock production in each county was modeled based on population density (See Appendix E).

**4.2.2.2 Direct and Indirect Land Use Change.** Growing dedicated biofuels feedstocks may result in both direct and indirect land use change. Direct land use changes refer to the change in the use of a parcel of land from one type, such as forest, to another type, such as farming of perennial bioenergy feedstocks. Indirect land use change (iLUC) refers to the indirect impacts that occur due to market changes. Using corn grain for bioenergy instead of feed, for example, may indirectly cause other land to be planted in corn to meet the demand for corn. Similarly, legislated preservation of forested areas that were previously harvested may create a need for wood products that must be met elsewhere in the world. Such indirect changes can occur locally, regionally, or globally, but much of the controversy about iLUC involves shifts of production from one country to another.

Such changes in land use may cause large emissions of GHG, especially if forests are cleared by burning, releasing most of the stored CO<sub>2</sub> into the atmosphere. Changes can also occur in soil carbon, especially if lands that were not previously cultivated are plowed, causing a substantial release of stored soil carbon to the atmosphere. Indirect land use change is a complex and controversial topic with respect to biofuels, and is currently centered around carbon/GHG emissions accounting. The scientific debate connecting iLUC to biofuels has received increased attention since 2008 when research papers were published in the journal, Science. This research connected increased demand for corn used for biofuel production with global, indirect land use changes in rainforests, peat lands, savannas and grasslands, which resulted in an increase of global carbon/GHG emissions as these specific lands are converted to meet food and feed demand. (Fargione et al. 2008; Searchinger et al. 2008) Criticism of the two studies states that neither paper provides any data correlating increased U.S. grain ethanol production to global land use change. Some view the papers as highly speculative scenarios with several flawed assumptions (Wang 2008, Dale 2008). While such iLUC effects are possible and may be significant in scale, it is very difficult to accurately quantify the degree to which land use change in one country causes specific changes in land use in another country because there are multiple causes of land use change (Liska and Perrin 2009). The point made by this debate is that the studies and responses demonstrate *indirect* land use change to be much more difficult to model than *direct* land use change and that new, more adequate global models are urgently needed so that biofuels policy is not misguided.

As discussed here and in Appendix E, incorporating iLUC emissions into life cycle GHG analysis is challenging. The EPA has recently issued regulations implementing the second renewable fuel standard, known as RFS2, as required under the Energy Independence and Security Act of 2007 (EISA). Under RFS2, four renewable fuel categories are created, and the EPA must develop life cycle GHG emission thresholds that each type of fuel must meet in order to qualify under the RFS. Notably, these life cycle emissions must include significant emissions from iLUC. In recognition of the fact that the science behind

assessing GHG emissions, especially those from iLUC, is ever-changing,<sup>30</sup> the EPA will be updating its methods as appropriate. California's low carbon fuel standard (LCFS) requires the incorporation of iLUC emissions into its life cycle analyses as well because the California Air Resources Board (CARB) concluded that these impacts are significant enough to be included. In order to address iLUC concerns and other technical issues, CARB created an Expert Workgroup comprising various experts that will meet publicly to develop policy recommendations on these matters (California Air Resources Board 2009). CARB will also continue working with universities to ensure that its methodologies are accurate and up-to-date. In light of the ongoing debate and research surrounding the area of iLUC emissions, the Roadmap team will continue to follow the issue and update its findings as appropriate during its annual updates.

Without adequate global models for iLUC at this writing, the impacts of New York-specific iLUC are very difficult to quantify. It was therefore not feasible to conduct the required global scale analysis to attempt to quantify such findings. However, the Roadmap analysis was conducted so as to greatly reduce the likelihood of iLUC impacts from each of the three Roadmap Scenarios. Specifically, for each of the three Roadmap Scenarios, total food, feed, and forest production in 2007 was maintained even as production of feedstock for biofuels increases.

By maintaining current levels of agricultural and forest production, the need to use new additional land outside New York State to meet the State's needs was avoided or substantially mitigated. There were differences among the three scenarios, however, in how much land use change was allowed. In all Scenarios, forest land producing wood products is maintained. In Scenario 1, all lands currently in food and feed production remain in food and feed production. In Scenarios 2 and 3, agricultural production is maintained at current levels, but it is assumed that some additional land becomes available due to increased crop yield and milk yield per cow. That is, in Scenarios 2 and 3 the same amount of food is assumed to be produced on less land than was needed in 2007, due to projected increases in crop yields and milk yields per cow. Specifically, 27% of cropland and 6% of hay land becomes available in Scenarios 2 and 3.

It should be noted that in recent decades, New York State has not usually produced enough grain to meet the needs of livestock in the State, not to mention the food needs of the people of the State. Additionally, population growth or decline in the State and any other changes in food or feed demand were not modeled.

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<sup>30</sup> A recent study combines ecological data with a global economic commodity and trade model to project the effects of U.S. corn ethanol production on CO<sub>2</sub> emissions resulting from land-use changes in 18 regions across the globe. This analysis adapts the model developed by Searchinger et al., and incorporates changes which may lessen land-use conversion impacts. Although the results are approximately a quarter of the Searchinger estimates of GHG releases attributable to iLUC, the authors conclude that these indirect, market-mediated effects on GHG emissions are enough to cancel out the benefits corn ethanol has on global warming, thereby limiting its potential contribution in the context of California's LCFS (Hertel et al. 2010).

If greater amounts of food or feed are desired due to human population increases<sup>31</sup> or changes in diet, additional land could, of course, be required to meet those needs either from within New York State or outside it. This issue is discussed further in Appendix E, including Section 11.3.

#### **4.2.2.3 Sustainability Considerations for Crop Lands and Crop Residue Feedstocks.**

- Current agricultural production capacity will remain constant at 2007 levels.
- Some cropland that is currently idle and fallow is assumed to be available for feedstock production.
- Crop residues have uses such as for animal bedding. For this reason, no small grain straw was assumed to be available for use as a bioenergy feedstock. Crop residues can be suitable bioenergy feedstocks, but it is important to leave residue on the soil surface to prevent erosion. The amount of corn stover that could be removed was therefore limited to no more than 25% from a given field, and further limited to half of all fields.

#### **4.2.2.4 Sustainability Considerations for Feedstocks on Herbaceous Land.**

- Lands currently in herbaceous cover (pasture, hay, grassland, crop land, shrub and scrub land) will remain in herbaceous cover. Not all lands in herbaceous cover are practical to access for harvest.
- The scenarios remove from consideration all acreage that is in fields less than five acres in size and also remove acreage that would be difficult for farm machinery to access (e.g., slope greater than 15%).
- For land that is currently in herbaceous (non-forest) cover, two representative types of feedstocks were included in the scenarios: (1) warm season perennial grasses such as switchgrass, and (2) short-rotation willow. Neither of these feedstocks is a food crop, but rather they are dedicated bioenergy feedstocks. Both of these are perennials, which have many advantages over annuals for the following reasons:
  - Properly managed perennials have the potential for high yields with relatively low environmental impacts. Perennial vegetation can provide valuable wildlife habitat and cover throughout many seasons of the year.
  - Because there is vegetation present throughout the entire year, the risk of erosion and off-site transport of nutrient and sediments in surface water flow is also greatly reduced compared to annuals.
  - Perennials store carbon in the soil, providing benefits to soil health as well as potentially sequestering carbon.
  - Leaching and volatilization of nitrogen is greatly reduced compared to annuals because roots are present all year around.

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<sup>31</sup> Population growth was not modeled in the Roadmap.

Further information and discussion on these issues are provided in Appendix E and sub-Appendix E-F.

**4.2.2.5 Sustainability Considerations for Woody Biomass from Forests.** Estimates of woody biomass available from New York’s forests incorporated a number of restrictions to ensure that existing wood products industries were not affected, environmental concerns were addressed, and annual yields were sustainable. These restrictions included:

- Harvesting in forest preserves and other protected areas was prohibited;
- Current levels of harvesting for traditional forest products were maintained;
- Harvest of traditional forest products and biomass for biofuels was limited to amounts less than or equal to the net annual growth rate of forests in each county;
- The proportion of tops and residues collected was limited;
- Collection of standing dead trees was restricted to address concerns related to nutrient depletion and biodiversity; and
- A sustainable yield computer model was applied to address concerns related to site conditions, future demographics, or potential development that might affect long term sustained yield management.

Details of these restrictions and how they were applied can be found in Appendix E-D, Table 18.

**4.2.2.6 Scenario Assumptions on Transportation Infrastructure.** Existing transportation infrastructure networks (roads, railways, waterways) will remain constant. The Roadmap transportation impacts focused on economic and environmental impacts but did not assess infrastructure wear or social impacts.

### **4.2.3 Price of Wholesale Fuels Evaluated**

Predicting transportation fuel prices for 2020 is just as difficult as projecting technology, biomass supply, feedstock cost and performance gains. Two price points (\$3 and \$4/gge) were selected on the biofuels supply curve for New York for detailed analysis in the year 2020 Scenarios. The forecast average wholesale price for gasoline for New York in 2020 is \$2.98 per gallon based on the U.S. Energy Information Administration (EIA)’s projected national gasoline price escalating 8.4% from 2008 values. In contrast, diesel is forecast to decline 1.67% from the current 2008 level, to \$2.94/gallon wholesale in 2020. (This projected diesel price equates to \$2.65/gge due to the higher heat content of diesel fuel.) For each Scenario, the impact of a \$1.00/gge increase over the EIA forecast price for gasoline in 2020 was evaluated. Thus each Scenario was evaluated at the wholesale price points of \$3 and \$4/gge in the year 2020. These are referred to as the “low price” case (\$3) and the “high price” case (\$4), respectively. For

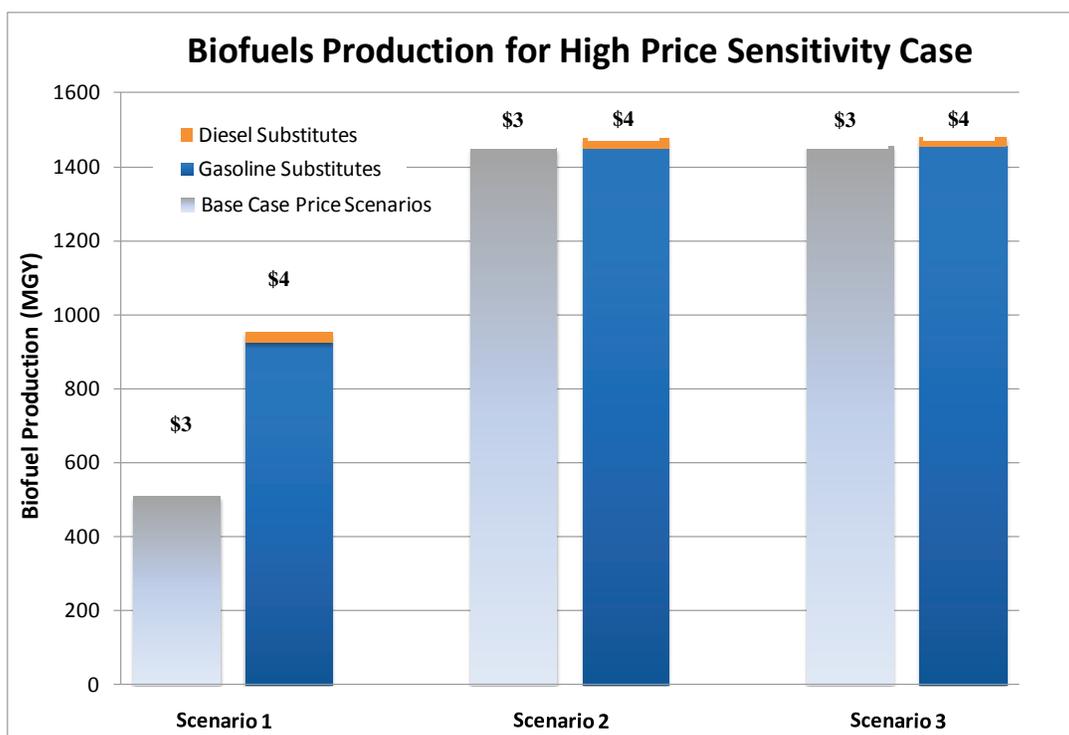
the high price case, this added value increases the forecast target price for gasoline and diesel substitutes to \$3.98/gge and \$3.65/gge respectively.

There are two ways \$4 gge price case could play out in the scenarios: (1) if EIA projections for modest price growth (\$3) are correct, then the increase in the forecast price (\$4) could equate to a biofuels subsidies or some combination of green fuel credits comparable to current subsidies; or (2) if prices rise faster than the EIA forecast, then the increased forecast price would sustain the predicted biofuels production without subsidy. For further explanation, see Appendices I and L.

#### 4.3 SCENARIO ANALYSIS FINDINGS

##### **4.3.1 Biofuel Price Sensitivity Analysis Findings**

For Scenario 1, the impact of higher prices for fuel is significant. Biorefinery output is projected to increase from 508 MGY to 924 MGY, an increase of 82% (Figure 4-3). Since Scenario 1 represents the use of near term (first generation) technology and has a lower quantity of available biomass resources, it is clear that the additional value for a biofuel product that higher prices would bring would provide a powerful incentive for early expansion of the industry. For Scenarios 2 and 3 (where advanced or second generation performance and cost improvements are incorporated into the production of biofuels), the higher price brings little or no increase in production because the scenario models assumed only New York biomass was available.



**Figure 4-3. Projected increase in biofuels production with wholesale price increase. Comparison of production levels at two wholesale price points shows that price change from \$3 to \$4/gge influenced production in Scenario 1. It did not influence production in Scenarios 2 and 3, due to the limiting factor of feedstock availability even at the higher price.**

In these scenarios, biofuels production is essentially resource-limited. This is an artifact of the modeling assumption to use only New York biomass. If resources outside the state were considered, it is likely that the facilities could profitably use resources with greater associated transportation costs and total New York production could increase. However, biorefineries in neighboring states and provinces are likely to be in competition for those resources. If the biorefineries can achieve the high level of performance modeled in Scenarios 2 and 3, they will be self sustaining at the low (\$3) price and should compete directly with petroleum-based transportation fuels.

#### **4.3.2 Biorefinery Siting Optimization Model**

The location of a given biorefinery in the Scenarios influences many of the computer model outcomes, such as distance from feedstock to the nearest biorefinery, transportation costs from the biorefinery to existing gasoline blending facilities, availability of suitable roads or other modes of transport, and economic impacts (including job creation) in a given local area. In order to model the most realistic picture possible of a New York biofuels industry in the year 2020, the analysts needed to locate sites for the biorefineries in each of the three Scenarios. A biorefinery siting optimization model was used for this purpose.

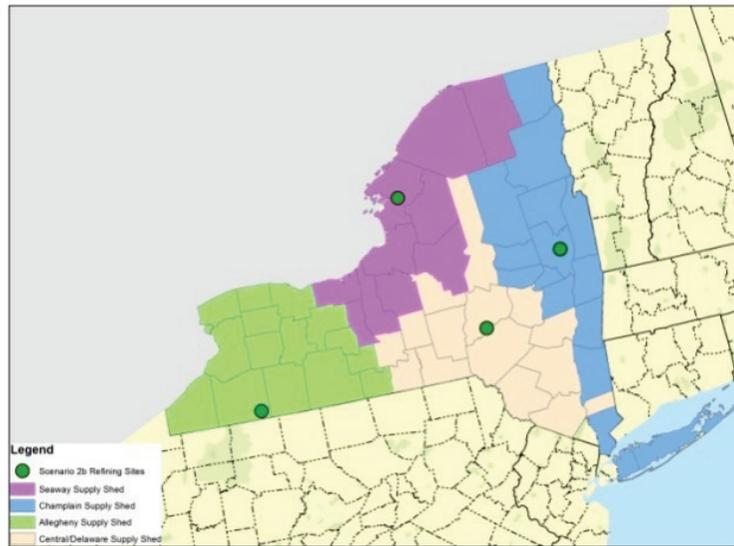
The selection of sites by the model does not take into account the time it takes to finance, permit and build projects of this magnitude. Rather, the model provides a snapshot of the industry that has reached steady state and is profitably producing biofuels for the New York transportation fuel markets. The model also assumes that the plants will use the available feedstock resources within economic hauling range of the facilities: in general, fewer than 100 miles by truck, and if traveling by barge, between 150 and 180 miles. In every case, the lignocellulosic feedstock is the predominant future biomass resource.

**4.3.2.1 Biorefinery Size/Capacity Results.** In all the projections, the greatest potential for biofuels production by 2020 lies in the development and deployment of lignocellulosic biorefineries producing gasoline substitutes (modeled here as ethanol but other future biofuels are possible). Among the scenarios analyzed, the projected ethanol production from lignocellulosic feedstocks varies between 350 MGY (Scenario 1) and 1,300 MGY (Scenarios 2 and 3). There is additional ethanol production from the existing grain ethanol facilities in New York, which are projected to have a combined output of 154 MGY when operating at full capacity in 2020. No growth is projected beyond 2020 for grain-based ethanol. At the 2020 forecast wholesale price of \$3/gge, New York biodiesel production is not projected to grow. However, if the higher forecast wholesale price of \$4/gge is realized, soy and waste grease could supply up to 30 MGY in each scenario, satisfying 2% of projected New York diesel demand.

The projected ethanol production capacities for all three low price case (\$3) scenarios are compared in Figure 4-3. As discussed above, New York could triple its biofuels production capacity in Scenarios 2 and 3 compared to Scenario 1 if feedstock availability and advanced conversion technologies meet their goals.

**4.3.2.2 Biorefinery Siting Location Results.** The National Biorefinery Siting Model (NBSM) was applied to the State of New York to estimate the approximate locations of projected ethanol production facilities in the future scenarios. One of the key features of the NBSM is to optimize the proximity of a projected lignocellulosic biorefinery to the raw feedstock and existing transportation corridors. New York has four prominent biomass supply sheds suggested by the contiguous areas of high feedstock production. These supply sheds are identified with names for the overall regions of New York:

- The Seaway Supply Shed – Jefferson, St Lawrence, Lewis and surrounding counties
- The Allegheny Supply Shed – Cattaraugus, Allegany, Steuben and surrounding counties
- The Central /Delaware Supply Shed – Delaware, Otsego, Chenango and surrounding counties
- The Champlain Supply Shed – Essex, Warren and surrounding counties



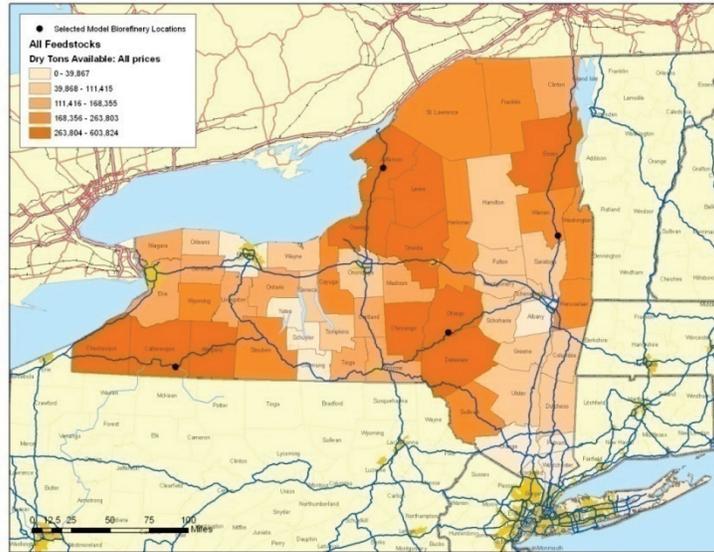
**Figure 4-4 Biomass supply sheds with Scenario2biorefinery sites shown.**

Within these supply sheds the computer model chooses potential biorefinery sites based on criteria for population (workforce and, by proxy, water supply infrastructure) and highway and rail access. Sites that would draw from the same supply shed are narrowed down to one site.<sup>32</sup>

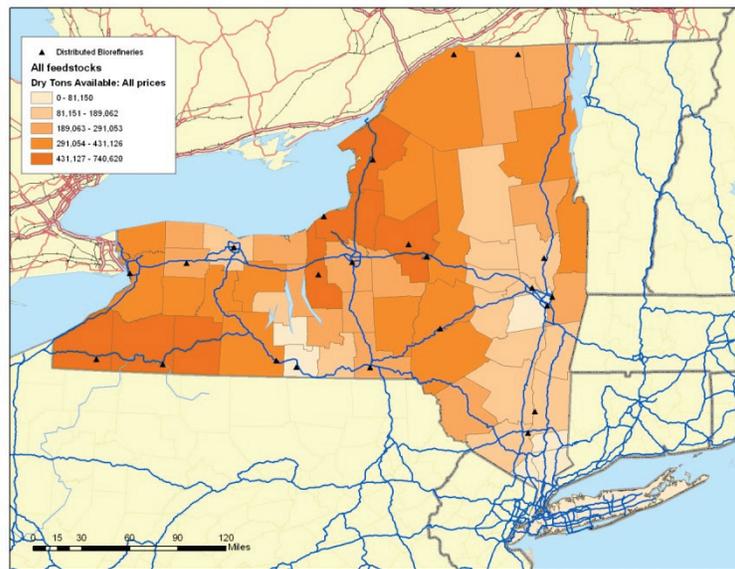
Scenarios 1 and 2 represent a centralized industry structure, with larger regional biorefineries. For Scenarios 1 and 2, representative sites were selected that are central to the supply in each region. For Scenario 2, sufficient feedstock supply exists to build multiple process lines for refineries at the designated locations (Figure 4-5). By choosing a specific site the model is able to select optimum transportation routes and modes for every biomass source, assuming feedstocks are loaded at the road at field edges (for economic analysis); the transportation modeling also assumes that all the biomass is located at the centroid of a county. Scenario 3 represents a distributed industry structure, with smaller-scale local biorefineries. For Scenario 3, the size of each biorefinery was constrained to a maximum capacity of 60 MGY. The analysis resulted in 24 biorefineries being sited over a wide geographic distribution in the biomass supply sheds. The results for Scenario 3 are shown in Figure 4-6.

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<sup>32</sup> The selection of specific site locations for each scenario is done to realistically determine transportation costs and impacts in the industry. Many alternate locations would produce similar results. The sites selected for computer modeling purposes may not be the best actual sites when all criteria for siting an industrial facility are considered.



**Figure 4-5. Siting Map for four Lignocellulosic Biorefineries projected in Scenarios 1 and 2. Scenario 1 biorefineries have average capacity of 90 MGY. Scenario 2 average capacity is 354 MGY with multiple biorefineries at each indicated site.**



**Figure 4-6. Siting Map for twenty-four Lignocellulosic Biorefineries projected in Scenario 3 (Distributed Production Scenario). Scenario 3 biorefineries have an average capacity of 60 MGY.**

For the grain ethanol and biodiesel biorefineries, a very different approach was taken. Two corn ethanol plants already exist. The plant in Shelby, New York is operational. The other, located in Volney, New York, has been purchased with the intent of replacing the fermentation technology. The operating grain ethanol biorefinery draws 80% of its total supply of corn from in-State. It was assumed in the 2020

Scenarios that all feedstock would come from within New York. Counties were “allocated” to each biorefinery on the basis of shortest transportation routes.

A similar approach was used for the soy resources. There is some smaller scale crushing capacity in the State; however, current soy production in New York may not warrant the construction of a new large-scale crushing mill. In fact, a large mill in Hamilton, Ontario is in operation and is reasonably close to the soy crop producing counties in New York. In fact, a large mill already exists in Hamilton, Ontario – within relatively easy reach of the soy crop producing counties in New York; an existing facility, Northern Biodiesel, may also use some of New York’s soy feedstocks to produce biodiesel. Therefore, the biodiesel plant was sited in the Buffalo area for all of the Roadmap analyses. While there are many other potential oilseeds crops that could be grown in New York, soybean is the most common oilseed crop in New York, and was selected as the example for this analysis. Additional maps and details on the siting optimization can be found in Appendix L.

### **4.3.3 Infrastructure, Transportation and Distribution (T&D) Analysis**

The existing locations and capacities of New York’s freight transportation systems (including train, barge and truck) will be an important consideration in development of a biofuels industry. Cost of transport, energy use, road capacity, and environmental impacts (emissions) associated with moving feedstock and fuel throughout the State were evaluated for each of the future scenarios. Additional details are provided in Appendix F.

**4.3.3.1 Comparing Costs of Transportation Modes.** The bulky, low-density nature of raw biomass materials makes long-distance shipment of biomass by truck less economically favorable compared to other modes. Comparing the cost to move a ton of biomass by truck, rail or ship shows that trucks have a higher marginal cost per mile than rail or ship. Even so, when shipping distances are less than 500-750 miles, the high fixed-costs associated with loading materials from a truck to a train (or ship) and then unloading the materials from the train (or ship) back to a truck make short-distance rail and ship shipments more expensive than short distance truck shipments.

For all the Scenarios evaluated, truck transport provides essentially 100% of the feedstock and fuel movement throughout the State. Even in Scenario 2 (the scenario in which feedstock transportation distances are the longest), only twelve origin-destination pairs (representing less than 2% of total feedstock) are more than 100 miles apart, and none is more than 200 miles apart. This indicates that a large-scale shift towards rail or waterway transport is unlikely unless the economics of transport change in favor of rail and waterway.

Two other costs not evaluated in the computer simulation were cost impacts to the infrastructure systems (e.g., road and bridge wear) and social impacts (increased traffic in harvest and biorefinery locations). Further research is needed to address these issues.

**4.3.3.2 Transportation Flows.** The flows of feedstock from origin county to biorefinery destination were calculated considering tonnage of feedstock and distance traveled for each origin-destination pair. Table 4-2 shows the average distance by feedstock type from origin county to biorefinery for each Scenario and price case.

**Table 4-2. Average Distance in Miles, Feedstock to Biorefinery by Scenario and Mode.**<sup>33</sup>

Scenario	Mode	Average miles feedstock travels from originating county to biorefinery in Scenarios						
		Corn Stover	Grasses	Willow	Softwood	Hardwood	Corn Grain	Soybeans
Scenario 1a	Truck	24.3	n/a	46.5	38.0	37.2	122.7	227.4
	Barge	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Scenario 1b	Truck	79.4	59.6	59.4	57.4	57.7	122.7	227.4
	Barge	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Scenario 2a	Truck	79.3	69.7	60.9	57.5	61.4	122.7	227.4
	Barge	179.2	179.2	179.2	178.7	176.1	n/a	n/a
Scenario 2b	Truck	79.5	70.2	60.9	57.5	61.4	122.7	227.4
	Barge	179.2	179.2	179.2	178.7	176.1	n/a	n/a
Scenario 3a	Truck	24.4	26.3	22.7	39.3	30.1	122.7	227.4
	Barge	146.9	158.1	179.2	179.2	179.2	n/a	n/a
Scenario 3b	Truck	25.1	26.2	22.2	39.0	30.2	122.7	227.4
	Barge	179.2	156.3	179.2	179.2	179.2	n/a	n/a

On average, lignocellulosic ethanol feedstock travels fewer than 100 miles if by truck, and travels between 150-180 miles if by barge. Corn grain travels more than 120 miles on average from farm to biorefinery, while soybeans travel nearly 230 miles in the transit from farm to crusher (in Ontario, Canada) to the biorefinery; corn and soybeans/soy oil travel exclusively by truck. In all Scenarios, the average biofuel transport distance from the biorefinery to the blending terminal was less than 30 miles.

<sup>33</sup> For purposes of the tables and the discussions that follow, scenario numbers followed by “a” indicate the \$3/gge price case and by “b” indicate the \$4/gge price case.

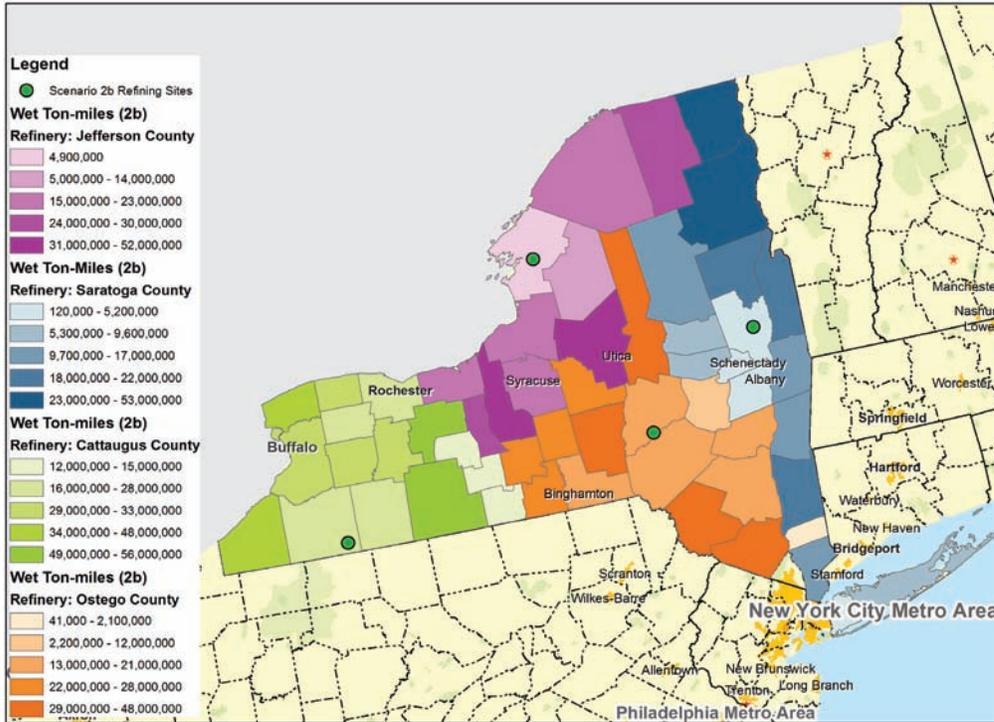


Figure 4-7. Feedstock Transportation, Scenario 2b Ton-miles by Origin County and Biorefinery.

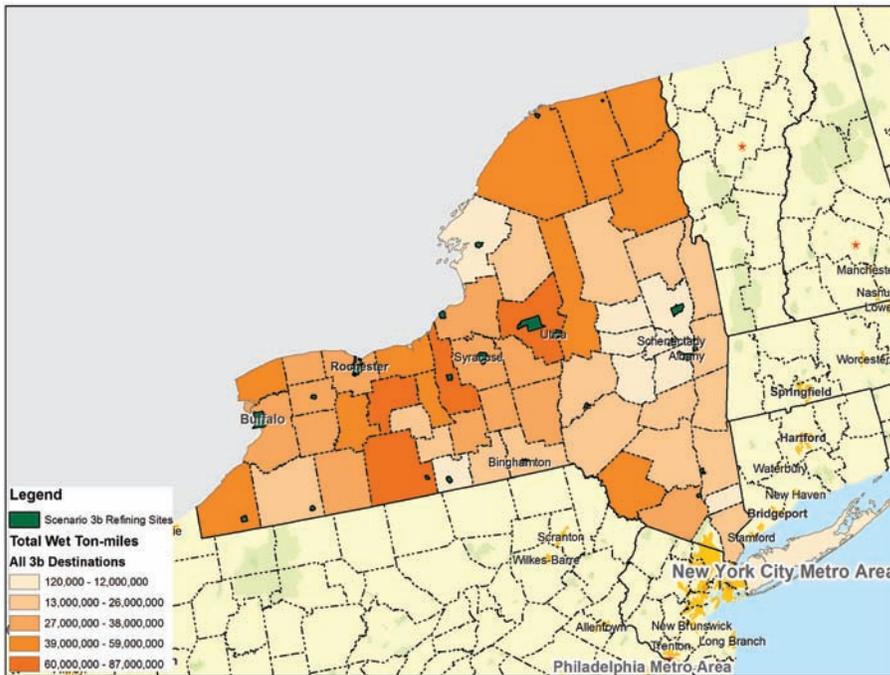


Figure 4-8. Feedstock Transportation, Scenario 3b Wet ton-miles by Origin County. The distributed biorefinery case (Scenario 3) generates equivalent quantities of feedstock and fuel as Scenario 2(Fig 4-4). The ton-miles required, however, are half that of a more centralized, larger scale biorefinery case shown in Figure 4-4. Ton-miles are directly associated with energy use, emissions and transport costs.

Figures 4-7 and 4-8 show the ton-miles<sup>34</sup> of total feedstock transport in Scenario 2b and 3b, respectively, by origin county. Figure 4-7 is color-coded to depict four destination biorefineries in Scenario 2, and Figure 4-8 shows ton-miles of feedstock flows by origin county to the 22 biorefinery locations identified in Scenario 3. (Two of the 24 biorefineries share a location in the model).

A decentralized biofuels industry (Scenario 3) measurably decreases required ton-miles of feedstock transport. Although Scenario 2b and 3b generate equivalent quantities of feedstock and ethanol, the quantity of ton-miles in Scenario 3b is roughly half that in Scenario 2b. This quantity of ton-miles is especially important from an emissions standpoint, because ton-miles are directly associated with energy use, emissions, and economics of transport. It is also important from a roadway safety and capacity standpoint, as some of the centralized scenarios imply many more additional ton-miles (and therefore trucks) on New York's roadways. Additional maps and details about feedstock flows in the three Scenarios are provided in Appendix F.

**4.3.3.3 Transportation and Distribution Energy Use and Emissions.** From an energy use and emissions standpoint, trucks are the most energy- and emissions-intensive per ton-mile, compared to barge and rail transport modes. Overall energy and emissions due to T&D were calculated and are presented in Table 4-3. Results represent a lower bound of T&D emissions, as full truckloads were assumed to be traveling only from feedstock source-county to biorefinery (i.e., impacts of a greater number of partially empty trucks were not calculated, and impacts of empty truck return trips that could jointly more than double these estimates, also were not calculated). The Scenario results show that energy and emissions associated with T&D in Scenario 2 are approximately twice those in Scenario 3, even though nearly identical quantities of feedstock and ethanol are produced (Table 4-3).

Figures 4-7 and 4-8 represent which counties may generate the most feedstock-related transportation emissions in the State. Although this feedstock movement may travel through other counties, these results suggest that darker source-counties and biorefinery-counties may be exposed to the greatest share of T&D emissions. Additional details on emissions are provided in Appendix G.

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<sup>34</sup> A "ton-mile" is a unit of freight transportation equivalent to a **ton** of freight moved one **mile**. Ton-miles are calculated by multiplying the cargo weight by the distance traveled.

**Table 4-3. Energy use and emissions results for each scenario by fuel stage and transportation mode.**

Scenario	Feedstock or Fuel Transport	Mode	Total Fuel Cycle Energy Use and Emissions, Feedstock + Fuel Transportation				
			Energy (MMBtu)	CO <sub>2</sub> (metric tons)	SO <sub>2</sub> (metric tons)	NO <sub>x</sub> (metric tons)	PM (metric tons)
Scenario 1a	Feedstock	Truck	363,221	28,369	6.50	26.33	3.31
		Barge	0	0	0	0	0
	Fuel	Truck	29,821	2,332	0.68	2.40	0.33
Scenario 1b	Feedstock	Truck	1,050,733	82,067	18.80	76.15	9.56
		Barge	0	0	0	0	0
	Fuel	Truck	70,071	5,477	1.47	5.44	0.73
Scenario 2a	Feedstock	Truck	1,688,316	131,865	30.20	122.37	15.36
		Barge	7,905	617	0.14	1.64	0.09
	Fuel	Truck	105,080	8,218	2.38	8.45	1.16
Scenario 2b	Feedstock	Truck	1,697,073	132,549	30.36	123.00	15.44
		Barge	8,357	653	0.15	1.73	0.09
	Fuel	Truck	105,288	8,234	2.38	8.47	1.16
Scenario 3a	Feedstock	Truck	764,490	59,710	13.68	55.41	6.96
		Barge	2,493	162	0.00	0.43	0.01
	Fuel	Truck	95,430	7,463	2.16	7.68	1.05
Scenario 3b	Feedstock	Truck	764,649	59,723	13.68	55.42	6.96
		Barge	2,514	196	0.04	0.52	0.03
	Fuel	Truck	95,450	7,465	2.16	7.68	1.05
Corn Grain	Feedstock	Truck	239,459	18,703	4.28	17.36	2.18
		Barge	0	0	0	0	0
	Fuel	Truck	11,578	905	0.26	0.93	0.13
Soy Biodiesel	Feedstock	Truck	40,363	3,153	0.72	2.93	0.37
		Barge	0	0	0	0	0
	Fuel	Truck	15	1	0.00	0.00	0.00

**4.3.3.4 Road Capacity Issues.** According to U.S. Department of Transportation, congestion on New York national highways in 2002 was limited to the greater New York City region, Buffalo, and Rochester. By 2020, however, congestion is expected to expand across Western New York highways and north of New York City; by 2035 peak period congestion is expected to expand across the State (for more details and maps see Appendix F). Future congestion is expected on roadways near biorefinery locations and near feedstock origins. Table 4-4 shows the Scenario-projections for ton-miles contributed by each feedstock type and mode of transportation in the three Scenarios. Note that the values in this table are a function of

both the amount of feedstock harvested under each scenario, and the distance that each feedstock must be transported to the biorefinery.

**Table 4-4. Feedstock Transportation: Ton-miles by Feedstock, Scenario and Mode.**

Scenario	Mode	Feedstock Type						Mode % of Transport
		Corn Stover	Grasses	Willow	Softwood Forest Residue	Hardwood Forest Residue	Total	
Scenario 1a	Truck	792,137	0	128,487,736	57,653,257	125,753,001	312,686,129	100%
	Barge	0	0	0	0	0	0	0%
Scenario 1b	Truck	22,770,595	155,949,610	222,233,028	143,191,236	360,381,618	904,526,088	100%
	Barge	0	0	0	0	0	0	0%
Scenario 2a	Truck	22,789,888	362,468,154	367,557,375	179,727,869	520,878,947	1,453,422,236	98.8%
	Barge	118,546	1,547,763	491,907	693,669	14,136,069	16,987,955	1.2%
Scenario 2b	Truck	22,828,525	369,861,095	367,557,376	179,732,695	520,980,559	1,460,960,249	98.8%
	Barge	118,546	2,518,526	491,907	693,669	14,136,069	17,958,718	1.2%
Scenario 3a	Truck	6,998,372	138,488,553	134,409,029	122,920,370	255,311,102	658,127,426	98.8%
	Barge	97,145	2,174,932	491,907	599,505	1,994,659	5,358,149	1.2%
Scenario 3b	Truck	7,221,651	138,243,662	134,241,398	121,949,355	256,608,246	658,264,312	98.8%
	barge	118,546	2,196,968	491,907	599,505	1,994,659	5,401,586	1.2%

Given the extensive use of trucking in the Scenarios to move feedstock and fuel throughout the State, potential capacity issues on roadways should be considered. A road-specific analysis of these capacity constraints is not possible given how modeled origin-destination pairs were reported. Nevertheless, given the available data, the numbers of trucks entering biorefinery areas was calculated, as shown in Table 4-5.

**Table 4-5. Average Number of Trucks Entering Biorefinery for Each Scenario.**

Time frame	Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b	Scenario 3a	Scenario 3b
Average trucks per year	87,430	174,910	262,920	263,720	47,950	47,950
Average trucks per day	240	480	720	720	130	130

Table 4-5 shows the average number of daily trucks entering each biorefinery by scenario. These calculations assume an even distribution of truck traffic at the biorefineries throughout the year (i.e., total truck traffic for the year divided by 365 days). In some locations, the number of trucks entering the biorefinery each day is quite high. For example in Scenario 2, refineries will receive 500 to more than 850 trucks per day. Together, the anticipated increases in highway congestion and truck traffic at biorefinery

destinations present considerations for regional planners when determining where to site lignocellulosic ethanol biorefineries, and also suggest that feedstock movement via rail or barge may be more desirable in the future. In addition, densification technologies for biomass could provide an important alternative relief mechanism.

Rail as a possible solution to road capacity constraints in 2020 Railroads in the State are currently operating under capacity, and in 2035 are anticipated to be approaching capacity. Therefore, in the future, rail may present a more optimal biofuel feedstock transportation option. Capacity constraints and congestion may present opportunities for the development of decentralized rail hubs that would collect and aggregate feedstock by truck and then transport larger shipments to the biorefineries via rail. This will, of course, have important implications as to where the biorefineries ultimately are sited, as access to rail services may be important. Additional information and maps regarding transportation and distribution issues are found in Appendix F.

#### **4.3.4 Economic Impacts Analysis**

**4.3.4.1 Price Points Evaluated.** The three scenarios were evaluated for economic impacts under the two wholesale price points discussed in the sections above. Ethanol at \$3/gge would sell for \$2.01 per gallon on the wholesale market. Ethanol at \$4/gge would sell for \$2.68 per gallon on the wholesale market.

**4.3.4.2 Scenario Results.** Important indicators determined through the economic analysis model include the number of jobs created, an estimate of labor income, and the value-added projection, gross domestic product (GDP). Table 4-6 shows estimates of statewide impacts.

- **Number of jobs created.** Jobs are the primary measure of regional economic wellbeing. Jobs are defined as the number of positions that are involved in some type of industrial activity expressed on an annual basis. In the model, however, jobs are not expressed in terms of whether or not they are full-time or non-seasonal jobs. For example, in this economic analysis model, a seasonal farm job is a job, as is a full-time factory job producing ethanol.
- **Estimate of labor income.** Labor income (in this case, primarily wage and salary payments) is the income that translates readily into regional household spending. Labor income has a highly localized impact that is intuitive and meaningful to communities and regions.
- **Value added projection.** The sum of labor income, proprietor income, investment income, and indirect taxes equals value added. Value added is the same as GDP. It is the preferred method for measuring the value of an economic activity in light of all other economic activity in an area.

**Table 4-6. Statewide Estimated Economic Impacts for Each Scenario.**

<b>Scenario</b>	<b>Number of jobs created</b>	<b>Estimate of labor income (wage &amp; salary payments)</b>	<b>Value added projection (GDP)</b>
Scenario 1a	3,891	\$172.6 million	\$464.34 million
Scenario 1b	7,780	\$350.4 million	\$931.72 million
Scenario 2a	14,604	\$640.6 million	\$1.73 billion
Scenario 2b	14,019	\$614.7 million	\$1.66 billion
Scenario 3a	14,189	\$608.3 million	\$1.78 billion
Scenario 3b	14,236	\$616.9 million	\$1.79 billion

**4.3.4.3 Scenario 1 (Big Step) Economic Analysis.**

**4.3.4.3.1 Scenario 1 Statewide Impacts.** Under Scenario 1 with a price of \$3/gge, the model estimates 3,891 jobs and \$172.61 million in labor income – an average of \$44,361 per job – will be created Statewide. Value-added (GDP) impacts to New York State would be \$464.34 million. (As a point of reference, the State of New York’s GDP for 2008 was \$1.144 trillion.)

Under Scenario 1 at \$4/gge, it becomes profitable to harvest feedstocks from more marginal lands or at greater distances from refineries. Accordingly, there are sharp increases in the input impacts as the prices paid for feedstock and the quantities demanded increase. However, all other factors (such as labor) increase based on the quantity of feedstock and fuel demanded. Statewide, Scenario 1 at \$4/gge will produce 7,780 total jobs, \$350.42 million in labor incomes, and \$931.72 million in GDP. Jobs, labor incomes, and GDP at the high price point (\$4/gge) are double the values in the Scenario 1 case at the lower price of \$3/gge.

The difference between the results at \$3/gge and \$4/gge is driven strongly by the quantity differences in feedstock resource availability and therefore production at the biofuels refinery. Jobs increase markedly in the inputs sectors as well as in the biorefinery sector, as there is a need for many more jobs at the processing facilities because their average sizes are substantially larger under this price assumption than in the \$3/gge situation.

**4.3.4.3.2 Scenario 1 Regional Impacts.** Under Scenario 1, the greatest job, labor income, and value-added impacts will accumulate to the Allegheny region. The Seaway Supply Shed will be second, the Central / Delaware area third, and the Champlain area fourth. The range of Scenario 1 total job impacts is from 842 in Central / Delaware to 1,155 in the Allegheny Supply Shed. Total labor compensation and value added are lowest in Champlain and highest in the Allegheny region. Additional regional economic impact details, data and information are found in Appendix I.

**4.3.4.4 Scenario 2 (Giant Leap) Economic Analysis.** In Scenario 2, the amount of available and sustainably harvested feedstock has reached near maximum capacity as estimated by the Sustainable Feedstock Supply (Appendix E). Feedstock becomes a limiting factor for further increases in fuel

production in this Scenario and in Scenario 3. This is in contrast to Scenario 1 where higher prices paid (\$4) brought additional feedstock resources onto the market. Scenario 2 contemplates much more aggressive lignocellulosic ethanol development than does Scenario 1.

**4.3.4.4.1 Scenario 2 Statewide Impacts.** Under Scenario 2, the number of refineries increases, and the volume and mix of feedstocks expands. Statewide, jobs climb sharply to 14,604, and labor compensation is \$640.6 million. The GDP grows to \$1.73 billion. Scenario 2 under the assumed price of \$4/gge did not produce the magnitude of quantity shifts in biomass supply as was the case in Scenario 1 when comparing the two price levels. There is virtually no meaningful change in biomass quantity demanded, although there are minor differences in supply among the four regions. Statewide the scenario generated 14,019 jobs, \$614.7 million in labor incomes, and \$1.66 billion in GDP. The Statewide economic impacts are slightly lower in the \$4/gge case than in the \$3/gge case, due to a trimming of returns to investors and a minor increase in scale economies in the feedstock collection and transport sectors.

**4.3.4.4.2 Scenario 2 Regional Impacts.** In the Allegheny area, total job impacts rise sharply to 5,146 – almost 4.5 times greater than in Scenario 1 at the same price/gge. Labor incomes and value added also show similar increases. The impacts accumulated to the four regions in the same manner as previously noted; from highest to lowest they were Allegheny, Seaway, Central / Delaware, and the Champlain supply sheds.

**4.3.4.5 Scenario 3 (Distributed) Economic Analysis.** This Scenario is a more regionally distributed production and processing system that allows for smaller plants, shorter feedstock transport routes, and shorter biofuel transport distances because the biofuels are consumed in greater quantities locally. Under a distributed production system, there are still a very high number of jobs, labor incomes, and value added created. The overall biofuel production capacity is similar to Scenario 2, but there are lower job values (salaries). The plants are more distributed and smaller in Scenario 3, so reduced plant labor is partially replaced by transport labor yielding slightly lower job totals in Scenario 3 than in Scenario 2.

**4.3.4.5.1 Scenario 3 Statewide Impacts.** Statewide, at the \$3/gge level this Scenario produces an estimated 14,189 jobs, \$608.3 million in labor incomes to those workers, and \$1.78 billion in GDP. In this Scenario, the smaller plants create a slightly lower labor efficiency. In addition, as has been mentioned, there is a reduction in the volume and distance of feedstock per plant, which results in a reduction of jobs related to transporting feedstock to the biorefineries. Lastly, transport miles from the biorefinery to blending terminal are reduced as this scenario assumes local production and consumption of the biofuels. Overall, the State would expect 14,236 jobs, \$616.92 million in labor incomes, and \$1.79 billion in statewide GDP.

**4.3.4.5.2 Scenario 3 Regional Impacts.** Under the \$4/gge price, there are not significant differences in total impacts but there is some shifting among the regions. There is a substantial gain in feedstock accumulating in the Central / Delaware Supply Shed and a reduction in the feedstocks available

in the Champlain Supply Shed. In effect, at this price point there is a shifting from one region to the other in Scenario 3.

Additional details and information on economic impacts are found in Appendix I.

#### **4.3.5 Industry Workforce and Worker Training Needs in New York**

The economic impact analysis of the scenarios indicates that approximately 4,000 -14,000 jobs may be created by the industry. Most will be in crop-based, forestry-based, and transportation (trucking) sectors, with a very small share of these jobs (between 275 and 1,320) in the refineries themselves (see Table 4-7). To determine whether New York has the workforce training resources needed to prepare the workers for this job growth, an analysis of workforce training programs in the State was conducted. Workforce training programs already in place can ensure that sufficient numbers of skilled workers are available to support the development of a new industry, if the efforts these programs have initiated are sustained. Though biofuels production represents a small portion of the New York economy today, New York colleges, universities and technical training programs already have begun focusing on preparing a workforce for employment opportunities in emerging biotechnology industries such as renewable fuels production.

**Table 4-7. Estimates of Jobs Created by Biofuel Refinery Growth, Statewide.**

<b>Job Sector</b>	<b>Scenario 1</b>	<b>Scenario 2</b>	<b>Scenario 3</b>
Agriculture and Forestry Based	1,675 (43%)	6,525 (45%)	6,959 (49%)
Transportation Based	912 (23%)	3,830 (26%)	1,864 (13%)
Miscellaneous Jobs	753 (19%)	2,525 (17%)	2,727 (19%)
<b><i>Subtotal – Input Sector Jobs</i></b>	<b>3,340 (86%)</b>	<b>12,880 (88%)</b>	<b>11,550 (82%)</b>
<b>Direct Jobs at Refinery</b>	275 (7%)	798 (6%)	1,320 (9%)
Induced Jobs (due to direct worker and investor spending)	276 (7%)	925 (6%)	1,317 (9%)
<b><i>TOTAL JOBS</i></b>	<b>3,891 (100%)</b>	<b>14,604 (100%)</b>	<b>14,189 (100%)</b>

*Estimates include direct and induced job growth resulting from biofuel refinery expansion*  
Source: Working papers from Roadmap Economic Analysis, Appendix I (Swenson, 2009)

**4.3.5.1 Workforce and Worker Training Assessment Objectives.** A workforce and worker training assessment was conducted to address the following questions about a possible New York renewable fuels industry:

- What types of jobs would be created (including jobs at new renewable fuel production facilities and in supporting businesses, .e.g., biomass feedstock production, processing and transportation)?

- What training programs are in place to address the needs of forecast growth in renewable fuel production in the immediate future and over the next 10 years?
- What steps are needed to ensure that a skilled labor force is available to serve the projected increases in renewable fuel production in New York State?

The assessment reviewed existing programs in New York’s colleges, universities, and technical training programs, including the current industrial and research base for a renewable fuels industry (See Appendix J). The assessment also reviewed similar studies in other states and other industries.

**4.3.5.2 Workforce and Worker Training Assessment Findings.**

**4.3.5.2.1 Types of Jobs.** The economic impact analysis estimates that about 80 percent of the jobs created by the biofuel expansion considered in the Scenarios will be in agriculture, forestry and trucking. The comparatively small number of jobs at biofuel refineries represent a wide range of career pathways. These include technical, professional, and managerial jobs requiring advanced postgraduate education to jobs not requiring any special skill or training. A study using U.S. Bureau of Labor Statistics data noted biofuels industry jobs are very similar to traditional chemical manufacturing jobs with respect to skills required and wages (White, S. and J. Walsh, J. 2008). Figure 4.6 shows biofuels jobs, skills and median wages.

**4.3.5.2.2 Training Programs in Place in New York State.** Existing institutions and available programs can meet the training needs if the efforts of these institutions to adapt to changing employment training needs are sustained. The NYS Department of Labor (DOL) has led efforts to provide a One-Stop Career Center system that includes 33 Local Workforce Investment Areas administered by Local Workforce Investment Boards. This program provides resources and links to New York’s energy planning by tying together the separate workforce training programs of many of the programs cited here. Further, Empire State Development includes workforce training grants in its portfolio of tools used to attract clean energy industries to New York (Energy Cost and Economic Development Brief, 2009). While not now focused specifically on biofuel production, these state programs provide resources that may support biofuel technology workforce training programs and provide planning and program coordination among separate workforce training efforts to ensure that available resources are used effectively.

Based on the number and types of jobs expected, and the current portfolio of training resources, no major new programs would be required if the existing programs have access to resources and participate in planning for an expansion of biofuel production in New York State. Although New York has an established training and research infrastructure to support a biofuels industry expansion, as “second generation” technologies come into play, a re-assessment of workforce training needs is recommended. For examples and descriptions of many of the formal training programs already in place in the State, see Appendix J of this report. Appendix J outlines steps that may ensure that New York’s job training

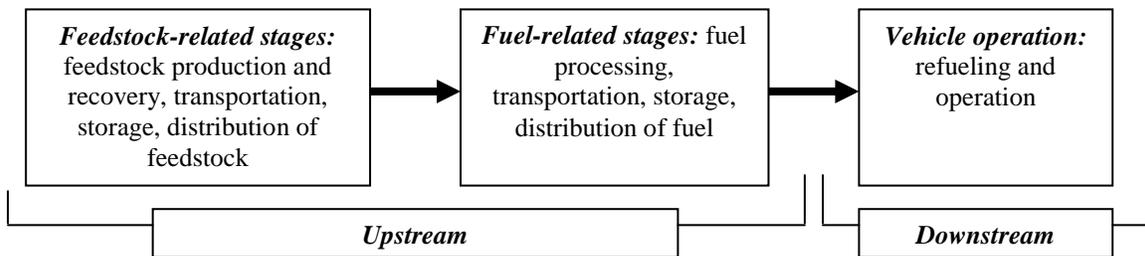
infrastructure keeps pace with an emerging biofuel production industry in New York State over the next decade.

New York Resources for Training & Research	Education & Training	Workplace & Career	Typical Jobs & Wages
NY Community Colleges and Universities with focus in bio-manufacturing programs	Advanced Postgraduate Education	Technical Professional & Managerial Jobs	<b>Work experience in related occupation</b> Sales representatives, wholesale & manufacturing, technical & scientific products (\$71K)
State University of New York Colleges and Universities with focus on Renewable Energy, Environmental Sciences, Resource Economics, Forestry, Agriculture, Sustainability, Biofuels Research, Advanced Biomedical & Bioengineering, Life Sciences, Equipment/machinery Design Theory and Repair, Education, Economic Development and Extension programs	4-year Baccalaureate		<b>Long-term on-the-job training (1-5 y apprenticeships)</b> Chemical plant and system operators (\$51K)
	Applied Associate Degree	Skilled Technician Jobs	<b>Associate Degree</b> Chemical technicians (\$46K)
Private Colleges and Universities in New York with focus on manufacturing studies, energy systems research, biotechnology, liquid biofuels, environmental impacts, economics, bioengineering, chemical engineering	1 or 2 year Technical Diploma	Entry-level Technician Jobs	<b>Postsecondary Vocational Award</b> Electrical and electronics repairers, commercial & industrial equipment \$47K)
NY Boards of Cooperative Educational Services (BOCES)	Short-term Occupation/Industry Certificate	Entry-level Skilled Jobs	<b>Moderate-term on-the-job training (1-12 months)</b> Chemical equipment operators & tenders (\$43K) Truck drivers, heavy & tractor-trailer (\$40K) Separating, filtering, clarifying, precipitating & still machine setters, operators & tenders (\$38K) Mixing & blending, machine setters, operators & tenders (\$31K)
NYSTAR Centers for Advanced Technology	Secondary Level Adult Basic Education (ABE) English Language Learners (ELL)	Semi-Skilled Jobs	
New York State Energy Research & Development Authority	Vocational- Workplace Basics Adult Basic Education English Language Learners		<b>Short-term on-the-job training</b> Shipping & receiving, traffic clerks (\$32K) Laborers & freight, stock & material movers, hand (\$27K)
New York business and trade associations with focus on renewable energy (Renewable Energy Network of Entrepreneurs in Western NY, New York Biotechnology Association, Environmental Business Association of New York State (EBA-NYS))	Intensive Work Readiness and Support	Jobs not requiring previous training or specific skills	

**Figure 4-8. Training, Jobs and Median Wages for Biofuels Refineries At-a-Glance.** (Adapted with permission from *Greener Pathways: Jobs and Workforce Development in the Clean Energy Economy*, (2008), S. White and J. Walsh. Center on Wisconsin Strategy (COWS)).

### **4.3.6 Life Cycle Analysis (LCA) of Lignocellulosic Ethanol, Corn Grain Ethanol and Soy Biodiesel in New York Scenarios**

The Roadmap team also conducted an analysis of the energy and emissions impacts from the three Scenarios. Both upstream and downstream portions of the fuel cycle were considered. The analysis considered energy use and emissions from the production of the feedstock (e.g., corn from fields, herbaceous or woody biomass from fields and forests), the processing of that feedstock (e.g., turning corn or lignocellulosic biomass into ethanol), and ultimately the distribution and use of the processed fuel in the vehicle itself. Figure 4-9 identifies the components of a total fuel cycle, partitioned into “upstream” and “downstream” processes.



**Figure 4-9. Components of a Total Fuel-Cycle from Winebrake, Wang, et al. (2001).**

Each stage in the fuel-cycle in Figure 4-9 includes activities that produce GHGs and air pollutant emissions. These emissions are typically caused by fuel combustion during a particular stage, although some non-combustion emissions occur (e.g., natural gas emissions from pipeline leaks, evaporative losses in refueling). The goal of a “well-to-wheels” (W2W) analysis is (or, in this case, “field to wheels”) is to account for each of the emissions events along the entire fuel-cycle chain.

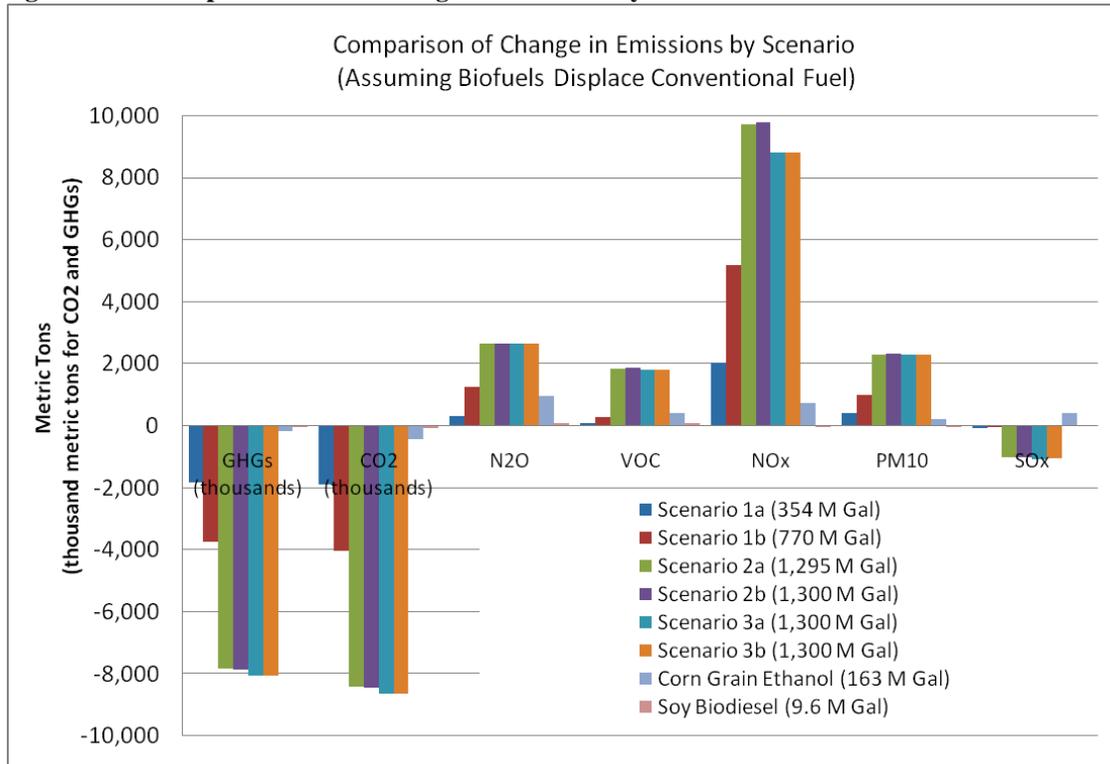
**4.3.6.1 Findings- LCA Lignocellulosic Ethanol.** Overall, LCA results suggest that a shift from conventional gasoline to lignocellulosic ethanol will reduce emissions of GHGs by 67% to 85% compared to equivalent energy content of petroleum fuel. As shown in Figure 4-10, results indicate that displacing gasoline with lignocellulosic ethanol (LCE) produced in the State will reduce GHG emissions by 1.8 million metric tons per year (Mmt/yr) in Scenario 1a to eight Mmt/year in Scenario 3. As shown in Figure 4-11, LCA results also demonstrate that displacing petroleum fuels with LCE will reduce life-cycle consumption of fossil fuels, with reductions ranging from more than 20 million MMBtu in Scenario 1a to more than 100 million MMBtu in Scenario 3 cases.

Figure 4-11 provides a frame of reference to illustrate energy savings by fuel type and scenario. The figure illustrates the physical quantity of each fuel type that would be displaced, derived from energy content..<sup>35</sup>

<sup>35</sup> This figure is for illustrative purposes only, as petroleum energy includes not only gasoline but also diesel fuel and other petroleum products.

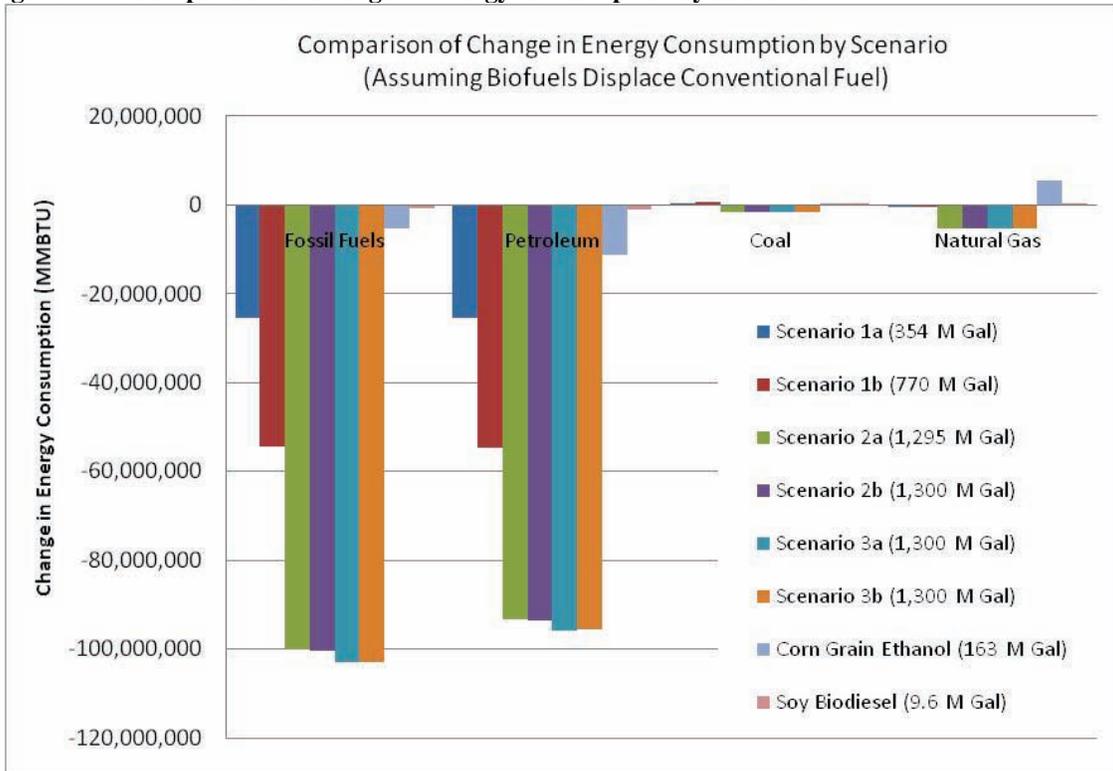
As shown in Figure 4-12, reductions in petroleum energy consumption equate to the annual displacement of more than 200 million gallons gasoline in Scenario 1a and over 800 million gallons gasoline in Scenario 3. (Note that New Yorkers used almost 6,000 million gallons of gasoline in 2007, so this represents displacement of approximately 3% to 14% of present-day gasoline consumption, respectively).

**Figure 4-10. Comparison of Net Change in Emissions by Scenario.**

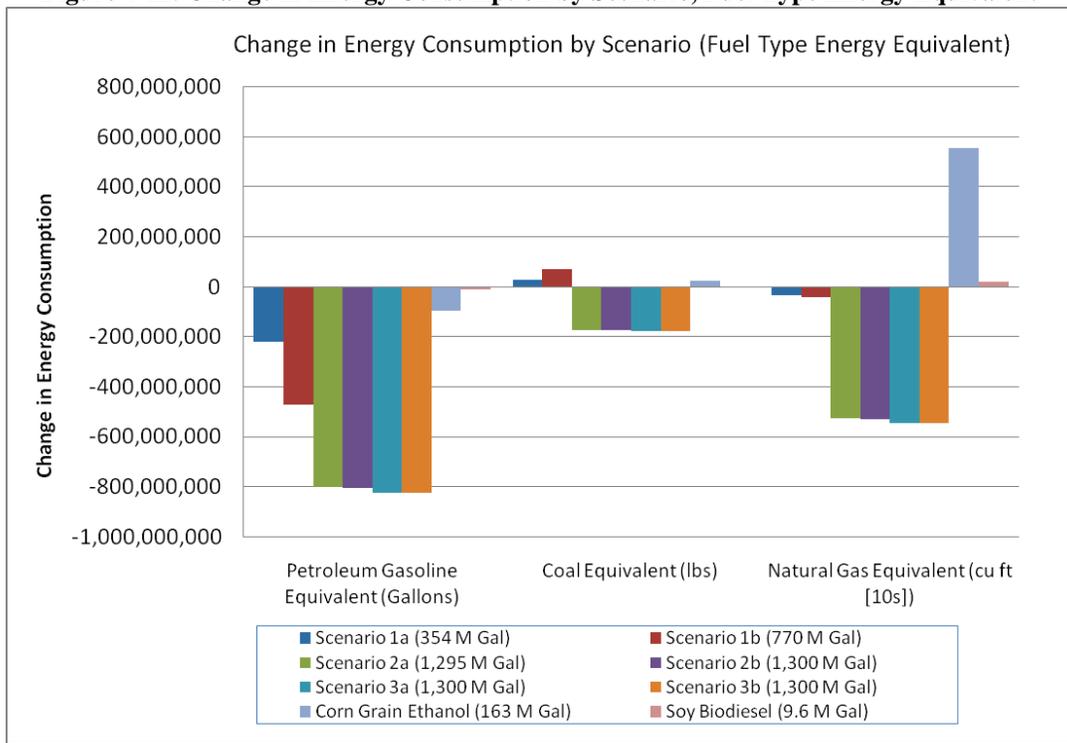


Displacing gasoline with LCE produced in the State will decrease GHG emissions, SO<sub>x</sub> emissions, and fossil fuel consumption; there are tradeoffs to LCE production and use in the State, however. Emissions of air pollutants (VOCs, NO<sub>x</sub>, PM) increase in all scenarios. Emissions of volatile organic compounds (VOCs) and particulate matter (PM) increase by approximately 2,000 metric tons in Scenarios 2 and 3, though in Scenario 1 emissions increases are a fraction of that. Emissions of NO<sub>x</sub> increase by 2,000 metric tons (Scenario 1a) to nearly 10,000 metric tons (Scenario 2 cases). As demonstrated in the results sections above, the majority of VOC and NO<sub>x</sub> emissions take place in the fuel production stage; advanced stationary source controls may be able to reduce these emissions in the future (application of advanced control technologies on biorefineries were not modeled). Finally, emissions of N<sub>2</sub>O, a GHG that is also ozone-depleting, increase in all scenarios. Though N<sub>2</sub>O is approximately 300 times as potent a GHG as CO<sub>2</sub>, N<sub>2</sub>O emissions are more than offset by reductions in CO<sub>2</sub>; as discussed earlier, net GHG emissions are reduced in all scenarios. Results indicate a number of notable differences among Roadmap scenarios. LCE production and use in Scenario 1 produces the least change in emissions, due in large part to the smaller quantity of LCE produced (Figure 4-10).

**Figure 4-11. Comparison of Change in Energy Consumption by Scenario**



**Figure 4-12. Change in Energy Consumption by Scenario, Fuel Type Energy Equivalent**



Increases in emissions of modeled pollutants are minimal for Scenario 1 compared to other scenarios; however, total GHG emission and petroleum use reductions are also minimal (about one-quarter the levels in Scenarios 2 and 3).

Scenario 2 and 3 are nearly identical in LCE production. As shown in Figure 4-10 and Figure 4-11, Scenario 3 results in greater reductions in GHG emissions, SO<sub>x</sub> emissions, and petroleum energy consumption, while producing fewer VOC, NO<sub>x</sub>, and PM emissions.

**4.3.6.2 Findings - LCA Corn Grain Ethanol.** Corn grain ethanol production and use in the Scenarios results in modest GHG reductions (14%) compared to equivalent energy content of gasoline. Though CO<sub>2</sub> is reduced by 452,000 tons, N<sub>2</sub>O is increased by 952 tons. Corn grain ethanol results in increased emissions of other air pollutants modeled, including SO<sub>x</sub>. Total changes in emissions are smaller than Scenario 2 and 3 emissions, though emissions per quantity of ethanol are similar (see Figure 4-13).

As shown in Figure 4-12, results indicate that corn ethanol production will decrease annual petroleum consumption in the State by the energy equivalent of more than 90 million gallons of gasoline. Coal energy use will increase slightly, and natural gas use will increase by more than six million cubic feet.

Though LCA results of corn grain ethanol are less positive than lignocellulosic ethanol, results demonstrate that corn grain ethanol could displace petroleum fuel in the State while resulting in modest GHG emissions reductions.

**4.3.6.3 Findings - LCA Soy Biodiesel.** LCA results from each Scenario indicate that emissions impacts of soy biodiesel production and use are minimal in comparison to ethanol cases—primarily due to the small quantity of biodiesel produced (9.6 million gallons per year). Results indicate a reduction of more than 50,000 metric tons of GHG emissions (51% compared to low-sulfur petroleum diesel). Emissions of N<sub>2</sub>O, VOCs, and SO<sub>x</sub> increase, while NO<sub>x</sub> and PM are reduced. Overall, emissions and energy use impacts of biodiesel production in the State are minimal compared to LCE and corn grain ethanol production.

#### **4.3.7. Public Health Impacts of Biofuels Production and Use - Literature Review and Relationship to Roadmap Data.**

**4.3.7.1 Overview.** Emissions from biofuel production and use have the potential to negatively affect human health (NYSERDA 2009). These emissions may occur either at the farm or fuel production facilities (upstream emissions) or at the tailpipe of the vehicle (downstream emissions). In both cases the direct emissions from production or use (*primary emissions*) can be harmful to exposed human populations. In addition, some of these primary emissions are transformed in the atmosphere to form *secondary emissions*. Detailed quantitative modeling of the atmospheric fate and transport of such pollutants is

beyond the scope of this project. Instead, the public health impacts are discussed through a presentation of the literature on this topic, which is then connected with the LCA results presented above.<sup>36</sup>

**4.3.7.2 LCA Results: Air Pollutant Emissions at Feedstock and Fuel Production Stages.** The LCA presented in Appendix G covers the following air pollutants:

**Volatil organic compounds (VOCs):** Volatile organic compounds are airborne toxics and precursors to ground-level ozone, which is linked to a number of negative health effects including aggravation of asthma, bronchitis, and emphysema, reduced lung function, and pain while breathing. Repeated exposure to ground-level ozone has been linked to premature mortality (EPA 2009a).

**Particulate matter (PM<sub>10</sub>):** An EPA criteria pollutant,<sup>37</sup> PM includes particles with an aerodynamic diameter of 10 micrometers or smaller (PM<sub>10</sub>), which are small enough to reach into the lower respiratory tract and lungs, causing adverse health effects. Numerous studies have linked increased concentrations of PM to negative health effects for exposed populations. PM<sub>10</sub> has been linked to damage to respiratory systems and lungs, chronic bronchitis, cancer, asthma, heart attacks, and premature mortality. Environmental effects of PM include decreased visibility (haze), alteration of nutrient balance, acidification of water, and damage to forests and crops (Nel 2005; EPA 2008).

**Nitrogen oxides (NO<sub>x</sub>):** An EPA criteria pollutant, nitrogen oxides are associated with respiratory problems including asthma and respiratory-related hospital admissions and contribute to ground-level ozone and particulate matter formation (EPA 2009b). NO<sub>x</sub> emissions also contribute to acidification and eutrophication of soil and water (NYSERDA 2009).

**Sulfur oxides (SO<sub>x</sub>):** An EPA criteria pollutant, sulfur oxides, including sulfur dioxide (SO<sub>2</sub>), react with water vapor and airborne particles to form acid and sulfates, which are harmful to health and the environment. Long-term exposure to SO<sub>2</sub> is linked with respiratory problems and disease, while exposure to sulfate particles is linked to respiratory problems and premature mortality (EPA 2009c).

Total life-cycle emissions of VOCs, NO<sub>x</sub>, and PM increase for all scenarios, and SO<sub>x</sub> emissions decrease in all LCE scenarios, but increase in corn ethanol and soy biodiesel cases. Although it is difficult to quantify the relative public health impacts from these emission profiles, more than half of the emissions occur in the upstream stages of the fuel cycle (see, for example, Figure 4-14 and Figure 4-15, below for Scenario 2b).

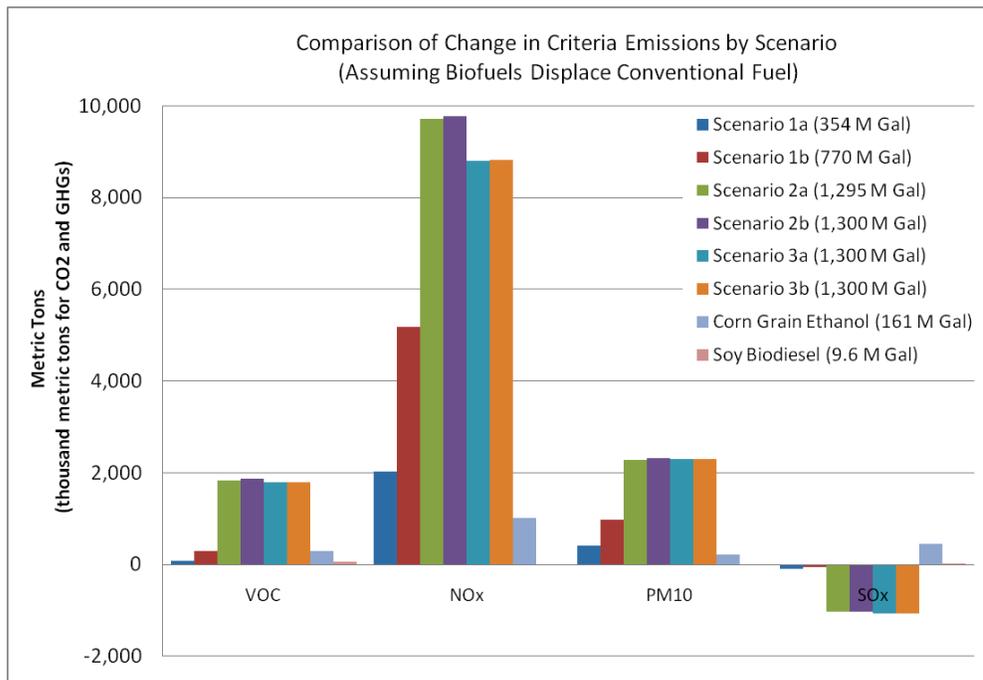
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<sup>36</sup> A detailed discussion of potential health and environmental impacts of biofuels production and use in the State can be found in NYSERDA (2009), *The Environmental Impacts of Biofuels in New York State*. Another NYSERDA study, "Applying the Northeast Regional Multi-Pollutant Policy Analysis Framework to New York: An Integrated Approach to Future Air Quality Planning," will propose mitigation options for air quality. Because the study is not complete, results will be assessed in the annual Roadmap updates.

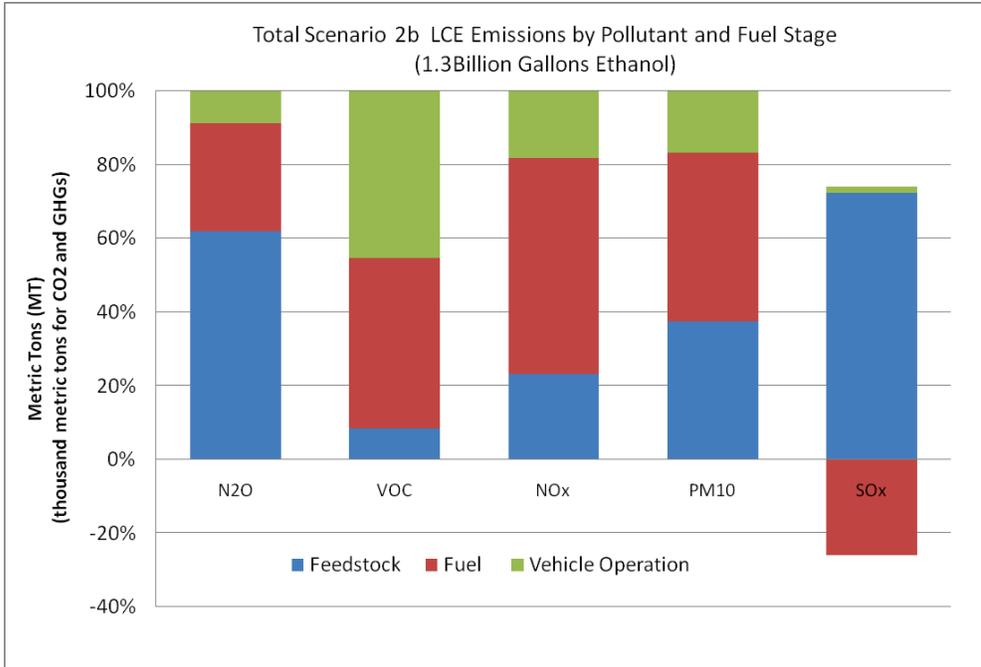
<sup>37</sup> Criteria pollutants (particulate matter, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead) are six common air pollutants that are prevalent throughout the United States, and can be harmful to human health and the environment. These pollutants are termed "criteria" air pollutants because the EPA regulates them by developing human health-based and/or environmentally-based criteria (science-based guidelines) that set allowable levels of the pollutants. (USEPA)

Additional graphs are provided in Appendix G. For biofuels, these upstream emissions will occur in New York; however, for conventional fuels, these emissions will occur mostly outside of New York in locations where petroleum fuel is extracted and/or refined. For that reason, biofuel use is expected to increase total pollution inventories for New York, particularly in those counties that expand feedstock production or operate biorefineries.

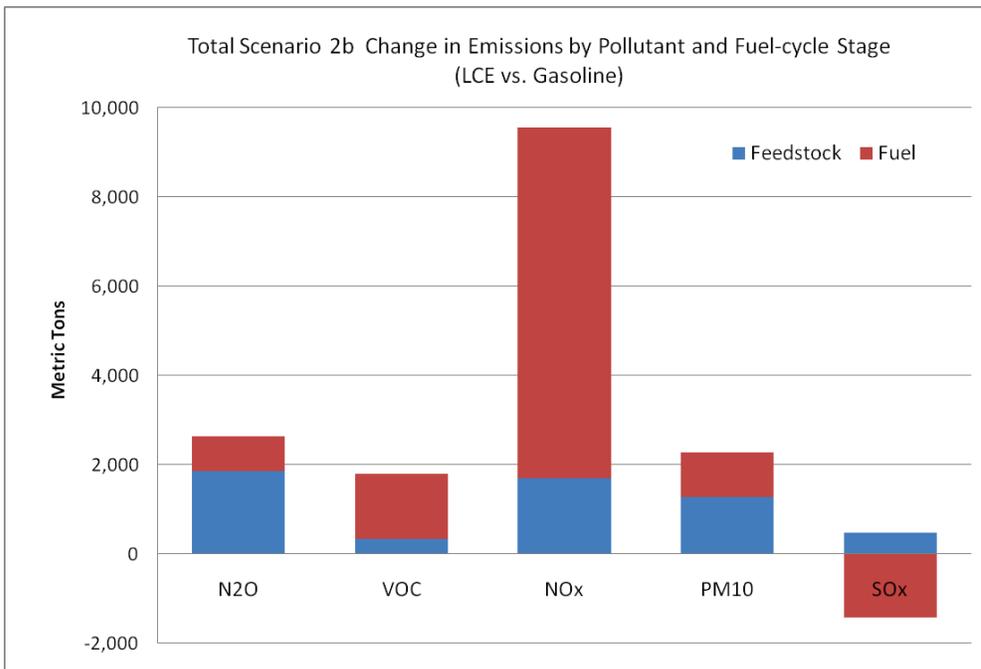
A geospatial characterization of upstream emission locations and transportation activities can be found in maps located in Appendix F of this report. Those maps (for example, Figure 4-3) depict counties where feedstock extraction and biorefinery activity is likely to expand for each scenario studied. Potential health impacts of increased emissions include a range of respiratory problems, asthma, heart attacks, cancer, and premature mortality. More research is needed to quantify the health impacts from these emissions through the application of atmospheric dispersion and population exposure models to characterize the health risk to exposed populations in these regions.



**Figure 4-13. Change in Air Pollutant Emissions by Scenario**



**Figure 4-14. Percentage of Total Scenario 2b LCE Emissions Contribution by Fuel-Cycle Stage.**



**Figure 4-15. Total Scenario 2b Annual Change in Air Pollutant Emissions by Fuel-Cycle Stage (LCE vs. Gasoline)**

**4.9.3 Downstream Emissions of Air Pollutants: Potential Changes Due to Biofuel Use in the State**

**4.9.3.1 Downstream Emission Types.** Downstream (tailpipe and evaporative) emissions may present the greatest risks to public health, as these emissions are often released in more densely-populated urban and residential areas. It is beyond the scope of this study to quantitatively model the health effects of downstream emissions, as data are not available on precisely where fuel would be consumed and in what quantities. However, the following presents a qualitative discussion of potential changes in tailpipe emissions and resulting human health impacts due to a shift from conventional fuel to biofuels. For this qualitative assessment, the EPA criteria pollutant CO and toxic air pollutants (also known as hazardous air pollutants, HAPS) are included (EPA 2009d; EPA 2009e; Winebrake, Wang and He, 2001):

- **Carbon monoxide (CO):** Carbon monoxide can reduce oxygen delivery to the body, exacerbating existing cardiovascular problems and producing negative central nervous system effects. At very high levels CO may cause death. CO is also a contributor to ground-level ozone, which can cause respiratory problems.
- **Acetaldehyde.** Acetaldehyde has been identified as a *probable human carcinogen* by the EPA, due to presence of tumors in rats exposed to acetaldehyde. Non-cancer effects include eye and respiratory tract irritation. Acetaldehyde is a product of fuel combustion and is also formed secondarily through reaction of VOCs.
- **Formaldehyde:** Formaldehyde is classified as a *probable human carcinogen* by the EPA based on evidence in humans, rats and monkeys; like acetaldehyde it can be produced through primary combustion and secondary formation through reactions of organic compounds.
- **Benzene:** Benzene is classified as a *known human carcinogen* by the EPA based on epidemiologic studies, causing leukemia by all routes of exposure. Long-term exposure to benzene has also been linked to non-cancer blood disorders. Benzene is emitted from vehicles as both exhaust gas and through evaporative emissions.
- **1, 3 Butadiene:** 1,3 butadiene is characterized as carcinogenic to humans by inhalation, and is classified as a *known human carcinogen* by the U.S. government (EPA 2009).

#### **4.9.4 Ethanol**

The potential health effects of ethanol use in the State are highly uncertain as the use of ethanol has been found to increase tailpipe emissions of certain VOC species, while decreasing emissions of others. Vehicle type, vehicle operation, fuel blend, and environmental conditions all influence ethanol emissions relative to conventional petroleum fuel. Adding further uncertainty, the literature examining ethanol tailpipe and evaporative emissions is often conflicting (DOE 2009). In this discussion general findings are presented on downstream emissions from ethanol use, and the potential implications on public health in New York State are discussed.

Table 4-8 shows the findings of Niven (2005), who performed a review of environmental impacts of ethanol in gasoline. As shown in Table 4.8, tailpipe emissions from E10 (10% ethanol, 90% gasoline) tend

to reduce emissions of CO, hydrocarbons (HC, of which VOCs are a component), PM, 1,3 butadiene, benzene, and non-methane hydrocarbons (NMHC), while increasing acetaldehyde, and having mixed impacts on NO<sub>x</sub> and formaldehyde emissions. Considering tailpipe and evaporative emissions, E10 has been found to increase HC, NO<sub>x</sub>, formaldehyde, acetaldehyde, NMHC, and ozone-forming potential; CO emissions are reduced. E85 reduces emissions of benzene and butadiene, while increasing formaldehyde and acetaldehyde; E85 reduces NO<sub>x</sub> and has mixed impacts on CO emissions (Jacobson 2007).

High blends of ethanol generally reduce tailpipe emissions of NO<sub>x</sub> compared to petroleum fuels, with E85 NO<sub>x</sub> reductions averaging 20-40% (NYSERDA 2009). In E10 vehicles, NO<sub>x</sub> emissions have been shown to increase or decrease compared to gasoline (DOE 2009, Karman 2003). Ethanol-diesel blends may reduce NO<sub>x</sub> compared to diesel fuel, or may vary according to engine conditions and speeds (He et al. 2003; Huang et al. 2009).

E10 and E20 tend to produce lower CO tailpipe emissions (Niven 2005). Higher blends of ethanol (E85) have been shown to increase tailpipe emissions of CO compared to gasoline, with a total life-cycle increase in CO emissions of 2-3% (NYSERDA 2009, Wu et al. 2005, Brinkman 2005); CO emissions have been found to increase or decrease when used in ethanol-diesel blends (He et al. 2003, Huang et al. 2009).

Though total life cycle PM<sub>10</sub> emissions of corn ethanol are increased substantially compared to gasoline, the majority of PM emissions occur at upstream stages; changes in tailpipe PM emissions of ethanol are uncertain or have been shown to be negligible (Jacobson 2007, Niven 2005, Mazurek 2007, as quoted in NYSERDA 2009).

**Table 4-8 Change in Emissions, E10 Compared to Gasoline**

Pollutant	E10 Tailpipe	E10 Tailpipe Plus Evaporative*
CO	Reduce	Reduce
HC	Reduce	Increase
PM	Reduce	NA
NO <sub>x</sub>	Increase (mixed)	Increase
1,3-Butadiene	Reduce	NA
Benzene	Reduce	NA
Formaldehyde	Mixed**	Increase
Acetaldehyde	Increase	Increase
Ozone forming potential	NA	Increase
NMHC	Reduce	Increase

Source: DOE (2009), reporting findings of Niven (2005)

Ethanol has been shown to increase tailpipe and evaporative emissions of formaldehyde and acetaldehyde (Jacobson 2007; Niven, 2005, Winebrake et al. 2001), toxics that are also ozone precursors. Compared to gasoline, E85 increases tailpipe and evaporative emissions of acetaldehyde by 1250% to over 4300%, and

formaldehyde by 20% to over 250% (Jacobson 2007, NYSERDA 2009, Winebrake et al. 2001). E10 also increases acetaldehyde and formaldehyde emissions, to a smaller degree (Niven 2005, NYSERDA 2009).

Emissions of benzene and butadiene—both known carcinogens—are reduced in ethanol compared to gasoline. Benzene is reduced by 62-87% in E85 and by 11% to 41% in E10 compared to gasoline, though benzene emissions may increase in E10 compared to reformulated gasoline.<sup>38</sup> Butadiene emissions are decreased 0% to 79% with E85, and by 6-19% with E10 (Jacobson 2007; Karman 2003; Niven 2005; NYSERDA 2009; Winebrake, He, and Wang, 2000; Winebrake, Wang, and He 2001). The relative toxicity of these pollutants is important to consider, as benzene and butadiene are considered much more toxic than formaldehyde and acetaldehyde by EPA's CURE (Cancer Unite Risk Estimate) scale. Use of ethanol will likely increase aldehyde toxics and reduce benzene and butadiene (NYSERDA, 2009; Winebrake, He, and Wang, 2000). A decrease in toxic emissions in urban areas from benzene and butadiene would be a positive sign (with respect to cancer impacts) as regards ethanol use in the State, although the decrease is tempered by the likely increase in other toxics, which are associated with other health impacts.

The variation in emissions impacts by different ethanol fuel blends may provide an opportunity to minimize potential negative public health impacts in the State. For instance, E10 has been shown to increase tailpipe NO<sub>x</sub> and benzene emissions compared to reformulated gasoline, while E85 has been shown to decrease benzene and NO<sub>x</sub> emissions. To curtail potential cancer cases and ozone development in urban areas, E85 blends may be preferable to E10 blends in densely populated regions.

The net effects of ethanol use on public health are uncertain, as the scale and location of emissions and affected population are unknown—as are future regulations of air pollutants and toxics. Recent research may shed light on the potential scale of health impacts from certain pollutants. A 2007 study examined the toxics and ozone-related cancer, hospitalization, and mortality impacts of a nationwide switch from gasoline to E85 for the year 2020. Compared to 100% gasoline use, the study found that E85 would increase ozone-related mortality, hospitalization, and asthma in the U.S. by 4%, and in Los Angeles by 9% (increases in Los Angeles were partially offset by decreased mortalities in other regions of the country). Using CURE values, little change in cancer risk was found (Jacobson 2007). Another study compared health effects of PM<sub>2.5</sub> emissions from corn ethanol, cellulosic ethanol, and gasoline, finding that cellulosic ethanol resulted in the lowest health impacts, while corn ethanol resulted in higher health impacts than gasoline (Hill et al. 2009); the study did not examine ozone concentrations or toxics.

#### **4.9.5 Biodiesel**

As with ethanol, the health effects of biodiesel use in the State are uncertain as biodiesel increases tailpipe emissions of certain pollutants, while decreasing emissions of others. Vehicle type, vehicle operation, fuel

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<sup>38</sup> Reformulated gasoline (RFG) is specially refined gasoline with low levels of smog-forming VOCs and low levels of hazardous air pollutants (HAPs).

blend, and environmental conditions all influence biodiesel emissions relative to diesel fuel. In this section, general findings are presented on biodiesel tailpipe emissions as compared to diesel fuel, and public health implications are discussed.

Table 4-9 shows findings of NREL (2003), which includes a review of literature on biodiesel emissions impacts in heavy-duty vehicles (HDVs). As shown in Table 4-9, compared to conventional diesel, B20 (20% biodiesel) increases tailpipe emissions of NO<sub>x</sub> while decreasing emissions of PM, CO, VOC, and SO<sub>2</sub> (SO<sub>x</sub>). Higher biodiesel concentrations (e.g., B100) yield greater changes in emissions, as shown in Table 4.9. Nevertheless, actual emissions results are very much dependent on vehicle type and load profiles, and some studies indicate NO<sub>x</sub> emissions increases to be negligible for B20 while others show NO<sub>x</sub> decreases.

**Table 4-9. Average change in HDV emissions, biodiesel fuel vs. petroleum diesel**

<b>Biodiesel Fuel</b>	<b>NO<sub>x</sub></b>	<b>PM</b>	<b>CO</b>	<b>VOC</b>	<b>SO<sub>2</sub></b>
B20	+2.4%	-8.9%	-13.1%	-17.9%	-20%
B100	+13.2%	-55.3%	-42.7%	-63.2%	-100%

Source: NREL (2003)

Variability in location of emissions and reaction of pollutants with other airborne substances also contributes to uncertainty. A 2003 study suggests the potential scale of health impacts of a shift to biodiesel, however. The study examined scenarios of 100% B20 penetration and 50% B20 penetration in the HDV fleet in Southern California, Las Vegas, the Northeast corridor, and Lake Michigan. Even at 100% penetration of B20, changes in modeled ambient concentrations of ozone, CO, PM<sub>2.5</sub> and PM<sub>10</sub> were extremely small (<± 1%) in all study regions. Ozone concentrations changed (+/-) by less than 1 ppb, and CO decreased by less than 0.2%. Changes in ozone and CO concentrations were low enough that the study determined *no measurable health impacts would occur from use of biodiesel*. In the Las Vegas study region, B20-related changes in PM were found to reduce exposure to annual and 24-hour exceedances of the PM<sub>10</sub> standard by 4% and 7% respectively. PM from B20 is less toxic than diesel PM; accordingly the use of B20 was estimated to reduce risk associated with toxics by 5% in the Southern California study region (NREL, 2003). As the extent of biodiesel use in New York State is likely much lower than that examined in the study, emissions and health impacts in New York State may be even less significant.

**4.9.6 Water, Soil, and Other Environmental Impacts of Biofuels**

While expansion of the biofuels industry in the State could reduce environmental impacts of fossil fuel production and transport outside of the State, it could potentially cause environmental impacts within the State, including soil erosion, impaired water quality, acidification of water and soil, eutrophication of bodies of water, damage to plants and animals, reduced biodiversity, and loss of habitat. Nitrogen (e.g. as fertilizer, N<sub>2</sub>O, or as an air emission, NO<sub>x</sub>) and ozone in particular have been linked to a number of

negative environmental impacts. Findings in Appendix E indicate that nitrogen fertilizer use, NO<sub>x</sub> and VOCs will increase in the State, thus negative environmental impacts such as those listed above might be anticipated. Though energy use and emissions estimates are quantifiable on an LCA basis, currently no research has examined the life-cycle environmental impacts of biofuels on soil, water, and habitat, etc. (NYSERDA 2009). Further, detailed geographical and local information is required to assess the potential impacts to soil and water in the State. Such research is needed in counties that have been identified as potential contributors to feedstock production under an expanded New York State biofuels industry. A comprehensive discussion of the potential soil, water, and other environmental impacts of biofuel production and use in the State can be found in *The Environmental Impacts of Biofuels in New York State* (NYSERDA 2009).

#### 4.10 TABLE SUMMARY OF SCENARIO FINDINGS.

**Table 4-10. Key findings of the Scenarios (compare with Table 4-1, assumptions).**

Attributes	Scenario 1	Scenario 2	Scenario 3
<b><i>Biofuels Statewide capacity (MGY/year)</i></b>			
Lignocellulosic, \$3/wholesale gge price point case	354	1295	1300
Lignocellulosic, \$4/wholesale gge price point case	700	1300	1300
Grain ethanol production in Scenarios	154	154	154
<b><i>New Biorefineries and Feedstock Sheds</i></b>			
Number of lignocellulosic feedstock sheds	4	4	4
Number of lignocellulosic biorefineries	4	12	22-24
Average lignocellulosic biorefinery site capacity (MGY)	90	354	60
Total state production capacity ethanol (MGY)	508	1449	1449
Percentage of New York gasoline consumption	5.6 %	16%	16%
<b><i>Energy use (MMBTU/year) to transport lignocellulosic feedstock and fuel</i></b>			
Transport energy used for moving lignocellulosics at \$3/ gge case	0.39	1.80	0.86
Transport energy used for moving lignocellulosics at \$4/gge case	1.12	1.81	0.86
Transport energy used for moving corn grain and fuel	0.25	0.25	0.25
Transport energy used for moving soybean and biodiesel	0.04	0.04	0.04
<b><i>Road capacity issues</i></b>			
Total ton-miles for moving feedstock (million ton-miles) \$3 gge case	313	1,470	663
Total ton-miles for moving feedstock (million ton-miles) \$4 gge case	905	1,478	663
Average number of trucks entering each biorefinery/day \$3 gge case	240	720	130
Average number of trucks entering each biorefinery/day \$4 gge case	480	720	130
Average number of trucks entering each biorefinery/year \$3 gge case	87,430	262,920	47,950
Average number of trucks entering each biorefinery/year \$4 gge case	174,910	263,720	47,950
<b><i>Statewide Economic Impacts</i></b>			
Number of jobs <sup>39</sup> created \$3 gge case	3,891	14,604	14,189
Number of jobs created \$4 gge case	7,780	14,019	14,236
Estimate of labor income* (wage & salary) \$3 gge case (\$ million)	\$172.6	\$640.6	\$608.3
Estimate of labor income* (wage & salary) \$4 gge case (\$ million)	\$350.4	\$614.7	\$616.9
Gross domestic product \$3 gge case (\$ billion)	\$0.46	\$1.73	\$1.78
Gross domestic product \$4 gge case (\$ billion)	\$0.93	\$1.66	\$1.79

**Table 4-10 (continued) summarizes the key findings of the Scenarios (compare with Table 4-1).**<sup>40</sup>

<sup>39</sup> Jobs are the primary measure of regional economic well-being. In the model, however, jobs are not expressed in terms of whether or not they are full-time or non-seasonal jobs. In the model, for example, a seasonal farm job is a job, as is a full-time permanent factory job producing ethanol.

\*On an annual basis

<b>Attributes</b>	<b>Scenario 1</b>	<b>Scenario 2</b>	<b>Scenario 3</b>
<i>Change in Total Fuel Cycle Emissions, Biofuels vs. Energy Equivalent of Petroleum Fuel (Ethanol vs. Gasoline; Biodiesel vs. Low-Sulfur Diesel)</i>			
<i>Thousand Metric tons/year</i>			
GHG <sup>41</sup> \$3 gge wholesale price case (lignocellulosic ethanol)	(1,843)	(7,839)	(8,065)
GHG \$4 gge wholesale price case (lignocellulosic ethanol)	(3,756)	(7,874)	(8,063)
GHG (Corn and soy, all scenarios & price cases)	(218)	(218)	(218)
CO <sub>2</sub> \$3 gge wholesale price case (lignocellulosic ethanol)	(1,888)	(8,419)	(8,643)
CO <sub>2</sub> \$4 gge wholesale price case (lignocellulosic ethanol)	(4,020)	(8,459)	(8,642)
CO <sub>2</sub> (Corn and soy, all scenarios & price cases)	(531)	(531)	(531)
<i>Metric tons/year</i>			
NO <sub>x</sub> \$3 gge wholesale price case (lignocellulosic ethanol)	2,028	9,701	8,786
NO <sub>x</sub> \$4 gge wholesale price case (lignocellulosic ethanol)	5,174	9,758	8,811
NO <sub>x</sub> (Corn and soy, all scenarios & price cases)	720	720	720
PM <sub>10</sub> \$3 gge wholesale price case (lignocellulosic ethanol)	416	2,279	2,293
PM <sub>10</sub> \$4 gge wholesale price case (lignocellulosic ethanol)	980	2,321	2,294
PM <sub>10</sub> (Corn and soy, all scenarios & price cases)	209	209	209
SO <sub>x</sub> \$3 gge wholesale price case (lignocellulosic ethanol)	(90)	(1,029)	(1,071)
SO <sub>x</sub> \$4 gge wholesale price case (lignocellulosic ethanol)	(57)	(1,029)	(1,067)
SO <sub>x</sub> (Corn and soy, all scenarios & price cases)	435	435	435
VOC \$3 gge wholesale price case (lignocellulosic ethanol)	89	1,830	1,790
VOC \$4 gge wholesale price case (lignocellulosic ethanol)	289	1,865	1,791
VOC (Corn and soy, all scenarios & price cases)	460	460	460

<sup>40</sup> Parentheses indicate negative values.

<sup>41</sup> GHG includes CO<sub>2</sub>, N<sub>2</sub>O, and CH<sub>4</sub>, and is reported as CO<sub>2</sub> equivalent.

## 5 POLICY IMPLICATIONS

The policy implications are preceded by a brief summary of Roadmap study findings. The findings are based on a combination of new raw data collection, literature review, expert interviews, and computer modeling efforts undertaken by the Roadmap team. The reader is cautioned not to interpret or apply any finding out of context or without considering the assumptions behind each finding. Each finding is supported and explained in more detail throughout the Roadmap document and through the Roadmap Appendices.

This summary introduces the findings with questions that focus on important topics of the Roadmap investigation. Following each question are key findings drawn from previous sections of this Roadmap report and from the supporting technical appendices. After briefly stating each finding, a further explanation is provided and in many cases suggestions for additional research that warrant further consideration are listed. Not all findings are accompanied by suggestions for additional research or follow up action.

### 5.1 BACKGROUND OF GUIDANCE FOR THE ROADMAP STUDIES

The following guidance was provided by NYSERDA to the Roadmap team in the design of the Roadmap study and expected end-use of the Roadmap findings (NYSERDA Request for Proposals [RFP] #1249, 2008).

*The New York State Governor's Renewable Energy Task Force report recommended that a Renewable Fuels Roadmap and Sustainable Biomass Feedstock Study for New York be developed. The Task Force report stated that New York first needs to assess critical environmental, capacity, technology, efficiency, and economic issues for renewable fuels. This assessment will provide policy makers with a better understanding of the possible impacts that increased use of renewable fuels may have on the environment and public health, and should put forth a plan to mitigate potential negative impacts and ensure sustainable feedstock production.*

*The Roadmap information will be used to help the State address the following questions in order to set strategic and performance goals for renewable fuels in New York:*

- *What are the current problems and how should we approach the solutions? What targets are needed? How do we create performance-based standards and policies that continually improve the environment and New York's economy, rather than feedstock-specific or technology-specific policies that create artificial market*

*responses and unintended consequences? What are the policy drivers and how should they be prioritized?*

- *What are the performance standards and environmental safeguards needed to responsibly produce and use renewable fuels in New York? For example, is a low-carbon fuel standard a sensible approach?*
- *If the first generation of renewable fuels is represented by corn-based ethanol and soy-based biodiesel, what are the second and third generation opportunities?*
- *What role should incentives play as New York transitions to advanced renewable fuels and where are those incentives best placed? What is the role of government? How does government create policies that are not too stringent, too lax, or too transient to be effective, yet are flexible enough to address future circumstances?*
- *Are there options for growing renewable fuels in New York that lead beyond sustainability to an actual enhancement of the environment and public health?*
- *What time frame should subsidies take and how should funding for the incentives be provided?*
- *What is the magnitude and time frame of the annual investment in research and development to provide a sustainable supply of feedstock to meet the projected demand?*
- *What will ensure success for a renewable fuels industry in New York?*
- *How can New York integrate our renewable fuels efforts with efforts elsewhere in the Northeast and nationally? How should New York incorporate international (e.g. Canadian) feedstock availability into our plans?*

The Roadmap document does not attempt to resolve any of these challenging questions directly, but instead furnishes relevant data, expert opinion and the best available information to date in order to provide information that will assist State policymakers in addressing these questions.

Since work on the Roadmap began, additional questions and policy concerns (such as international/indirect land use change, cap and trade, etc.) have arisen. The Roadmap team has attempted to keep abreast of the evolving issues in order to provide the most complete picture of the industry strengths, weaknesses, and major issues of the day.

## 5.2 LAND AVAILABILITY FINDINGS

*How much land is available in New York State for sustainable biomass feedstock production?*

**FINDING: There is the potential for between one million and 1.68 million acres of non-forest land to be used for bioenergy feedstock production in New York.** There are several assumptions built into this estimate. The lower estimate assumes that no cropland is used for new bioenergy feedstock production;

instead, the new production lands come from abandoned farmland, old pasture, and scrub and shrub lands not currently used for production. The estimate also assumes that only about half of New York land owners would be interested in production. The high-end of the estimate (1.68 million acres) assumes additional land (calculated to be approximately 0.68 million acres) becomes available by the year 2020 due to projected increased crop and milk yields such that the same amount of crops and milk can be produced as in 2009, but on less land, freeing some current crop land for lignocellulosic energy feedstocks.

The feedstock supply assessment assumed that the amount of forest land in New York will not change significantly in the future. There are almost 18.5 million acres of forest land in New York. After excluding areas in the State such as the forest preserve in the Adirondacks and Catskills where harvesting is restricted, there are nearly 15.8 million acres of forest land producing or capable of producing woody biomass, which is referred to as timberland.<sup>42</sup> This is the land base that was used to determine the potential feedstock supply from forests. It is important to note, however, that biofuels technology is emerging, and the availability of future feedstocks or technologies that might have less impact on land (e.g., algae) could increase the amount of biofuels that could be sustainably produced in New York.

**Read more about it:** Roadmap Sections 2 and 4 and Appendix E.

***Further Research Needs:***

- More information is needed on land-owner preferences in producing bioenergy feedstocks in New York State. A survey of larger-plot land owners (i.e., > 100 acres) and smaller-plot land owners (<100 acres) would help clarify the amount of land that might actually be available for biomass energy feedstock production.
- There are also specific considerations regarding sustainable biomass feedstock production that require further examination, such as advancing combined field research and modeling of both greenhouse gas emissions from feedstock production as well as environmental impacts of bioenergy feedstock production over large areas; investigating effects of large-scale biomass harvest from existing forests on species diversity; creating a participatory process and iteratively reviewing sustainability criteria and performance standards for adaptive management of biomass resources; and developing an adaptive management program that iteratively monitors each feedstock and its overall system life cycle for financial, social, and environmental costs and benefits to guide incentives for the most sustainable feedstock production.
- Best management practices for sustainable biomass production and harvest for annual and perennial feedstocks need further development. Best management practices will be needed for site specific production practices to ensure sustainable feedstock production. Throughout this research, special attention should be paid towards ensuring that science-based, comprehensive criteria on GHG emissions of biofuels and co-products are considered.
- There has been much discussion and debate about how future demands for feedstocks from biofuels' producers might affect agricultural and wood products markets. A study could be conducted on how bioenergy crops fit into the future of the agricultural sector in New York.

<sup>42</sup> Modeled estimates of forest biomass based on the 2002-2006 Forest Inventory and Analysis (FIA) Database and 2007 Timber Products database of the USDA Forest Service show that New York forest biomass is growing approximately three times faster than it is being harvested.

### 5.3 NEW YORK BIOMASS CAPACITY AND COMPETING USES FINDINGS

*Could New York State produce enough biomass from this land to support a liquid transportation fuels industry?*

**FINDING: New York State could produce enough biomass to support a lignocellulosic ethanol industry.** The study finds that, at feedstock prices at the farmgate of \$45 to \$75 per dry ton, and assuming the limits to land use change described in the scenarios, New York could sustainably produce between 4.2 and 14.6 million dry tons of cellulosic biomass per year (this includes 6.4 Mdt from forests).

**Read more about it:** Roadmap Sections 2 and 4 and Appendix E.

***Further Research Needs:***

- Research combined feedstock breeding, agronomic practices and modeling
- Demonstrate mixtures of different species in the same field
- Quantify opportunities for multiple services from a single production system, such as feed and feedstock from grasses or high-value wood products, biomass, and wildlife habitat from existing forests
- Assess the capacity of the logging industry infrastructure to meet the potential harvest rates identified in this Roadmap

*If New York lands could sustainably produce between 4.2 and 14.6 million dry tons of biomass per year, how many gallons of fossil fuel would be replaced with this amount of biomass?*

**FINDING: Based only on feedstock from New York State (4.2-14.6 million dry tons), New York lands could provide 5.6% to 16% of estimated 2020 in-state gasoline consumption.** Assuming that the technological barriers to commercial scale production of lignocellulosic ethanol are overcome by the year 2020, the total State capacity for lignocellulosic ethanol is estimated to be between 508 and 1,449 million gallons, representing 5.6% to 16%, respectively, of projected 2020 gasoline consumption in New York State. This estimate makes an assumption that all of the sustainably available biomass in New York is sold for lignocellulosic ethanol production.<sup>43</sup> In reality, there will be competing uses and competing markets for that biomass (such as heating and electricity). The upper end of this range is intended as an estimate of the “upper boundary” of feasible and sustainable New York biomass and biofuel production. Achieving this level of annual production would require substantial investments in R&D and very rapid deployment that may be difficult to achieve by 2020 or even 2030.

**Read more about it:** Roadmap Section 4 and Appendix L.

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<sup>43</sup> These estimates are in addition to current agriculture and forest production volumes.

*Are there other in-state feedstocks that could be considered by New York State in a developing biofuels industry?*

**FINDING: The municipal solid waste stream (MSW) is another potential feedstock source for ethanol production.** Using data from two New York State municipal waste characterization studies and the National EPA waste characterization study, estimates of waste biomass available for ethanol production were extrapolated from the NYSDEC Waste Management Plan 2000 update. If New York were to convert only the yard waste and paper waste fraction (not currently being recycled) into ethanol, it could theoretically yield 426 million gallons of ethanol in the short term and 524 million gallons in the long term, depending upon the conversion process used. These are theoretical yield potentials; actual yield of ethanol is dependent on the availability of the waste biomass in the MSW stream which, in turn, is dependent on MSW management practices that vary across New York State.

**FINDING: Based on assumptions generated for modeling purposes (see Appendix E sub-Appendix E-G and Appendix L for more details), it was calculated that of the total 180 million lbs of yellow grease produced within New York State an estimated 150 million lbs would be available for biodiesel production.** Although the waste yellow grease resources are widely distributed throughout the state, urban areas are the major generators, including the metropolitan areas of New York City/Long Island, Buffalo and Rochester. In reality, the amount of yellow grease captured for biodiesel production will depend largely on the logistics of collection and the location of biodiesel production facilities.

***Further Research Needs:***

- Research is needed to characterize the waste stream (including yellow grease) in New York, to determine the actual amount and availability of waste biomass. In addition, an analysis of the trends in MSW generation among rural, suburban, and urban areas would provide information on where waste biomass is being generated.
- Research is needed on the economics of waste to ethanol production. Such research would provide insight into waste biomass resource competition, and whether waste to ethanol is a profitable alternative to composting, recycling, or diversion to other waste to energy technologies.
- A life cycle analysis (LCA) is needed on waste to ethanol emissions that compares this technology with other waste to energy technologies such as landfill gas recovery and waste to electricity. In addition, valuing these emissions as externalities would be useful in developing a social-cost comparison that would help policy makers evaluate which disposal method has the least net cost from an environmental and economic perspective.

What are the competing uses of biomass feedstock in New York? How does the Roadmap address the question of using biomass most effectively?

**FINDING: Over the next five to ten years, there may be considerable competition between liquid biofuel producers and other users of lignocellulosic biomass feedstock in the region, including thermal fuel production (e.g., wood chips, pellets, and firewood), biomass electricity (e.g., utility-scale co-firing and stand-alone wood-fired power plants), and combined heat and power (CHP).**

With respect to existing markets, use of wood by New York's large and small sawmills, wood chip producers, pulp/paper producers, and for net wood exports is significant, totaling 2.3 million dry tons in 2007. Despite the substantial decline experienced by the Northeast's sawmill and pulp/paper industries in recent years from their highest levels of production, these industries still comprise the largest demand for woody biomass feedstocks in New York. The market for firewood is also a significant source of demand for New York woody biomass resources, with NYSDEC estimating that the firewood market is more than 60% of the market for industrial uses, or equal to approximately 1.6 million dry tons in 2007. Biomass is also currently used for electricity generation. A growing opportunity for biomass generation is combined heat and power (CHP), which is an efficient use of biomass for heat and electricity.

With respect to emerging markets, co-firing with biomass is currently the only low-cost opportunity for RGGI coal plants to achieve direct GHG reductions. Demand for biomass to support co-firing at all of these RGGI coal plants even at a 2.5% level would be formidable, equaling 4.3 million green tons (or 2.6 million dry tons), roughly equal to the volumes used by the entire New York wood products industry. However, NYSDEC's preliminary guidance suggests the definition of sustainable biomass could be quite limited depending upon the provisions of the NYSDEC program policy currently under development. Such requirements could substantially limit the quantity of woody biomass that could be used for co-firing in New York's RGGI plants.

In addition to biomass electricity, another probable growth area for New York biomass demand is as a feedstock for producing heating fuels. Demand for wood as a heating fuel, either as firewood or in pellet form, historically has been highly sensitive to the price of heating oil in the Northeast. Because the region's heavy dependence on oil as a heating fuel exposes consumers to the volatility of prices for a commodity the price for which is controlled by global markets, wood is increasingly seen as an option that can increase the Northeast's energy security.

**FINDING: The Roadmap finds that there will continue to be multiple uses of biomass, but it does not conclude that any one use should be given priority over the others.** This is a complex question that may have as many answers as there are stakeholders. The Roadmap does not predict how the competition will play out, but it is designed to be limited to the scenarios that investigate whether biofuels could be produced without displacing other resources – assuming continued levels of certain resources. Today, there are no equations or criteria that can be applied to a given acre of land to determine whether this particular

acre is best used for food, feed, forest, biomass feedstock production, or a multitude of other possible uses. To further complicate matters often the land and the resulting biomass can serve multiple purposes simultaneously. For example, some biofuel production processes produce lignin that could be burned.

**Read more about it:** Roadmap Section 2 and 3 and Appendix O, P and D.

***Further Research Needs:***

- Model available supply and the effect of competition on pricing, considering increases in demand that might result from the expansion of biofuel production or the expansion of other competing uses for biomass
- Conduct a comparative market analysis of current biomass uses and future trends

#### 5.4 LIGNOCELLULOSIC ETHANOL INDUSTRY STRUCTURE

*If a lignocellulosic ethanol industry develops in New York State, where should biorefineries be located? How many biorefineries (and what size) could be operated based on New York lignocellulosic feedstock supply?*

**FINDING: In the three scenarios modeled, cellulosic ethanol production facilities rely on road transport, based on current transport infrastructure options and feedstock economic modeling. Facilities also were located in close proximity to the feedstock supply sheds.** The presence of lands that could potentially produce feedstocks does not imply that landowners in this area would want to use their land for feedstock production.

**FINDING: If lignocellulosic biorefineries were large-scale, centralized facilities (capacity range 90-354 million gallons per year) four large complexes could operate in the State. Alternatively, up to 24 smaller-capacity (60 million gallons per year) biorefineries could operate with the estimated sustainably available biomass in the State.** This estimate assumes that all new biomass feedstock development is directed to lignocellulosic ethanol production. Existing industries requiring biomass feedstock (e.g., wood pellet industry, food and feed supplies) are also assumed to remain at 2007 Census of Agriculture capacity. The three scenarios evaluated and presented in the Roadmap report are not the only possibilities for a biofuels industry in New York State, but are presented as a way to place realistic bounds on the possibilities based on the availability of a sustainable biomass feedstock supply from within the State that does not compete with existing food and animal feed markets.

**Read more about it:** Roadmap Section 4 and Appendix F and L.

***Further Research Needs:***

- When siting a new commercial scale biorefinery, a detailed study of supply, siting issues (infrastructure and environment), facility design and operations, and local economic and tax benefits could both benefit future development and point to critical issues that must be resolved.

How close is the lignocellulosic ethanol industry to meeting technological goals that will carry the industry from demonstration phase to commercial scale development?

An assessment of the current technologies to convert biomass to lignocellulosic ethanol and interviews with industry experts suggest the industry is five to ten years away from meeting the technological goals that would allow scale up to commercial production. The Roadmap identified the following major technological barriers:

- Overcoming the technological barriers to using cellulosic biomass at a commercial scale;
- Lowering the costs for biofuels through improvements such as simplified pre-treatment and technologies such as consolidated bio-processing; and
- Building demonstration plants to test scaled-up technologies and verify the environmental, economic, and technological benefits.

**Read more about it:** Roadmap Section 2 and 4 and Appendix C and H.

***Further Research Needs:***

- Update models as new technologies are introduced
- Consider multi-product integrated biorefineries that optimize use of biomass and maximize revenue streams
- Improve yield and conversion efficiencies

## 5.5 LOGISTICS AND TRANSPORT

How far will feedstocks need to move to biorefineries and how far would ethanol need to move from biorefinery to blending facilities?

**FINDING:** One possibility is for the industry biorefinery plants to be large, centralized facilities positioned in, for example, four locations around the State. In this case feedstocks would need to be transported an average of about 90-100 miles. Alternatively, many smaller-capacity facilities could be distributed, for example in 24 locations around the State, where feedstocks would need to be transported an average of about 40-50 miles.

**Read more about it:** Roadmap Section 4 and Appendix F and L

***Further Research Needs:***

- In order to better understand the distances biofuels will need to move, the role of various policies on feedstock and fuel movements could be analyzed. In addition, the possibility of centralized feedstock collection points should be considered.

Assuming only New York-grown (local) feedstocks are used, what is the best way to transport biomass feedstocks in New York from field to conversion facility?

**FINDING:** Based on a least-cost production model conducted for the Roadmap, trucks will be used extensively, if not exclusively, in all scenarios. This is due in part to the short distances needed for

feedstock and fuel transport as well as the fact that the highway network in the State extends into all feedstock origin counties. In contrast, the State waterway and rail networks do not reach into several northeastern and southwestern counties in the State where potential feedstock production is plentiful, so in many cases truck transportation is the only currently existing option for feedstock transport. In terms of cost, water-based transport and rail transport are both less expensive on a marginal-cost basis but still remain less desirable because of the fixed transfer costs associated with them. For long distance travel, however, these fixed costs are divided over a great many miles, so the average cost of rail or ship transport is usually less than for truck transportation. For shorter distances, these fixed costs lead to higher average costs compared with trucks. Some literature has shown that trains and ships can effectively compete with trucks economically when shipping distances are greater than 500-750 miles. If the New York State Rail Plan is implemented, three new intermodal facilities/inland ports, at least two of which would be sited in upstate New York, would be developed. If properly sited, these new facilities might allow for use of rail transport where it is currently infeasible or uneconomical. This finding is based upon economic considerations of transport; however, social factors also should be a consideration. (See next two findings for further discussion.)

**Read more about it:** Roadmap Section 4 and Appendix F.

***Further Research Needs:***

- To fully optimize logistics and transport systems, both least-cost and least-impact models are needed. This Roadmap did not model the transportation pathway that would have the least impact to society. Instead a least-cost model was used in siting the biorefineries, then those outputs were used to model transportation options. In the future, these results (Appendix F) could form part of a baseline for developing a social-costs model that values the environmental and health impacts from the transportation and distribution of biofuels.
- Currently, water and rail play a very minor role in feedstock transport. If centralized collection facilities develop in the future, the expansion potential of rail and water to should be reanalyzed.
- The impact of financial incentives on transportation choices should be examined.

*Does New York currently have the road, bridge, rail and waterway capacity to handle the needs of a biofuels industry? What are the potential truck traffic impacts to an area housing a lignocellulosic ethanol facility?*

**FINDING:** While a road-specific analysis was not feasible within the current study, an examination of projected congestion patterns on roadways in conjunction with the Roadmap scenarios leads to the conclusion that feedstock movement via rail or barge may be more desirable than via truck transport. By 2020, roadway congestion is expected to expand. A state-wide congestion peak is expected by 2035. Railroads in the State, on the other hand, are currently operating under capacity and in 2035 are anticipated to be under- or near-capacity. Capacity constraints and congestion may present opportunities

for the development of decentralized rail hubs that would collect and aggregate feedstock by truck and then transport larger shipments to the biorefineries via rail. In the future, therefore, rail may present a more optimal biofuel feedstock transportation option. In addition to rail, densification technologies for biomass could provide an important alternative relief mechanism by increasing transportation efficiency.

**FINDING: Truck traffic would increase surrounding a biorefinery.** A large centralized facility producing 90 million gallons per year biofuel requires 240 trucks per day. A larger centralized facility (354 million gallons per year) requires 720 trucks per day. Smaller facilities (60 million gallons per year) distributed throughout the State each would require an average of 130 trucks entering daily. Increases in heavy truck traffic of the scale estimated here may potentially result in (1) excessive damage to roadways near and en route to biorefineries, (2) potential disturbances and concern in residential areas (depending on biorefinery site), (3) important safety concerns warranting further research, and (4) increased emissions that may result in negative health impacts in exposed populations.

**Read more about it:** Roadmap Section 4 and Appendix F.

***Further Research Needs:***

- Research is needed on the impact of biorefineries on local traffic patterns and road maintenance. Detailed route analysis could provide more insight into specific traffic issues that may arise.
- Research is needed on efficient feedstock distribution networks.
- An analysis of how improved biomass densification technology might affect transportation options is needed.
- Improvements in biomass densification technologies are also needed.
- Geospatial emissions inventories, air modeling, and health risk assessments are needed to further examine traffic impacts on air quality and health.

## 5.6 ECONOMICS

### *How many new jobs would be created in New York State?*

**FINDING: Each Scenario generates different totals for the number of new jobs<sup>44</sup> created statewide. For Scenario 1, approximately 3,900 jobs would be created; for Scenario 2, approximately 14,600 jobs would be created; and for Scenario 3, approximately 14,200 jobs would be created.** This new industry will also require a new generation of forestry and agricultural workers. Direct jobs in biorefineries represent a relatively small share of the total job impact -- less than 10%. These jobs, however, are likely to provide well-paying, sustained employment. The economic analysis indicates about half of all jobs created by industry expansion will be crop- or forestry-based feedstock production and processing, and another quarter of the jobs will be involved in trucking the agriculture and forestry feedstocks to the new

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<sup>44</sup> In the analysis, a "job" is defined as any new position of employment, including both full-time and part-time/seasonal jobs.

refineries and transporting the liquid fuels from the refineries. The remaining ~15% are additional jobs in the input-sector, including business services, waste disposal, materials and machinery, water, chemical, enzymes, etc.

In addition, industry expansion will likely create jobs for plumbers, electricians, plant operations, and process engineering, as well as some limited expansion of “downstream” jobs in transport, storage, and blending, although these jobs will be limited.

**Read more about it:** Roadmap Section 4 and Appendix I and J.

**Table 5.1. Estimates of Jobs Created by Biofuel Refinery Growth, Statewide.**

<b>Job Sector</b>	<b>Scenario #1</b>	<b>Scenario #2</b>	<b>Scenario #3</b>
<b>Agriculture and Forestry Based</b>	1,675 (43%)	6,525 (45%)	6,959 (49%)
<b>Transportation Based</b>	912 (23%)	3,830 (26%)	1,864 (13%)
<b>Miscellaneous Jobs</b>	753 (19%)	2,525 (17%)	2,727 (19%)
<b><i>Subtotal – Input Sector Jobs</i></b>	<b>3,340 (86%)</b>	<b>12,880 (88%)</b>	<b>11,550 (82%)</b>
<b>Direct Jobs at Refinery</b>	275 (7%)	798 (6%)	1,320 (9%)
<b>Induced Jobs (due to direct worker and investor spending)</b>	276 (7%)	925 (6%)	1,317 (9%)
<b><i>TOTAL JOBS</i></b>	<b>3,891 (100%)</b>	<b>14,604 (100%)</b>	<b>14,189 (100%)</b>

*Estimates include direct and induced job growth resulting from biofuel refinery expansion*  
Source: Working papers from Roadmap Economic Analysis, Appendix I (Swenson, 2009)

*What is the estimated gross domestic product (GDP) of an industry that produces 5.6% to 16% of New York transportation fuels?*

**FINDING:** The estimated GDP of a biofuels industry producing 5.6% of New York transportation fuels is \$0.5 to \$0.9 billion. The estimated GDP of a biofuels industry producing 16% of New York transportation fuels is \$1.8 to \$1.9 billion. Scenarios were modeled to determine the upper *sustainable* bounds of a New York biofuels industry based on New York feedstock alone. For comparison, 2008 New York GDP was \$1,144.5 billion; the forest products industry contributes \$3.7 billion to the State gross product.

**Read more about it:** Roadmap Section 4 and Appendix I.

## 5.7 ENVIRONMENTAL AND HEALTH IMPACTS

### *What would be the public health impacts of an expanding biofuels industry in New York State?*

**FINDING:** Compared to fossil fuels, in a total life cycle analysis, certain emitted air pollutants will be reduced, while others will be increased. Lignocellulosic ethanol (LCE) production and use will reduce life-cycle emissions of sulfur oxides (SO<sub>x</sub>), with reductions ranging from 90 metric tons to more than 1,000 metric tons. The tradeoffs associated with biofuels production include increased emissions of some air pollutants that may lead to increased public health concerns in locations where feedstock expansion and fuel production occur.

Emissions may occur either at the farm or fuel production facilities (upstream emissions) or at the tailpipe of the vehicle (downstream emissions). Detailed quantitative modeling of the atmospheric fate and transport of such pollutants is beyond the scope of this project. Instead, the public health impacts are discussed through a presentation of the literature on this topic, which is then connected with the Roadmap life cycle analysis results. The net effects of biofuels' use on public health are uncertain, as the scale, location of emissions, and affected populations are unknown—as are future regulations of air pollutants and toxics. In addition, it is important to note that competing uses of biomass for energy are also associated with negative health impacts. For instance, residential use of firewood produces emissions of particulate matter (PM) and volatile organic compounds (VOCs), and potentially carcinogenic pollutants. These pollutants are linked to respiratory problems, lung damage, and cancer.

Because the sources of the upstream emissions from a biofuels industry will be located in New York, whereas upstream emissions sources for conventional fuels often are located out-of-state, New York may observe increases in upstream emissions as a biofuel industry emerges. Downstream (tailpipe of the vehicle) emissions often occur in areas with high population density, and therefore the impacts to human health may be proportionately greater.

As an example of the complexity of assessing public health risk, the literature indicates that replacing gasoline with ethanol results in a decrease in toxic emissions from benzene and butadiene. This would be a positive sign with respect to cancer impacts. This is tempered, however, by the likely increase in formaldehyde and acetaldehyde, which are associated with other health impacts. The relative toxicity of pollutants is important to consider; benzene and butadiene are considered much more toxic (with respect to cancer risk) than formaldehyde and acetaldehyde by EPA's CURE (Cancer Unit Risk Estimate) scale.

**Read more about it:** Roadmap Section 4 and Appendix G.

What are the GHG impacts of a future biofuels industry in New York State?

**FINDING: LCE pathways in New York show potential to decrease greenhouse gas (GHG) emissions by millions of tons annually compared to gasoline.** Moreover, these benefits are even greater under a distributed, localized biofuels industry. Overall, LCA results suggest that a shift from conventional gasoline to LCE will reduce emissions of GHGs by 67% to 85% compared to equivalent energy content of petroleum fuel. Results indicate that displacing gasoline with LCE produced in the State will reduce GHG emissions by 1.8 million metric tons (Mmt) to ~eight Mmt per year. Carbon capture and sequestration at the biorefinery was not modeled. Nor did the modeling address indirect land use change and its effects on GHG emissions.

Corn ethanol and soy biodiesel production also reduce GHGs, though to a lesser degree than LCE.

What would be the environmental impacts? (Soil, Water, Air)

**FINDING: Potentially negative environmental impacts of increased feedstock production, biofuels production, and biofuels use in the State include: soil erosion, impaired water quality, acidification of water and soil, eutrophication of bodies of water, damage to plants and animals, reduced biodiversity, and loss of habitat.** Nitrogen (e.g., as fertilizer, N<sub>2</sub>O, or NO<sub>x</sub>) and ozone in particular have been linked to a number of negative environmental impacts; findings in Appendix E indicate that nitrogen fertilizer use, NO<sub>x</sub> and VOCs (precursors to ozone) will increase in the State with the development of a biofuels industry, and thus negative environmental impacts such as those listed above might be anticipated. Odor issues near farms and biorefineries might also be expected from a large-scale biofuels industry in the State. Implementing appropriate best management practices would minimize some of the adverse environmental impacts, as would use of perennial crops.

**Read more about it:** Roadmap Section 4 and Appendix E and G.

***Further research needs on this topic:***

- Geospatial air chemistry and dispersion models and population data are needed to determine potential health effects.
- Detailed geographical and local information is needed to assess the potential impacts to soil and water in the State; such research should be supported in counties that have been identified as potential contributors to feedstock production under an expanded New York State biofuels industry.
- More research is needed to define and characterize advanced biofuel pathways, such as liquid transportation fuels from algae, or the economics and logistics of production of biodiesel from yellow grease.
- Research is needed to quantify the health effects and life cycle environmental impacts of current and emerging biofuels including impacts on soil, water, and habitat.
- Research is needed to quantify the health effects and life cycle environmental impacts of various competing uses of biomass.

How did the Roadmap address indirect land use change effects?

**FINDING: New York-specific indirect land use change (iLUC) impacts are possible and potentially significant in scale.** Generally, iLUC impacts are very difficult to quantify, and global models to measure potential impacts are still under development. At the time of this writing (March 2010) it was not feasible to conduct the global-scale analysis necessary to quantify potential New York-specific adverse effects.<sup>45</sup> However, the scenarios included in the Roadmap analyses were selected to minimize the likelihood of significant iLUC impacts. Specifically, total food, feed, and forest production in 2007 was maintained for each of the three Scenarios, even as production of feedstock for biofuels increases. As global iLUC models are developed, it would be appropriate to integrate them into future New York biofuels life cycle analyses.

There is an in-depth discussion of this topic in Section 4 and Appendix E.

**Read more about it:** Roadmap pages Section 4 and Appendix E.

***Further research needs on this topic:***

- Integration of New York biofuels life cycle analysis with indirect land use modeling is needed.
- There should be an improved understanding of the potential for direct and indirect land use change with different bioenergy development scenarios.
- Assess the potential for greenhouse gas emission changes resulting from new incentives and policies regarding biomass and other renewable sources of energy.

Is financing available for conversion plant facilities or other industry infrastructure needs?

**FINDING: Financing for biofuels production facilities is essentially unavailable in the current economic climate (late 2009 and early 2010).** This is the case for both private investors and public funds. Many private investors are waiting to see how the technology progresses and how public support for the industry unfolds. There are no New York public funds either available currently or for the foreseeable future for such an effort, though the State has made direct investments in biofuels research and demonstration facilities. Properly structured policies such as incentives or subsidies can also stimulate growth in this area.

**Read more about it:** Appendix M.

## 5.9 POLICY ANALYSIS: FINDINGS AND OPTIONS

While there are many innovative policies being implemented at the state, regional and federal levels, there are certain examples that warrant special attention. The New York State Energy Planning Board, for

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<sup>45</sup> The Roadmap analysis of iLUC was conducted in November 2009. The body of knowledge is rapidly evolving. New information will be provided in the 2011 annual update of the Roadmap.

example, has issued the 2009 State Energy Plan which, among other things, recommends that the DOT and NYSERDA “[d]etermine the optimal fuel(s) for a substantial replacement of petroleum, considering environmental, economic and energy benefits” (State Energy Planning Board 2009). In addition to funding that NYSERDA has provided for alternative fuels, New York City has introduced legislation requiring improvements in fuel economy as well as alternative fuel use requirements. New York has also established a Climate Action Council (CAC) which is currently assessing how New York can best address climate change by examining how “all economic sectors can reduce greenhouse gas (GHG) emissions and adapt to climate change” (New York State Climate Action Council 2010).

California’s Low Carbon Fuel Standard requires a 10% reduction in the carbon content of fuels sold in the State by 2020. In Kentucky, the Governor's Office of Energy Policy (OEP) is focusing on developing a strategy for the production of alternative transportation fuels and synthetic natural gas from fossil energy resources and biomass resources, including biodiesel and ethanol. The Vermont Department of Agriculture, Food and Markets is developing an economic initiative to provide assistance for research and planning to aid farmers in developing business enterprises that harvest biomass, convert biomass to energy, or produce biofuels such as biodiesel and ethanol. There are also several types of incentives that have been widely implemented. For example, California, Iowa, Michigan, Ohio, Tennessee, and New York have all provided for alternative fuel fueling infrastructure grants. Further, California, Ohio, Pennsylvania, Michigan, New York, Iowa, Vermont, Massachusetts, Tennessee and Kentucky all have implemented vehicle acquisition and alternative fuel use requirements for state vehicles.

At the regional level, Michigan and Ohio have joined Indiana, Iowa, Kansas, Minnesota, South Dakota, and Wisconsin in adopting the Energy Security and Climate Stewardship Platform Plan designed to promote the use of biofuels in the region. New York, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, Rhode Island and Vermont also participate in the Regional Greenhouse Gas Initiative (RGGI), which facilitates the trading of carbon emission allowances in order to reduce GHG emissions.

Federally, the Energy Independence and Security Act (EISA) of 2007 requires the national supply of renewable fuels, such as cellulosic biofuels and biomass-based diesel, to reach 36 billion gallons by 2022. Under the American Reinvestment and Recovery Act (ARRA) of 2009, \$16.8 billion in funding was given to the DOE’s Office of Energy Efficiency and Renewable Energy (EERE) to support alternative fuel and advanced vehicle technology grant programs, research and development initiatives, and fleet improvement efforts. The EPA has finalized regulations implementing the National Renewable Fuel Standard Program (RFS) for 2010 and beyond (RFS2), establishing specific annual volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that must be blended into transportation fuel each year.

### **5.9.1 Overarching policy considerations**

As policies are developed by State leaders, there are several overarching themes that emerge.

**5.9.1.1 Integrated Approach.** An *integrated approach* considers the whole value chain including all segments of the industry. For example, policies could incentivize the construction of a biofuels production facility, but also include consideration of the biomass production potential of the surrounding supply shed or an incentive program to produce biomass for the facility.

**5.9.1.2 Time Frame.** Policies enacted for *mid- (minimum five years) to longer- term* could bolster investor confidence in the New York market as a location for biofuels facility development. Longer-term policies allow project developers to produce financial projections which support the developing industry as it gets off the ground, eventually able to compete without continuing subsidies.

**5.9.1.3 Regional Coordination.** The biofuels market is a regional one; promoting biofuels in the region would benefit all regional states and provide greater market certainty, demand and ability to support infrastructure. The Midwestern Governors Association has undertaken a regional biofuels initiative. A regional program in the Northeast could potentially leverage relations and shared objectives established through the RGGI program and the Northeast – Mid-Atlantic LCFS initiative.

**5.9.1.4 Training and Education.** The need for training and education of workers across all segments of the biofuels industry was raised many times in the course of interviews. The current agriculture and forestry workforce in New York is aging. Programs are needed both to train the current and future workforce in all aspects of the biofuels business as well as to educate the public. Courses are needed in biofuels feedstock production, existing crop and silviculture production, and business modeling for feedstock producers. Partnerships are also needed that lead to joint ownership of biorefineries and biomass production systems by landowners, biomass producers and project developers. Existing training programs could be deployed to create a skilled workforce for aggregation, biorefinery, distribution, and retail job opportunities.

A single core resource center, through which all training materials flow, could attract biorefinery developers. A cooperative network of education and research entities, or a clearinghouse for training materials, is also needed

**5.9.1.5 Focus on Non-Food Biomass.** Given the direction of federal and regional programs encouraging the development of low carbon biofuels and concerns expressed in stakeholder meetings and commentary regarding potential competition for land between feed/food production and biofuels feedstock production, incentives could be focused on dedicated energy crops, wood waste and crop residues. Energy crops grown on the estimated 1.5 million acres of readily available underutilized and idle crop land highlighted in Appendix E are of particular importance.

**5.9.1.6 Costs of Incentives.** As a policy package is developed for biofuels in New York State, the costs to the State need to be evaluated by considering the overall benefits produced. Programs could include taxes or fees on the use of traditional fuels, as well as self-financing of insurance or other mechanisms.

*Are there public policies, either envisioned by stakeholders or already in use in other states, that could enable a state-level government to move forward in environmentally and economically sustainable ways?*

**FINDINGS: There are several policy options for States to consider, some already in use in other states. The Federal government also has provided an assessment guide for state-level governments to assess the feasibility of a biofuels industry in their states (EPA Clean Energy State Best Practices).** A policy analysis is presented in Appendix M and an expanded listing of biofuels and bioenergy policy in other States is provided in Appendix N.

Policies presented in Appendix M are organized around the following segments of the industry: (1) Retail sales; (2) Distributors; (3) Refiners; and (4) Feedstock Producers.

### **5.9.2 Retail Sales Policies**

- Increase blending beyond E10: 10% ethanol in gasoline
- Low Carbon Fuel Standard: Transportation fuels meet a low carbon standard when evaluated on a life-cycle basis.
- State-Based Renewable Fuel Standard: Fuels sold in the State contain a certain percentage of biofuels.
- Sales tax exemption for biofuels
- More detailed reporting on use of biofuels in State vehicles
- Heating oil incentives:
  - Renewable Fuel Standard
  - Cash for Oil Burner Clunkers

### **5.9.3 Distributors Policies**

- Grants and loan guarantees were identified in most of the interviews conducted with industry stakeholders as the two highest priorities to achieve funding for any new biorefinery
- Tax credit to distributors that sell biofuel blends
- Infrastructure tax credit

### **5.9.4 Refiners Policies**

- Incentives for construction of biorefineries

- Production tax credit
- Research and development to improve biofuel production technologies
- Energy economic development zones that reduce taxes for biofuel producers

### **5.9.5 Biomass Feedstock Producers and Harvesters Policies**

- Establishment costs for biomass producers may be a barrier to availability to the feedstocks as a resource. The Federal BCAP program may provide the State leverage in feedstock resource development.
- Feedstock producer insurance
- Incentives for biofuel production facilities to invest in biomass crop development
- Insurance programs that guarantee feedstock producers a profitable price
- Other cash incentives for the production, harvest, transportation and storage of biomass
- Property tax incentives for landowners

**Read more about it:** Appendices M, N, and O.

***Further research needs on this topic:***

- If a greater percentage of ethanol blends were introduced (such as E13, E15, or E20), the environmental impacts of these blends should be studied.
- Expand the state reporting requirement for use of biofuels in the state vehicle fleet.
- Establish an independent economic analysis team that interfaces with policy makers, interest groups and industry developers to evaluate different policy options. Establish a team to analyze the environmental and rural sociological impacts of proposed policy options.
- Develop an acceptable methodology for indirect land use change criteria in any state- or regional-based life cycle analysis of GHG emissions.
- Review existing laws enacted by local governments that overly restrict harvesting and provide these governments with information on how these laws can be amended to minimize their impact on sustainable forest practices.

## 6 CONCLUSIONS

1. New York State could produce enough biomass to support a lignocellulosic ethanol industry: there is the potential for between one million and 1.68 million acres of non-forest land to be used for bioenergy feedstock production in New York. There are also 15.8 million acres of available timberland where woody biomass could be harvested (which excludes forest areas in parks and preserves).
2. New York could sustainably produce between 4.2 and 14.6 million dry tons (Mdt) of cellulosic biomass per year (this includes 6.4 Mdt from forests).
3. New York biofuels could provide 5.6% to 16% of estimated 2020 in-State gasoline consumption.
4. A comprehensive biofuels sustainability framework does not yet exist for New York. Development of ecologically sustainable practices for producing biofuel feedstock is a crucial first step. Sustainability criteria need to be identified through a public process, and must be science-based, quantifiable, and relevant to biofuels.
5. Ethanol was compared to gasoline in a total life cycle analysis of ethanol. The modeling showed that certain emitted air pollutants will be reduced, while others will be increased. The tradeoffs associated with biofuels production include increased emissions of some air pollutants that may lead to increased public health concerns in locations where feedstock expansion and fuel production occur.
6. Lignocellulosic ethanol (LCE) production shows potential to decrease greenhouse gas (GHG) emissions by millions of tons annually compared to gasoline.<sup>46</sup> Moreover, these benefits are even greater under a distributed, localized biofuels industry. Corn ethanol and soy biodiesel production also reduce GHGs and petroleum consumption, though to a lesser degree than LCE.
7. In addition to air impacts, other potentially negative environmental impacts of increased feedstock production, biofuels production, and biofuels use in the State include: soil erosion, impaired water quality, acidification of water and soil, eutrophication of bodies of water, damage to plants and animals, reduced biodiversity, and loss of habitat. Proper implementation of best management practices could mitigate negative effects.

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<sup>46</sup> This does not take into account indirect land use effects.

8. New York-specific indirect land use change (iLUC) impacts are possible and potentially significant in scale. Generally, iLUC impacts are very difficult to quantify, and global models to measure potential impacts are still under development. At the time of this writing (March 2010) it was not feasible to conduct the global-scale analysis necessary to quantify potential New York-specific adverse effects.<sup>47</sup> However, the scenarios included in the Roadmap analyses were selected to minimize the likelihood of significant iLUC impacts. As global iLUC models are developed, it would be appropriate to integrate them into future New York biofuels life cycle analyses.
9. Based on modeling that used least-cost inputs, biofuel production facilities will rely on road transport. An examination of social costs such as projected congestion patterns on roadways leads to the conclusion that feedstock movement via rail or barge may be more desirable than via truck transport.
10. Four large-scale centralized lignocellulosic biorefineries (capacity range 90-354 million gallons per year) using New York biomass could operate in the State. Alternatively, up to 24 smaller-capacity (60 million gallons per year) biorefineries could be built.
11. The estimated GDP of a biofuels industry producing 5.6% of New York transportation fuels is \$0.5 to \$0.9 billion. The estimated GDP of a biofuels industry producing 16% of New York transportation fuels is \$1.8 to \$1.9 billion.
12. There is potential for robust job growth in the New York economy for a biofuels industry. For Scenario 1 approximately 3,900 jobs would be created; for Scenario 2 approximately 14,600 jobs would be created; and for Scenario 3 approximately 14,200 jobs would be created.
13. Workforce training programs have a good foundation in existing institutions. Specific programs such as in biofuels industry research or business support may be needed. Program development would benefit from a research consortium that would focus specifically on issues posed by next generation biofuel industry deployment in New York and the Northeast.
14. A variety of biofuel technologies exist, but they will need to improve until they have similar or better yields and similar or lower production costs than the technologies evaluated in this report.

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<sup>47</sup> The Roadmap analysis of iLUC was conducted in November 2009. The body of knowledge is rapidly evolving. New information will be provided in the 2011 annual update of the Roadmap.

15. Over the next five to ten years, there may be considerable competition between liquid biofuel producers and other users of lignocellulosic biomass feedstock in the region, including thermal fuel production (e.g., wood chips, pellets, and firewood), biomass electricity (e.g., utility-scale co-firing and stand-alone wood-fired power plants), and combined heat and power (CHP). There will continue to be multiple uses of biomass, but the Roadmap does not conclude that any one use should be given priority over the others. A key consideration in evaluating the potential competition between current and emerging users of New York's woody biomass is that some biomass resources are less appropriate for certain production processes and end-uses than others. Overall, supplies of biomass may increase in response to market prices.
16. The distribution of land ownership in New York (and throughout the Northeast) is dominated by many landowners with relatively small parcels of land (i.e., under 100 acres). It is difficult to anticipate how and whether these owners might want to produce bioenergy crops. Additional research on landowner preferences could help to refine the understanding of biomass availability.
17. A number of laws enacted by local governments may overly restrict harvesting, and these governments should be provided with information on how these laws can be amended to minimize their impact on sustainable forest practices.
18. Financing for biofuels production facilities is essentially unavailable in the current economic climate (late 2009 and early 2010).
19. The establishment of a successful biofuels production industry in New York State requires diligent analysis of policy options and consideration of the impact on existing environmental and social protections in the State. Establishing a sustainable biofuels industry in New York will require the adoption of a well-crafted suite of policies that provide flexibility, balance and opportunity to the entire spectrum of stakeholders in this industry's development.

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# **RENEWABLE FUELS ROADMAP AND SUSTAINABLE BIOMASS FEEDSTOCK SUPPLY FOR NEW YORK**

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**FINAL REPORT 10-05**

**STATE OF NEW YORK**

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