New York State Energy Research and Development Authority

Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply for New York

2011 Update to the Final Report

October 2011

No. 11-27

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RENEWABLE FUELS ROADMAP AND SUSTAINABLE BIOMASS FEEDSTOCK SUPPLY FOR NEW YORK

2011 Update to the Final Report

Prepared for the
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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, which was issued in April 2010, assessed the prospects for the expansion of biofuel production in New York State, focusing on resource availability and economic and environmental impacts. This first of two Annual Updates (Update) provides new information that has become available since the Roadmap was published. This Update highlights methodological improvements in biofuel lifecycle analysis and considers the associated policy-related developments. In addition, analyses and estimates of biomass potential from regional studies are compared with the biomass potential as presented in the Roadmap. Finally, this Update includes a discussion of how the current policy climate might affect biomass energy use and planning in the State, including New York's Climate Action Plan as well as the State's Energy Plan. No new quantitative analysis was performed in this Update.

KEY WORDS

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Biofuels
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Competing uses
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Feedstock
Greenhouse gas emissions
Life cycle analysis
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INTRODUCTION

Energy from liquid biofuels represents a possible pathway for reducing greenhouse gases, establishing a domestic energy economy, and adapting to climate change. Technological improvements are moving biofuels closer to conventional use while state, regional, and federal energy policies are influencing the development of a biofuels industry. Therefore, it is important to review changes in biomass energy potential in the context of the Roadmap's comprehensive analysis.

The purpose of this Annual Update (Update) to the *Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply for New York* (Roadmap) is to provide any new information that has become available since the Roadmap was issued (April 2010). In the past year new developments have arisen with respect to life cycle analysis, regional biomass assessments, and state energy and climate policies. The Update explores how certain advances within the biomass industry and relevant policy developments might affect Roadmap findings or conclusions. The Update also addresses some of the comments provided to NYSERDA when the Roadmap was issued, as well as provides updates to a few of the Roadmap's tables and figures. Finally, this Update includes a discussion of how the current policy climate might affect biomass energy use and planning in the State, including New York's Climate Action Plan as well as the State's Energy Plan. No new quantitative analysis has been performed in this Update.

BIOFUEL FEEDSTOCKS

Two recently published regional biomass assessments are reviewed in this section of the Update. Algae, though it is not considered to be a near-term alternative biofuel feedstock in New York State, has received a good deal of attention in the past year. Summaries of the biomass assessments and a synthesis of recent research on algae are presented below.

A new set of forest inventory data that represents the first complete inventory of New York's forests using FIA's annualized forest inventory system is now available. This data set will provide more up-to-date information on the forest biomass resources that are available in the State and will be provided in the 2012 Annual Update.
No other significant feedstock studies have been released since April 2010 that would be directly relevant to the Roadmap's purpose.

In the months following publication of the Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply for New York (Roadmap), a study was published in Massachusetts that generated much discussion about the sustainability of using biomass for energy purposes – thermal, power and fuel. The findings of this study, though its focus on one biomass end-use (power generation), location (Massachusetts), and policy conditions differ from the Roadmap, caused a good deal of debate relating to the sustainability of using biomass for energy (including liquid transportation fuels). Another study issued by the Cary Institute included different amounts of available biomass than the Roadmap, primarily due to different assumptions made by the authors. The following summary provides some context with regard to the extensive dialogue that followed issuance of the two reports.

Manomet Study

The *Biomass Sustainability and Carbon Policy Study*, commissioned by the Massachusetts Department of Energy Resources (DOER) and published by the Manomet Center for Conservation Sciences (June 2010) analyzed the potential of a biomass-to-energy industry in Massachusetts. The study attempted to answer three energy and environmental policy questions regarding the use of the state's forest biomass:

- greenhouse gas implications when shifting energy sources from fossil fuels to biomass
- the capacity of forests to support biomass energy, and
- potential ecological impacts from increased biomass harvests.

Conclusions **are specific to Massachusetts** and are based on assumptions made regarding feedstock availability, forest management characteristics, and market demand for forest biomass. Results from the Manomet study suggest that in the short-term, carbon emissions from biomass used to generate utility-scale electricity are greater than carbon emissions from fossil fuels. Depending upon the future price for biomass in Massachusetts, the Manomet study calculated that biomass could supply from 20 to 80 MW of electricity.

In order to estimate implications from moving to a biomass-based energy industry, authors relied on a carbon accounting scheme that considered net changes in carbon when substituting biomass for fossil fuels. Generally, per unit of energy produced, combustion of biomass in a conventional power plant emits more greenhouse gases than fossil fuels. Because of this relative inefficiency of common wood-to-electricity processes compared to electricity production from fossil fuels, biomass would initially emit greenhouse gases in excess of the emissions associated with the fossil fuels it replaced, thus leading to what the authors describe as a *carbon debt*. Over time, the re-growth of biomass feedstocks would absorb carbon from the atmosphere and reduce the carbon debt. Once the carbon debt is "paid off", biomass begins to yield *carbon dividends*. The study considered the emissions from potential changes in land use when biomass is harvested or grown for energy. The speed at which the biomass carbon debt is "paid off" depends on forest management practices, efficiency of energy conversion technologies, and the type of fossil fuel being replaced by biomass. A figure from the study highlights one specific scenario to estimate years required in that scenario to pay off the biomass carbon debt for various fossil fuel technologies.

Figure 1: Comparison of carbon debt payoff for fossil fuel technologies

Fossil Fuel Technology	Carbon Debt Payoff (year)
Oil-fired, thermal and CHP capacity	five
Coal-fired, electric capacity	21
Natural gas-fired, thermal capacity	24
Natural gas-fired, electric capacity	>90

Source: Manomet Center for Conservation Sciences. 2010. Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources.

Alternative methods for carbon accounting exist and each attempts to account for the movement of carbon over time between sources and sinks in a system. Other carbon accounting methods arrive at different conclusions than those of the Manomet study. A major difference between accounting schemes is the point during the carbon cycle at which carbon accounting begins. The Manomet study begins accounting at the point of harvest and with an initial release of biomass carbon into the atmosphere. This is the source of the carbon debt in the scenario. The amount of carbon debt and subsequent payback periods will change based on initial accounting decisions. Other accounting methods consider carbon debt to be paid up front, meaning that carbon released from biomass-based fuel is carbon that has recently been sequestered from the atmosphere, as opposed to carbon from fossil fuels that are added to total carbon in the cycle. Using other accounting methods, the carbon debt and payback periods would be shorter than those proposed in Figure 1. In the short-term, accounting schemes might show carbon debts or surpluses. Over the long-term, replacing fossil fuels with biomass-based fuels would reduce the addition of carbon to the total carbon cycle; however, the timing of the carbon additions and subsequent sequestering may prove to be important to climate change management, an issue that is still unresolved.

The Manomet study used market analysis to estimate the economic availability of in-state biomass supplies available for energy generation. The authors estimated biomass supply by assuming a future market price for biomass, and then estimating the available supply for that price. Biomass supply estimates in this study were not based on theoretical maximum biomass yields given finite resources (such as available arable and marginal lands). By assuming that future electricity prices would remain similar to current prices, authors estimated that utilities would not be able to increase current market prices paid to biomass suppliers. Landowners in Massachusetts currently receive between $1 and $2 per green ton of biomass. Given these economic conditions, the low-price scenario estimated that between 150,000 and 250,000 tons of new green biomass could be harvested. This amount, enough to produce 20 MW of electricity, could double when out-of-state biomass sources are considered. Under the high-price scenario, one where utilities pay $20 per green ton of biomass, both in and out-of-state sources could be as high as 1.2 to 1.5 million green tons per year.

Biomass harvests from forests were considered from both public and private lands. Historical data from Massachusetts indicated that forest biomass is mostly harvested from private lands (22,000 acres annually), while public lands contribute significantly less (4,000 acres). Note that these estimates only consider harvests through management activities as sustainable. Therefore, biomass from land clearing was not included in harvest estimates. (The average annual acreage of land cleared each year is estimated at 5,000 acres.) Other important sources of biomass noted but not included in the analysis were non-forest sources of woody biomass, including mill residues and sources from tree care and landscaping. Estimating potential biomass from landscaping and tree care sources is difficult. Authors cited a study that estimated this biomass potential to be one million tons of a total available supply of 2.5 million tons of non-forest wood biomass in Massachusetts. Mill residues and urban waste were not estimated in this analysis.

There are many differences between the Manomet study and the Roadmap, which make conclusions from these studies difficult to compare. The Manomet study assessed potential biomass energy for electricity generation, while the Roadmap assumed all available biomass would be converted to liquid transport fuels. The Manomet study is based on a specific scenario in Massachusetts, while the Roadmap's analysis focused on New York's resources. Also, the Manomet study based biomass supply around estimates of future demand from the biopower market, among other parameters. The Roadmap's methodology estimates available biomass based on future liquid fuel price scenarios, as well as a variety of other parameters.

Additional technical studies and policy decisions in the coming years may guide decision makers as to optimal feedstocks or use of feedstocks for various bioenergy solutions.

Cary Institute Study

The *Forest Biomass and Bioenergy: Opportunities and Constraints in the Northeastern United States* study, produced by the Cary Institute of Ecosystem Studies (February 2011), assessed the amount of biomass that could be sustainably harvested from Northeastern forests for energy purposes, and the conversion technologies and applications that would most significantly reduce GHG emissions and reliance on foreign oil, and promote the region's economy. Estimates of sustainable biomass were lower than other recently conducted studies, including the Roadmap. The authors claimed that other studies extrapolated total available forest biomass using smaller, localized samples of forest biomass, which may have overrepresented biomass potential for the region. Both the Cary study and the Roadmap relied on U.S. Forest Service's Forest Inventory Analysis (FIA) and Timber Products Output (TPO) databases to estimate forest biomass and constrained assumptions of available forestland using biological, physical, legal, social, and economic factors. Differences in weighting these factors led to biomass estimates in the Cary report that were lower than those produced by other studies, including the Roadmap. The authors of the Roadmap stand by their estimates and their analysis.

The Cary study considered the Northeastern region (Pennsylvania to Maine, excluding New Jersey). Recent studies have estimated that forests in the Northeast have significant, sustainable biomass capacity. While this report does consider the Northeast region in its entirety, it also provides some statistics regarding biomass potential from individual states.

The Cary study pursued two objectives. The first objective was to assess the forest-based biomass potential for energy from the Northeastern states. This involved assessing current biomass stocks, considering constraints from biophysical, legal, economic and social factors, and calculating biomass supply under a range of scenarios. The second objective was to propose how energy from biomass resources could be used to displace current consumption of coal and liquid fossil fuels in the Northeast. This second objective was achieved by calculating CO_2 emissions from current fossil fuel consumption data and comparing these emissions to CO_2 emissions estimated from a number of scenarios in which biomass was substituted for fossil fuels.

Areas considered as “forestland” were defined as “land at least 10% stocked with forest trees of any size, or land formerly with such land cover and not currently developed for a non-forest use.” This definition includes roughly 67% of the total area of the Northeastern states. The report cites analysis suggesting that the regrowth of forestland over the last century has peaked, and the area of forestland has stabilized, or perhaps declined slightly.

The Cary study considered scenarios that assume different amounts of forestland available for harvest (63% to 78%), and different end uses for biomass, than the Roadmap. This study estimated biomass production to be 13.7 – 15.8 million metric tons per year if current pulp harvests were to be diverted to biomass energy. If current pulp and paper biomass were to not be diverted to energy use, this study estimated 4.2 – 6.3 million metric tons of biomass per year. A biomass supply of between 4.2 and 15.1 million metric tons per year would supply 1.4 – 5.5% of the region’s current energy consumption. This average would vary across states depending on available forestland and energy consumption. In addition, the energy efficiency of conversion technologies determines the amount of conventional fuel that might be replaced with biomass energy. As an example, in terms of CO_2 emissions, the Cary report found that replacing coal with biomass co-firing or using biomass in combined heat and power plants is significantly more efficient than replacing gasoline with cellulosic ethanol; however, these reports differ in assumptions of biomass-to-ethanol conversion efficiencies.

Different assumptions and weighting of biological, physical, legal, social and economic factors between the Roadmap and this study produced different estimates of available biomass for New York. For example, the Roadmap assumed a minimum operable size for biomass harvest to be five acres, while the Cary report set this minimum at 20 acres. Similarly, the Cary report defined stands greater than one mile from an existing road to be only “partially” available due to cost of building access roads. The Roadmap also considered transportation of feedstocks, but the analysis focused on estimates of average ton-miles required to move various feedstocks to specific bio-refineries. The Roadmap estimated 4.8 – 6.4 million metric tons of biomass available per year in New York, while the Cary study estimated a range of 0.7 to 1.0 million metric tons of biomass per year for New York for new harvests. In terms of cellulosic ethanol potential, the Roadmap estimated New York could produce between

508 and 1,449 million gallons per year. These volumes would satisfy between 5.6% and 16% of projected 2020 gasoline consumption. The Roadmap scenarios assume all biomass to be sold for cellulosic ethanol production and that technological and market barriers to commercial cellulosic ethanol would be overcome by 2020. As a reminder, the Roadmap scenarios were not meant to be predictions, rather they were developed to illustrate potential system boundaries. Finally, the two reports' total energy potential estimates differ -- whereas the Cary report estimates a potential of 5,802 terajoules (10^{12} joules) of energy from cellulosic ethanol per year, the Roadmap estimates between eight and 20 times that amount.

Algae

Introduction

Algal biofuel production has seen an expanding interest since the completion of the Roadmap. Both private energy firms and the U.S. government have invested significant resources into improving algal biofuel production efficiency, often partnering with leading university researchers. A reliable and affordable domestic algal biofuels industry could reduce carbon emissions, as well as dependence on foreign sources of petroleum-based liquid transportation fuels.

Algae-based biofuel, like other biofuels, relies on a plant's ability to capture solar energy and store it in chemical bonds. Algae are an attractive biofuel feedstock because of their ability to produce high-energy oils, which can then be converted into a variety of biofuel products. The diversity of algal species allows algae to be grown in a variety of aquatic environments.

High oil production coupled with rapid cellular growth means that algae can produce 10 to 100 times more oil than terrestrial oilseed crops on the same amount of land (IEA Bioenergy, 2010). However, the energy, water, and material inputs are different compared to a field crop. Since biodiesel production from terrestrial oilseed crops is not projected to satisfy worldwide diesel demand, many hope algae can become a significant source of advanced, bio-based transportation fuel. When compared to other biofuel feedstocks, algal biofuels may offer competitive results in terms of productivity with less competition for arable land. Currently, there remains a lack of consensus regarding the role of algae within the biofuel sector, the commercial readiness of algal biofuels, and how quickly an algal biofuel manufacturing industry may or may not develop in New York State and elsewhere.

Algae are found naturally in lakes, rivers, and oceans. Algae includes microalgae, macroalgae (like seaweed), and cyanobacteria (formerly known as "blue-green algae"). Like terrestrial plants, algae capture sunlight and store it as chemical energy through photosynthesis. Algae store this chemical energy as oil within their cells. There is great diversity among algal species, which have evolved to grow in environments that range in pH, salinity, and temperature. In addition, algal species differ in the amount of oil produced. The rate at which some algae store oils is significant (greater than 50% of their dry weight in some cases) (U.S. DOE, 2010). These oils can be extracted and converted to a variety of fuel types for the end user. While biodiesel remains the most common fuel type produced from algae, other fuel products include methane, hydrogen, alcohols, and products derived from the residual biomass.

History

From 1979 to 1996, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) ran an Aquatic Species Program, which sought to understand the biology of oil production in algae. NREL explored various setups for growing algae and genetic engineering techniques to increase overall oil yields. NREL's research demonstrated that if algae were deprived of nutrients, they grew slower but also produced greater amounts of oil (U.S. DOE, 2010). These initial studies did not continue, because the cost of algal oil production remained uncompetitive with petroleum oil. Since the closure of NREL's Aquatic Species Program, increased energy demand, historically high petroleum prices, concerns over CO_2 emissions, and improved research techniques have all contributed to the resurgence in studies of algal biofuels (IEA Bioenergy, 2010). The tradeoff between nutrient deprivation and oil production remains a critical challenge for today's algal R&D efforts.

Where Is Technology Now?

In order to make algal biofuels commercially viable, R&D efforts are continuously seeking mechanisms for maximizing yields and reducing production costs. Algae-growing systems are designed to maximize algal oil production (and fuel production from these oils, or in some cases, production of fuels directly[1] without making an intermediate oil product) from land, water, and nutrient resources. Some microalgal strains have exhibited oil yields significantly higher than yields of land-based oilseed crops. While some producers make theoretical claims of 10,000 to 100,000 gallons of oil/acre per year, more realistic yields seem to be between 1,000 and 5,000 gallons/acre/year, but land use is only one factor. Algae production requires energy, water and material inputs that differ from those needed by oil crops. In addition, life-cycle analyses also need to be conducted for the full production cycle of algae.

Crop	Oil Yield (gallons/acre/year)
Soybean	48
Camelina	62
Sunflower	102
Jatropha	202
Oil Palm	635
Algae	1,000 – 6,500

Table 1: Oil yields per acre, compared across a variety of biofuel feedstocks. *Source: Roadmap, 2010*

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[1] An example of a company that is working on this technology: http://www.algaeindustrymagazine.com/photon8-developing-%E2%80%98drop-in%E2%80%99-fuels-from-algae/

Energy is needed for various steps in the production of biofuels or bioproducts, including harvesting, dewatering, and conversion from the algal oil. Since algae grow in aquatic environments, harvesting the algae from its aquatic medium and removing water from inside algae cells is energy intensive. Many research and development efforts focus on reducing the energy required to harvest and dry algae. Various conversion techniques are used to extract target oils and process them into fuels for the end user. Depending upon the chemical, biochemical, or thermochemical techniques used, algal oil can be converted into biodiesel, biogas, alcohols, and co-products such as animal feed, fertilizers, enzymes, and bioplastics (U.S. DOE, 2010).

There are two main systems being used to cultivate microalgae: open ponds (also known as raceways) and photobioreactors (PBRs). Macroalgae are cultivated in offshore or coastal farms or in large land-based open ponds that are exposed to the air. Because ponds are an open system, they are subject to water evaporation and contamination by other organisms including foreign algal species. In addition, control of water temperature is difficult as is optimization of algal growth. PBRs, which have been developed more recently than open ponds, are closed systems that allow for greater control of nutrient content and temperature, and minimize contamination. In addition, the land use footprint of PBRs is less than that of open ponds. Still, PBRs cost more to build, and may also require larger energy inputs for maintaining optimal temperature and a homogeneous mixture. As of now, there is no evidence indicating that PBR methods result in more significant oil yields than open ponds (IEA Bioenergy, 2010).

As biofuel producers scale-up processes, proper facility siting and resource management become essential for maintaining or improving technical and economic efficiency. Temperature, water availability, topography, solar irradiation, and severe weather are some of the factors to be considered when siting an algae production facility. While many parts of the United States would be suitable for algal production, states in the southern latitudes offer greater year-round production capability (especially California, New Mexico, Arizona, Texas and Florida). States in the northern latitudes would offer less solar irradiation potential during winter months. Nevertheless, areas with abundant water resources and ideal topography, such as the Great Lakes region, could improve production efficiency as these locations could reduce consumptive freshwater and land use requirements.[2]

Algae production facilities may seek opportunities for co-location with sources of waste carbon emissions and nutrients, which are required for algal growth. Electric power plants might be an advantageous site for co-location due to its source of CO_2 emissions. The amount of carbon that can be offset from electric power plants is limited by the distance required to pump flue gases to algae facilities and by space required for algae cultivation. It is estimated that because of these limitations, 20% - 30% of a typical power plant’s total emissions could be offset through algal production (Brune et al., 2009). Sites of nutrient-rich wastewater, such as water treatment facilities or animal feedlot facilities, present other co-location opportunities for algae operations. Algae can treat water by removing nutrients such as nitrogen, phosphorous, and potassium, and harmful chemicals including metals, organic

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[2] PNNL study at http://www.agu.org/pubs/crossref/2011/2010WR009966.shtml

compounds, and potential endocrine disruptors. Demand for improved wastewater treatment combined with the potential for reduced costs of algal-based treatment when compared to traditional, mechanical water treatment facilities, presents an opportunity to couple algae cultivation with wastewater treatment; however, systems need to be chosen carefully to maintain end product quality.

LIFE-CYCLE ANALYSIS (LCA)[3]

Purpose

This analysis presents new information generated during calendar year 2010 and the first quarter of calendar year 2011, and segments this new information into three major categories: (1) methodological advancements related to LCA; (2) updates impacting LCA input assumptions; and (3) policy related developments associated with LCA applications. In all cases, the focus is on the relevance of this new information on the analysis that was conducted for the Roadmap. Although no new quantitative analysis is performed in this update, a qualitative discussion is included on how the new information would likely influence future Roadmap analyses.

Background

As part of the Roadmap project, LCA was conducted to explore the total fuel cycle energy use and emissions associated with biofuel production and use in several scenarios. Each scenario involved different cellulosic ethanol feedstock pathways, including: corn stover, switchgrass, willow, and forest residue (hardwood and softwood). Additionally, LCA impacts of in-state corn grain ethanol and soy biodiesel production and use were analyzed. The methodology and results of the LCA can be found in *Appendix G* of the Roadmap report. As discussed in the Roadmap, the modelers used the NY-GREET model, which is a total fuel cycle model based on the Federal GREET (Greenhouse Gas and Regulated Emissions and Energy Use in Transportation) model, but tailored to NY; that is, the Roadmap analysis employed NY-specific inputs for farming energy use, crop yields, fertilizer use, and feedstock and fuel transportation, among others.

Some of the important results of the LCA included energy use and emissions by pollutant (GHGs, CO_2, N_2O, VOC, NO_X, PM_{10}, and SO_X) for biofuel production and use; conventional fuel emissions by pollutant; comparison of biofuel and conventional fuel emissions; percentage change in emissions (assuming that biofuels displace conventional fuel), and comparison of energy consumption. Figure 2 depicts the percentage change in emissions between the cellulosic ethanol mix and gasoline (left side of figure), and corn grain ethanol and gasoline (right side of figure) for Scenario 2a, assuming that ethanol displaces gasoline. The figure shows the change in emissions for an energy equivalent quantity of fuel.

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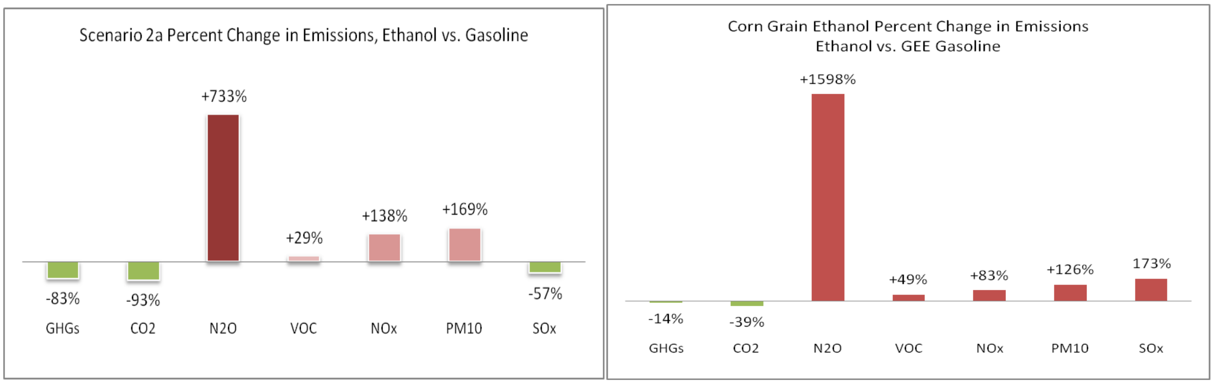
[3] This section of the Annual Update was prepared by Energy and Environmental Research Associates, LLC.

In the time since the LCA work was conducted for the Roadmap, there have been several advancements in LCA that deserve attention. These advancements align in three major areas: (1) methodological advancements; (2) data advancements; and (3) policy advancements. This document provides a brief update on these advancements and suggests how they might influence future LCA work within the NY Roadmap context.

Figure 2. Roadmap LCA results for Scenario 2a showing percentage change in emissions comparing ethanol and gasoline assuming ethanol displaces gasoline. The graph on the left represents cellulosic ethanol, while the graph on the right represents corn grain ethanol. ***Source: Roadmap, 2010.***



Life-Cycle Analysis Update

<u>Methodological Advancements</u>

<u>The NY GREET Model</u>. From a methodological perspective, the LCA modeling tool used in the Roadmap (NY-GREET) is still the most applicable model for LCA of NY biofuels and conventional fuel, as the inputs and assumptions used in NY-GREET are specific to NY and are not available in a comprehensive package elsewhere. Additionally, the federal GREET model was used by California Air Resources Board (CARB) in development of the low carbon fuel standard (LCFS), and was used in the EPA analysis of the Renewable Fuel Standard (RFS2). Since the Roadmap analysis, a new federal GREET model (1.8d) has been developed that includes:

- An updated corn ethanol pathway, in which corn farming energy and fertilizer use, ethanol plant energy use, and animal feed production from dry mill plants have been modified
- Options for including land-use change associated with ethanol production (see *Indirect Land Use Change* section below)
- Updated cellulosic ethanol pathways, in which farming requirements and plant design have been modified
- Updated soy biodiesel pathway, in which farming and biodiesel conversion estimates have been modified
- Updated gasoline pathway, in which petroleum refinery efficiency has been modified; and
- Fuel economy updates for baseline and alternative vehicle technologies.

Many of the modifications to GREET involve parameters for which NY-specific variables were used in the Roadmap (i.e. fertilizer use, energy use), and so the changes to these GREET parameters would not necessarily have an immediate effect on the Roadmap LCA results. Future LCA research might integrate changes in general GREET assumptions (i.e. petroleum refinery efficiencies or automobile fuel economy), or might examine how the modifications to GREET farming and biorefinery assumptions might inform future estimates for farming and biorefinery energy use in New York.

General Methodological Considerations for LCA. A recent article by McKone et al. (2011) summarizes seven major challenges in conducting LCA assessments of biofuels. These challenges include:

- *Understanding farmers, feedstocks, and land use*, which refers to the need to understand the decisions made by farmers and in the production of feedstocks, including, and understanding the impacts of indirect land use changes
- *Predicting biofuel production technologies and processes,* which refers to examining a range of biorefinery technologies and their potential impacts, including electricity production and other co-product production, and location and scale
- *Characterizing tailpipe emissions and other health effects,* which refers to quantification of criteria pollutants and hazardous air pollutant emissions from combustion, and examination of related health effects, which would require spatial assessments
- *Incorporating spatial heterogeneity into assessments,* which refers to the need to account for and quantify the disparity in population densities between regions, recognizing that pollutants released in highly populated regions will result in greater health effects
- *Accounting for time*, which refers to a) the need to clearly note and evaluate time-based assumptions, including populations, fleet mix, technology options, regulatory requirements, etc.; and b) time-scales for impacts, or the timeframe under consideration for allocating GHG emissions, and discount rates used to discount GHG reductions in the future
- *Assessing transitions as well as end states,* which refers to the need to incorporate and examine GHG impacts of transitionary phases in the development of biofuels, including building new infrastructure and vehicles, etc. and
- *Confronting uncertainty and variability,* which refers to the need to incorporate uncertainty analysis into LCA assessments, rather than using point estimates for variables that are highly uncertain.

McKone et al. (2011) acknowledge several challenges in LCA that point to potential areas of improvement for future LCA assessments. Several aspects discussed by McKone et al. were addressed in the Roadmap LCA (activities at the farm and feedstock level, quantifying criteria pollutants, examining a range of production processes in different scenarios), however the article highlights a number of areas where future LCA work could be improved, some of which were recommended in the Roadmap LCA appendix. For instance, future work could delve into examining health effects associated with biorefinery emissions (incorporating local population densities), and could examine the LCA GHG impacts of infrastructure development. Importantly, future work should incorporate uncertainty and variability into the analysis, as the Roadmap LCA used point estimates for each scenario. The importance of uncertainty analysis and indirect land use effects in LCA are covered more thoroughly in the following sections.

Incorporation of Indirect Effects.

Incorporation of Indirect Land Use Changes

In recent years, indirect land use change (iLUC) has moved to the center of the debate in LCA assessments. As noted in McKone et al. (2011), the premise of iLUC is that since land for crops is already extensively used, the production of biomass for biofuels could lead to deforestation (which releases large amounts of carbon, and removes a large carbon sink), or could displace existing food crops. Also, changing the purpose of the land could increase prices of goods, thus inducing land use conversion in other areas. Although iLUC changes have been estimated for a number of biofuel feedstocks (e.g. see Al Riffai (2010) discussion below), concerns about extensive iLUC effects are primarily associated with the land use changes related to greater use of corn and soybeans (and the cropland used to grow them) for biofuel production rather than for human consumption or animal feed. This is important to note in the context of the Roadmap LCA, as the feedstocks assumed in the Roadmap were primarily cellulosic, and included relatively smaller quantities of corn for ethanol and soy for biodiesel (for instance, Scenarios 2 and 3 assumed 1.3 billion gallons of cellulosic ethanol, compared to 163 million gallons of corn grain ethanol). The iLUC effects from cellulosic feedstocks, such as wood from forests differ from those from food crop feedstocks like corn or soy. Further, and more importantly, assumptions of biofuel production and land use in Roadmap scenarios were carefully constructed to minimize any potential iLUC effects to the greatest extent possible. Specifically, (1) no forest land was converted to other land use, (2) no crop land was used in Scenario 1, and (3) only cropland that might become available due to increases in crop yield was included in Scenarios 2 and 3.

Nonetheless, iLUC effects have recently been a central focus of biofuel LCA literature, and thus warrant discussion here. The existence of iLUC effects with food crop feedstocks is no longer under serious debate in the academic community; however, the extent of iLUC effects is highly uncertain and is a point of contention. In the time since the Roadmap LCA assessment was conducted, a number of prominent studies have attempted to measure iLUC effects from biofuel production.

Hertel et al. (2010) examined the GHG impacts of indirect land use changes (iLUC) from corn grain ethanol, using the global economic commodity and trade model (GTAP-BIO) and incorporating market-mediated responses and byproduct use into their analysis. The authors estimated total iLUC effects of roughly 800 grams of CO_2 per MJ (gCO_2/MJ), or 27 gCO_2/MJ per year over a 30-year period of ethanol production. The authors note that this iLUC estimate is roughly one-quarter that of the well-known Searchinger et al. (2008) study. They also note that the 27 gCO_2/MJ effect is enough to nearly or completely offset the GHG reduction benefits of corn ethanol compared to gasoline, assuming the U.S. average LCA emissions of corn ethanol (65 gCO_2/MJ) compared to the U.S. average for gasoline (~95 gCO_2/MJ) (i.e. 65 + 27 = 92 gCO_2/MJ).

Plevin et al. (2010) used a reduced form model of iLUC (RFMI) to examine iLUC GHG emissions from U.S. corn ethanol production and expansion, with estimates ranging between 21 to 142 g CO_2e/MJ, and a median estimate ranging from 55 to 59 gCO_2e/MJ. The authors recognize that iLUC effects are highly uncertain, but that they are nontrivial at nearly the entire range of estimates, and may reach a level several times that of gasoline lifecycle GHG emissions. They also note that the iLUC estimates used by CARB and the U.S. Environmental Protection Agency (USEPA) (30 and 34 g CO_2e/MJ, respectively) are at the low end of the Plevin et al. estimates.

Al Riffai et al. (2010) examined the impacts of the EU biofuels mandate, finding iLUC effects in the range of 54-79 gCO_2/MJ for corn ethanol and 55-60 gCO_2e/MJ for soy biodiesel (note that iLUC effects of a significantly smaller scale were estimated for the feedstocks sugarcane, sugar beet, wheat, and rapeseed oil; however these feedstocks were not included in the Roadmap).

Tyner et al. (2010) examined the land use changes from corn ethanol production in the United States and globally. Conducting analysis for several simulations, the study found that land use changes from corn grain ethanol are responsible for 1159 – 1846 gCO_2 per gallon of ethanol (~14 to 23 gCO_2/MJ) . Accounting for land use changes, the study found that compared to gasoline, ethanol reduces GHGs by 9.5% to 16.3%, depending on input assumptions. The authors note that they cannot say whether corn ethanol could meet a 20% GHG reduction standard, given the uncertainty in the analysis. Additional discussion on this study can be found on pages 29-30, in the Policy section of this Update.

Gawel and Ludwig (2011) review the state of the discussion and approaches used in taking into account iLUC effects. The authors show that while accounting methods have been developed to measure iLUC effects, a sound consensus or methodology that incorporates both GHG impacts and biodiversity impacts still does not exist. The authors note problems with impact-related methods of accounting, product assignment methods, and model-based attribution (which are uncertain, inaccurate, or contentious). Therefore the authors recommend shifting focus away from biofuel targets, and rather choosing biofuel pathways with minor land use conflicts (such as residues). Indeed, as noted by Cherubini (2011), if biomass crops are grown on marginal or degraded land (where conventional crops have not been grown previously), and proper management strategies are employed, iLUC effects will be absent. These provide additional justification/support for the Roadmap Scenario 1 assumptions, in which currently idle farmland and forest residue would be employed to produce biofuels in New York State.

Others have estimated minimal iLUC effects associated with ethanol production, or have indicated that current studies have substantially overestimated iLUC effects. For instance, regarding models used to estimate iLUC effects, Lywood (2010) raises a number of concerns including: lack of accounting for biofuel byproducts, yield increases and use of idle land, and lack of transparency in current iLUC models. Together, Lywood argues, these factors may result in significant overestimation of iLUC effects in current models.

Oladosu and Kline (2010) examined empirical data in the 2001-2008 timeframe, to assess the extent of measurable iLUC effects occurring during that time period (during which ethanol production increased substantially). The study did not find empirical evidence supporting effects on U.S. exports of corn, or on expansion of crops or cropland in the U.S. due to corn ethanol production. According to a presentation of the study findings to the CARB Low Carbon Fuel Standard Expert Workgroup**,** "the analysis suggests minimal to zero indirect land use change (iLUC) was induced by use of corn for ethanol over the last decade" (Oladosu and Kline 2010).

Finally, Dale et al. (2010) examined the potential use of three technologies that would allow more efficient use of land for food production, thus allowing for use of land for large scale ethanol production. The study found that ~105 billion gallons of ethanol could be produced each year in the United States without decreasing U.S. food production or exports—thus this system allows for large-scale ethanol production and substantial GHG emission reductions without iLUC effects.

The *magnitude and extent* of iLUC effects is uncertain and continues to be the subject of debate. Much work has been conducted in measuring and understanding iLUC effects since the Roadmap LCA was conducted (where iLUC effects were discussed, but were not incorporated quantitatively into the analysis). Future LCA research could incorporate iLUC effects quantitatively (where relevant for food crop feedstocks in particular), exploring a range of iLUC effects to account for uncertainty in the estimates.

Incorporation of Indirect Fuel Use Change

Rajagopal et al. (2011) challenge the general assumption that biofuel replaces an energy-equivalent quantity of fossil fuel, leaving total fuel consumption unchanged. They demonstrate that increasing the quantity of biofuel in the market will change fuel prices and thus affect total fuel consumption in the home country and worldwide. Examining a scenario where one region (U.S.) implements a 7.5% biofuels mandate and the rest of the world (ROW) does not, they find that fuel prices in the U.S. will increase, decreasing total fuel consumption to a lower level than would be seen in absence of the mandate. Conversely, the biofuels mandate will have the effect of decreasing fuel prices in the ROW, thus increasing demand there. However, Rajagopal et al. find that the effect of decreased total fuel consumption in the U.S. overshadows the increased fuel consumption in the ROW, effectively leading to a total *reduction* in global fuel consumption — which they term indirect fuel use change. The GHG reduction effects of indirect fuel use are found to be substantial, amplifying the fuel replacement GHG reduction effect by 50-75%. An additional finding is that biofuel mandates would result in the indirect fuel use effect described above, while biofuel subsidies would result in the opposite effect (decreasing fuel prices in the U.S. and the ROW, thus increasing total fuel consumption).

Rajagopal et al. (2011) findings are of relevance to the Roadmap LCA results. As with most LCA assessments, the Roadmap analysis assumed that the biofuel produced and used in the state would displace an energy equivalent amount of gasoline. Future research might consider the potential indirect fuel use impacts of Roadmap biofuel mandates (that would bring fuel prices up and decrease total fuel consumption), or of biofuel incentives (which would decrease fuel prices, increasing total fuel consumption). Understanding the demand implications of these indirect effects may be important in the context of estimating the entire extent of biofuel GHG emissions compared to baseline petroleum consumption; it may also be important when considering alternative policy mechanisms to encourage Roadmap biofuels in the future.

Uncertainty Analysis and LCA. In addition to concern surrounding iLUC changes, recognition of uncertainty in LCA assessments has also moved to center stage in the LCA literature. In the time since the Roadmap LCA was conducted, several studies have demonstrated the importance of incorporating uncertainty into biofuels LCA assessments, and have shown the large range of LCA GHG estimates that can result when uncertainty is taken into consideration.

Spatari and MacLean (2010), acknowledging the increasing importance of accounting for uncertainty in LCA analyses, conducted LCA assessments of switchgrass and corn stover ethanol using Monte Carlo simulation. The study found that switchgrass ethanol may have potentially high and uncertain GHG emissions, due to uncertainty in CO_2 changes from land use and N_2O emissions from nitrogen fertilizer. As Roadmap scenario analyses incorporated assumptions to minimize both direct and indirect land use change effects, the GHG emissions associated with land use changes are less relevant to the Roadmap LCA analyses. Corn stover ethanol was found to have a lower range of uncertainty, and showed LCA GHG emissions far lower than gasoline and corn grain ethanol. Major variables of importance are co-product assumptions: specifically, the electricity production credit reduces GHGs significantly, and removing the credit increases LCA emissions substantially; in this study GHG emissions from ethanol are even greater than gasoline when electricity credit is removed.

Spatari, Bagley et al. (2010) examine LCA emissions associated with production stages of cellulosic ethanol (well-to-gate or WTG analysis), examining multiple pre-treatment and conversion processes. Accounting for uncertainty in the analysis, they examine a range of estimates for variables in the production process, including sugar yield and cellulose conversion to alcohol. Ethanol yields, energy requirements, and GHG emissions were found to vary substantially between technology options. In agreement with Spatari and Maclean (2010), electricity co-product credits are found to have considerable impacts in reducing GHGs emissions associated with ethanol production. In fact, the authors acknowledge that one finding of the study is almost counterintuitive—lower yield ethanol conversion technologies actually result in lower GHG emissions, due to the GHG credit associated with higher electricity production.

Mullins et al. (2010) note that many biofuel studies use point estimates, and that accounting for uncertainty is important in LCA analyses. In their paper, Monte Carlo simulation is used to estimate LCA emissions from corn and switchgrass ethanol. Corn ethanol LCA emissions are found to range from 50 to 250 gCO_2e/MJ (point estimate of 101), and switchgrass ethanol point emissions range from 4 to 71 gCO_2e/MJ, depending on assumptions. The majority of the variation in the results was attributed to uncertainty in iLUC, but production energy, direct land use changes, N_2O emissions, and conversion efficiency contributed to variance as well. The authors conclude that given the uncertainty in LCA GHG emissions, it is difficult to say with certainty whether biofuels (even cellulosic feedstocks like switchgrass) will meet policy emission reduction targets. As iLUC effects were a primary contributor to the corn ethanol LCA estimates in this study, it is important to note that the land use assumptions in the Roadmap may not align with those in the Mullins work.

Hsu et al. (2010) examined the LCA energy use and emissions of ethanol used to power E85 vehicles in the year 2022. The study examined a range of feedstocks (corn grain, corn stover, wheat straw, switchgrass, and forest residues), and several conversion technologies, finding that E85 vehicles result in GHG emissions 43%−57% lower than that from conventional gasoline vehicles (year 2005 gasoline). The study also found that GHG emissions resulting from advanced corn grain are comparable to cellulosic E85 GHG emissions (advanced corn grain E85 assumes improvements in energy efficiency at the refinery). Uncertainty analysis indicated that factors involved with the feedstock production phase (i.e. nitrogen-to-N_2O emissions, biomass yield, and fertilizer application) are the most influential parameters, together accounting for over 70% of the deviation in GHG emissions between the reference case and the median of the frequency distribution. Uncertainty analysis using Monte Carlo simulation found that reference cases (point estimates) of the study were frequently outside of the 25 -75 percentile of the distribution, and that the point estimates were on the far low end of the uncertainty analysis range for nearly all feedstocks.

Venkatesh et al. (2010) demonstrate that uncertainty in LCA extends to petroleum-based fuels. Using probability distributions, partial-least squares regression, and Monte Carlo simulation, the study found that the uncertainty range for gasoline LCA emissions was 13%, with a 90% confidence interval of 85 to 97 gCO_2e/MJ. The authors note that the uncertainty range is higher than the typical minimum 10% emissions reduction requirements set by low-carbon fuel policies.

The above studies demonstrate the importance of incorporating uncertainty analysis into LCA assessments, and show how large the range of LCA GHG emissions estimates can be after accounting for uncertainty. Given these findings, future Roadmap LCA work could incorporate uncertainty analysis into LCA estimates.

Incorporation of Additional Environmental Effects of Biofuels Production. Though GHG emissions and climate change are typically the focus of biofuel LCA assessments, there are additional environmental impacts of biofuel production and use that are important to consider. Recent studies have begun to capture and measure these impacts.

Lankoski and Ollikainen (2011) examined the environmental effects of biofuel production, including not only lifecycle GHG emissions but also nitrogen and phosphorus runoff and the quality of wildlife habitats. Using willingness-to-pay to assign monetary values to environmental attributes, they find that the negative environmental impacts of biofuels production outweigh the environmental benefits of GHG reductions when rapeseed, wheat, or barley are the feedstocks. Only biofuel from reed canary grass shows net environmental benefits. Nevertheless, the authors note that the net economic impacts of biofuels production are positive. It is important to note that the findings of this study may not be relevant to the Roadmap ethanol production, as none of the examined feedstocks in Lankoski and Ollikainen were included in the Roadmap scenarios.

Another recent LCA study by Cherubini and Jungmeier (2010) examined the production of ethanol from switchgrass (note that switchgrass was a feedstock included in the NY Renewable Fuels Roadmap scenarios). In addition to comparing the GHG impacts of ethanol production to a fossil fuel reference, the study also compared the lifecycle impacts of each fuel in the following environmental categories: abiotic depletion, ozone layer depletion, human toxicity, fresh water aquatic ecotoxicity, marine aquatic ecotoxicity, terrestrial ecotoxicity, photochemical oxidation, acidification, and eutrophication. The study found that the switchgrass ethanol system performed better than the fossil fuel reference system for all environmental impacts, with the exception of acidification and eutrophication (both of which are linked mostly to the use of nitrogen fertilizers). The authors note the importance of best practices in nitrogen fertilizer management, including improved control of the amount, timing and placement of fertilizer. Finally, the study calculates that when switchgrass is produced on set-aside land, soil carbon sequestration leads to greater GHG reductions.

In a similar study, Cherubini and Ulgiati (2010) conducted an LCA assessment of ethanol production from agricultural residues (corn stover and wheat straw), and compared results to a reference fossil fuel system. The study found that ethanol from agricultural residues has lower environmental impacts than the fossil fuel system for all impacts except eutrophication. The authors note that when agricultural residues are used as feedstocks, best management practices are required to minimize erosion, protect soil quality, and maintain soil organic carbon.

Delucchi (2010) discusses climate change, water use, and land use impacts of biofuels production and the metric by which the impacts have been measured. Delucchi makes a qualitative assessment of the impacts of biofuels, finding that it is unlikely that biofuels produced with current agricultural processes will reduce GHG emissions and will worsen water supply, water quality and land use problems compared to petroleum fuels. The author concludes that policies should focus on promoting biofuel pathways and approaches that use minimal energy and water inputs, and that use land with minimal alternative value (economic or ecological). As Roadmap scenario development focused on best agricultural practices and use of idle land in the future, many of the concerns raised by Delucchi may be less relevant to the Roadmap biofuel production assumptions. Nonetheless, Delucchi's recommendations point to the importance of ensuring that New York biofuel production is designed in a way to minimize potential negative environmental impacts.

Though the environmental and ecological impacts of biofuel production were discussed qualitatively in the Roadmap LCA assessment, results of the above studies indicate that further consideration of the potential impacts in New York may be warranted.

Data Assumptions

As indicated in the preceding sections, the focus of biofuels LCA literature has shifted from attributional analysis (examination of the energy use and emissions associated with each stage of production and use of biofuels) to consequential LCA (examining the effects of changes outside the system, such as iLUC effects). Though attributional analysis is still used, there is increased focus in the literature on the high level of variation and uncertainty in effects outside the production system. Nonetheless, assumptions in biofuels production and use are constantly changing. Presented here are a few updated assumptions in the following stages of biofuel production and use: feedstock data, transportation data, fuel processing data, and vehicle use data. The following list of advances/findings is in no way a comprehensive picture of technological advances or assumptions used in LCA studies, but rather this section is intended to illustrate how assumptions at each stage are continually modified.

Feedstock Data

Wang et al. (2011) use the GREET model to examine the LCA energy use and GHG emissions associated with corn and cellulosic (corn stover, forest residues and switchgrass) ethanol production, employing updated assumptions for corn yields, energy use, and fertilizer intensity in farming, all of which have improved considerably in recent years (yields have increased while fertilizer intensity and energy intensity have decreased). Overall, the study found LCA GHG reductions greater than that estimated in other recent studies; perhaps due to additional efficiency improvements at the fuel processing stage that were also incorporated in the analysis (see Fuel Processing Data below).

Transportation Data

Zhu et al. (2011) examined the challenges in developing logistics for biomass-to-bioenergy, noting that these challenges include: low bulk density of biomass, restrictions on harvesting, storage, weather effects, and wide geographical distribution. The authors used a mixed integer linear programming to examine a case of switchgrass bioenergy production, and found that operations were significantly different between harvesting and non-harvesting months. For example, they assumed transportation of biomass to biorefinery by truck varied from 0 dry tons per month to 120,000 dry tons per month.

Fuel Processing Data

Wang et al. (2010) examine the available methods to deal with allocation of GHGs from biofuel co-products, and explore the strengths and weaknesses of each method. The study compares the well-to-wheel GHG emissions associated with several feedstocks and fuels (corn grain ethanol, switchgrass ethanol, soy biodiesel, and soy renewable diesel) in the U.S., finding that the GHG allocation method used (displacement, mass, market value, or process purpose) can have considerable impacts on LCA GHG emissions of biofuels. Further, the authors note that the displacement method (recommended for use in LCA by the International Organization for Standardization ISO 14040) may result in distorted results when co-products are actually the main products.

Wang et al. (2011) use the GREET model to examine the LCA energy use and GHG emissions associated with corn and cellulosic ethanol production, using updated assumptions for energy use in ethanol plants. The study notes that energy use in corn ethanol plants (dry milling plants in particular) has decreased considerably in recent years (19.5 in 1980 to 10 in 2005, to 7.97 GJ m^3 in 2008), and this efficiency improvement is incorporated into the analysis. Further, recent estimates of co-production of electricity for export have been updated to 0.61 MWh per m^3 for corn stover and switchgrass, and zero for forest residue. Additional updated assumptions in the feedstock stage were incorporated as well (see feedstock data above); the study found that corn ethanol reduces GHGs to a greater extent than that estimated by other recent studies—with 24% reduction in LCA GHGs compared to gasoline (including iLUC effects).

Kollaras et al. (2011) compare the performance of one strain of yeast to a leading industrial strain under specific conditions, finding increased alcohol yields (~11% higher than control in their example). This and other studies indicate that improved ethanol yields could help an ethanol plant achieve higher production while lowering heating requirements, increasing throughput and increasing profitability (due to increased yield).

Vehicle Use (Downstream or Tailpipe) Data

Misra and Murthy (2011) conducted a review of the use of additives in biodiesel and their impacts in terms of improving cold flow properties, improving engine performance, and controlling emissions. The authors conclude that additives, ethanol in particular, can decrease tailpipe emissions (NOx, HC, CO and smoke) from biodiesel in a diesel engine. Further, as discussed earlier, the federal GREET model (version 1.8d) has been updated to include modified fuel economy estimates for use of biodiesel and ethanol in conventional and alternative fuel vehicles.

Technological advancements and research improvements are ongoing, and thus the latest assumptions in LCA assessments related to feedstock development, transportation, processing, and end use are continually modified.

Conclusion

This section provides an update on the LCA assessment portion of the New York State Renewable Fuels Roadmap, presenting key studies and information advances, and discussing how the state of understanding in LCA assessments has changed since the Roadmap LCA assessment was conducted. Recent LCA studies show that direct GHG emissions from biofuel production and use are trending downwards. Indirect emissions are also trending down since Searchinger's early paper focusing on iLUC, though subsequent analyses have estimated iLUC effects exceeding those of Searchinger, when considering the entire range of uncertainty. Uncertainty is still greater for indirect parameters than direct parameters, and there are many kinds of uncertainty in LCA. Particularly relevant to the New York Renewable Fuels Roadmap, recent research has demonstrated that as systems are designed more carefully to meet GHG targets and minimize indirect effects, the GHG intensity of biofuels systems decreases.

Finally, iLUC review of the literature to date indicates that environmental impacts of biofuel production pathways need to be carefully considered to minimize environmental impacts. These findings have important implications for policy, and thus should be considered quantitatively to the extent possible.

STATE AND FEDERAL POLICIES

New York State Policies

New York State Climate Action Plan

Executive Order 24 (2009) requires preparation of a plan to reduce the state's greenhouse gas emissions 80% by 2050 (known as 80 by 50) (NYSERDA, 2010 (a)). The Climate Action Council, representing a variety of state agencies, worked together with more than 125 stakeholders to recommend climate change mitigation and adaptation strategies to the governor. Five working groups considered possible approaches to increase energy efficiency, reduce greenhouse gas emissions, and adapt to the changing climate within the state. The five working groups were

- Agriculture, Forestry, and Waste
- Power Supply and Delivery
- Residential, Commercial/Institutional and Industrial
- Transportation and Land Use; and
- Adaptation.

Working groups considered biomass as a sustainable resource when comparing energy sources. Energy from biomass was required in a number of possible scenarios proposed to achieve a low-carbon future by 2050. In all scenarios, it was estimated that fossil-based fuels would be replaced by a suite of fuel sources. The New York State Interim Climate Action Plan (CAP) was released in November 2010.

Policy options in the Transportation and Land Use (TLU) group emphasized shifting the vehicle fleet away from conventional internal combustion engines and petroleum-based fuels towards a mix of vehicles powered by electricity, hydrogen, and sustainably derived biofuels. This technology shift might be facilitated by a future low-carbon fuel standard (LCFS), which would rely on both conventional and advanced biomass technologies to power light duty vehicles as early as 2030. Specific analyses into the relative size of biomass fuel contributions and the associated benefits have not yet been conducted within the context of the interim CAP report. The TLU group does recognize that only a portion of New York's sustainably produced biomass would be available to the transportation sector. This recognition is in line with assumptions made in the Roadmap (NYSERDA, 2010 (b)).

In order to move New York closer to the 80 by 50 goal, the Residential, Commercial and Industrial working group assumed that by 2030, 90 TBtus of sustainable bioenergy would displace fossil fuel-based heating fuel. This could include direct combustion of biomass or the use of liquid biofuels derived from biomass feedstocks.

The Power Supply and Delivery (PSD) group emphasized policies that would encourage development of low-carbon renewable energy sources, such as wind, solar, and biomass/biofuels. In their policy recommendations, this group called for additional engineering studies and surveys to determine potential climate protection benefits from renewable energy sources, as well as to foster market introduction of these technologies. Various low-carbon portfolio standards considered by the PSD group between 2015 and 2030 assumed the addition of between 3,442 and 9,000 GWh of energy from sustainable wood and other biomass.

The Agriculture, Forestry, and Waste (AFW) group highlighted opportunities to both reduce greenhouse gas emissions through the displacement of fossil fuels, and provide economic opportunities through increased in-state circulation of energy expenditures. This means that the dollars spent for biomass harvesting, transport, and biofuel refining would remain within the State.

The AFW group called for the creation of a state-level Biomass Energy Program to provide coordination of research efforts as well as public/private partnerships, track sustainability criteria, and monitor the flow of biomass. This group would support policies to increase the sustainable production of agricultural and forest biomass within the State and would recommend the commitment of public funding to support the development of conversion technologies and to aid in market entry of these technologies. Sustainable feedstocks could be converted into energy carriers such as electricity, heat, steam, and gaseous/liquid biofuels, or they could be converted into bioproducts that could be substitutes for more energy-intense products. The AFW group developed its policy recommendations using the Roadmap estimates of the State's capacity to produce sustainable biomass.

The Adaptation workgroup noted that future changes in the State's climate could alter New York's ability to produce certain biomass feedstocks. Strategies to adapt to changes in climate, such as raising different biomass crops or adopting alternative agricultural management practices, should be conducted in concert with state or regional strategic planning.

In addition to the specific policy recommendations of the five working groups, the CAP acknowledged opportunities to expand workforce training and continuing education around biomass energy, including feedstock production and biorefinery operations.

It is important to note that the CAP analysis allocated available biomass feedstock in thirds to three sectors: 1/3 to transportation; 1/3 to the residential, commercial and industrial sector; and 1/3 to the power supply and delivery sector. The Roadmap assumed a larger proportion of available biomass feedstock would be available to produce biofuel for the transportation sector, which translates into differences between the estimated emissions from the Roadmap scenarios and the emissions implied by the CAP allocations.

The CAP recommended comprehensive policy options across all major sectors to achieve the CAP 80% reduction in greenhouse gas emissions by 2050. New York's energy policies have the potential to significantly stimulate a clean energy economy in the state. Biomass energy is very much a part of the strategy the CAP offers to achieve the 80% reductions.

The New York State Interim Climate Action Plan (CAP) recommendations are relevant to the Roadmap LCA analysis. Changes in agricultural practices and carbon intensity will affect the GHG emissions of NY biofuel, and a low-carbon fuel standard (clean fuel standard) will change the baseline GHG intensity of fuels to which biofuels are compared, and will also require use of low-carbon biofuels in NY.

New York State Energy Plan

The New York State Energy Plan (Plan) was released in December 2009. Because it was released prior to the Roadmap, its assessment of renewable energy from biomass is based on preliminary analysis from the Roadmap. The Plan estimates that, if fully developed, renewable energy resources could provide 38% of New York's projected primary energy[4] needs in 2018, estimated to be approximately 3,900 TBtus. In 2007, in-State use of biomass energy (energy produced from biomass, including forestry and agricultural products, biogenic waste, and biogas) totaled 116.1 TBtus. The Roadmap estimates that by 2020 New York biofuels could provide between 5.6% and 16% of estimated in-State gasoline consumption.

An update to the NYS Energy Report is being prepared by the State Energy Planning Board and calls on that Board to complete a Draft State Energy Plan (Draft Plan) by September 1, 2012 and a Final State Energy Plan (Final Plan) by March 15, 2013.

NYS DEC Biomass Rule

In Spring 2009, the New York State Department of Environmental Conservation (DEC) released a draft policy entitled "Policy DAR-12: 'Sustainably Harvested' Determination for Purposes of 'Eligible Biomass,' Part 242 – Draft." Under the Regional Greenhouse Gas Initiative (RGGI), regulated facilities burning biomass are permitted to deduct CO_2 emissions resulting from the biomass from their compliance obligations as long as the fuel qualifies as "eligible biomass." In order to be considered "eligible biomass," it must have been "sustainably harvested." This policy is designed to address what qualifies as "sustainably harvested." After a public comment period, the DEC released the final version of this policy on December 1, 2010.

In order to be considered "sustainably harvested" for purposes of qualifying as "eligible biomass" under RGGI, two criteria must be met. First, the "Certification Criterion" requires that the land from which the biomass was obtained must either have a United States Department of Agriculture (USDA) stewardship plan in place or have proper certification under either the Real Property Tax Law or a DEC- approved non-governmental forest certification body. Second, the "Carbon Re-sequestration Criterion" requires that the land from which the biomass was harvested must be subject to a legally binding document, such as an easement, that requires documentation of the length of

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[4] Primary energy is energy that has not undergone a conversion process. It is the energy contained in raw fuels that are received as an input into a system.

time the land is maintained in a forested state. Specifically, the land must remain forested for either 100 years or for a length of time that the DEC finds sufficient to ensure that the amount of CO_2 emitted will be re-sequestered.

It is possible that if the standards are more restrictive than similar policies found in other states or programs, biomass may be used less frequently in New York for co-firing, thereby resulting in greater reliance on fossil fuels. Similarly, some feel an overly restrictive policy could significantly harm New York's emerging low-value wood industry. The DEC, however, has responded to concerns about the impact of the rule on the availability of "eligible biomass." Citing the Roadmap, DEC states that "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 (NYSERDA, 2010 (b)). Once developed, these sustainable practices should provide New York with specific biomass retention and harvesting guidelines that balance ecological protection, on-site carbon storage, and renewable fuel use with modeling of carbon flows over time….the Department may revise guidelines as appropriate, based on updated technical or scientific information."

New York City B2

In Summer 2010, Mayor Bloomberg signed Introductory Number 194-A into law. This law requires that, beginning on October 1, 2012, all heating oil used in New York City must contain at least 2% biodiesel fuel (known as B2). This legislation is expected to create new jobs and improve air quality in the metropolitan area.

Federal Policies

E15 Waiver

Until recently, the maximum percentage of ethanol that could be blended into gasoline was 10% (E10). In order for greater percentages of ethanol to be blended, a petition must be submitted to the EPA under the Clean Air Act (CAA) requesting that this standard be "waived." The EPA received such a petition from Growth Energy and 54 ethanol producers in March 2009 requesting that the EPA raise the limit on the percentage of ethanol that could be blended into gasoline from 10% to 15% (E15). The EPA granted a partial waiver in October 2010 allowing E15 to be used in Model Year (MY) 2007 vehicles, and this partial waiver was expanded on January 21, 2011 to MY 2001-2006 vehicles. As of May 2011, the EPA is reviewing comments on its Proposed Rule designed to mitigate the possibility of misfueling cars MY 2000 and earlier with E15. The increase in ethanol from E10 to E15 could have the effect of encouraging biofuel production in a situation where circumstances are otherwise unfavorable. For example, the recent downturn in the economy coupled with increasing gasoline prices reduced demand for gasoline that in turn reduces demand for ethanol. In addition, the increase to E15 addresses the blend wall issue in some measure. The blend wall is the concept that, if the permissible blending level remained at E10, the market would be saturated with ethanol because demand would be met, and ethanol production would stop increasing. The increase to E15 provides the opportunity for more ethanol to enter the marketplace, thus having the potential to encourage ethanol production.

Tailoring Rule

The EPA promulgated the Tailoring Rule in response to the ruling of the U.S. Supreme Court in *Massachusetts v. EPA*. The Court held that GHGs are pollutants under the Clean Air Act (CAA) and that the EPA must regulate them if it is found that GHGs endanger the public health and welfare, and that GHG emissions from motor vehicles cause or contribute to air pollution, which endangers public health. The EPA made these findings and published them on December 15, 2009. As a result of these findings, the EPA eventually concluded that the CAA requires it to regulate GHG emissions from new or modified facilities through the New Source Review Prevention of Significant Deterioration (PSD) and Title V Operating Permit programs. Because such a permitting requirement would be overly burdensome for the EPA given the large number of facilities that emit GHGs, and would thus be required to be regulated, the EPA developed the Tailoring Rule. The Tailoring Rule, issued on May 13, 2010, establishes thresholds limiting the number of facilities the EPA must regulate based on the quantity of GHGs emitted, meaning that only the largest emitters will be required to comply with EPA permitting. The rule covers stationary sources that collectively represent 70% of the national GHG emissions.

In terms of implications for biomass, there was concern from members of the industry that biogenic CO_2 emissions, such as those from bioenergy production, should be treated differently under these regulations given the carbon sequestration and other benefits associated with the growing of the biomass. On March 21, 2011, the EPA published a proposed rule that would defer application of CAA permitting requirements to biogenic sources of CO_2 emissions for three years. During that time, the EPA will study these emissions in order to determine the most accurate methods to account for them.

Indirect Land Use Change

The issue of indirect land use change (iLUC) continues to be debated. Early studies indicated iLUC had large impacts. Some studies released over the past year, however, indicate that the impacts of iLUC may not be as great as previously thought. For example, a study completed by Purdue University (briefly discussed earlier in this Update, on page 17) found that emissions from iLUC, accounting for population and yield growth, were 14.5 grams CO_2/megajoule (g/MJ) for corn-based ethanol (Tyner et al., 2010). According to this report, these emissions are only 13.6% of the emissions found in the study published by Searchinger et al. in 2008 (Searchinger et al., 2008) and 48.3% of the emissions found by the California Air Resources Board for corn-based ethanol (California Air Resources Board, 2011). The Purdue report emphasizes, however, that while there is a great deal of uncertainty involved with quantifying iLUC emissions, this information should not be ignored:

"Land use change and associated GHG emissions is a very controversial topic. Some argue it is impossible to measure such changes. Others argue that failure to measure the land use changes and the consequent GHG emissions would lead us to incorrect policy conclusions. After working on this topic for over two years, we come out between these extremes. First, with almost a third of the U.S. corn crop today going to ethanol, it is simply not

credible to argue that there are no land use change implications of corn ethanol. The valid question to ask is to what extent land use changes would occur. Second, our experience with modeling, data, and parameter estimation and assumptions leads us to conclude that one cannot escape the conclusion that modeling land use change is quite uncertain. Of course, all economic modeling is uncertain, but it is important to point out that we are dealing with a relatively wide range of estimation differences" (Tyner et al., 2010).

As stated in the Purdue report, there are some who feel that the uncertainty is so great that it warrants leaving it out of policy considerations. In one paper, for example, the authors argue that iLUC should not be integrated into biofuels policy because "[t]he indirect land uses are uncertain, vary over time, and their current estimates diverge significantly" (Zilberman et al., 2010). As stated in the Roadmap, however, the analysis for New York was conducted so as to minimize the possible implications of iLUC by maintaining current levels of agricultural and forest production. It should also be noted that the Roadmap focuses on cellulosic ethanol, and many of the iLUC studies focus on ethanol made from corn grain. Not all study results, therefore, translate well to New York's situation. The Roadmap will continue to be updated as more information becomes available.

Renewable Fuel Standard

In March 2010 the U.S. Environmental Protection Agency (EPA) finalized the Renewable Fuel Standard 2 Program (RFS2), establishing new annual volume standards for renewable fuel required to be blended into transportation fuel (increasing to 36 billion gallons by 2022), and setting GHG emission thresholds for cellulosic ethanol, biomass-based diesel, advanced ethanol, and non-advanced ethanol (corn grain ethanol). GHG thresholds were determined through LCA analysis, which is defined by the EPA as incorporating direct and indirect emissions from land use changes. See also the following subsection describing the USDA Roadmap analysis of the impacts of the new Renewable Fuel Standard.

EPA accounted for iLUC changes from corn ethanol production, finding lower iLUC impacts than initially anticipated in the proposed rule. According to the EPA, lower iLUC effects were estimated due to studies showing higher crop yields due to price, new studies showing that DDGS is more efficient as animal feed than previously estimated (so less land is needed to grow corn for animal feed), and improved satellite data. A lower iLUC effect per unit of energy was found for switchgrass, though other feedstocks were examined for total international land use change. EPA noted that several feedstocks are estimated to have minimal or no iLUC effects, compared to those of corn grain ethanol or soy biodiesel, including crop residues, forest residue material, perennial grasses including switchgrass, and food and yard waste.

As noted by Plevin (2010), EPA made several improvements to the methodology for determining GHG intensity of biofuels in their final RFS2 LCA assessment compared to the initially proposed rule, including: new soil carbon data, analysis of some uncertainty in remote sensing and emission factors, and corrected N_2O emission factors. Plevin also critiques several aspects of the EPA's RFS2 LCA study, noting that:

- The GHG reductions attributed to cellulosic ethanol are largely dependent on the electricity co-product credit (an argument supported by Spatari and Maclean (2010), and Spatari et al. (2010) findings—see above), and that electricity co-products are not modeled in a market context. (EPA assumes that average grid electricity is displaced, rather than assuming that marginal electricity will be displaced).
- Switchgrass yields used by the EPA are much higher than those reported in a Pacific Northwest National Lab study (which EPA reports were the basis of their yield estimates), and exponential increases in switchgrass yields were assumed (though historic yield increases have been linear).

The EPA RFS2 is of relevance to New York in a number of respects. First, the RFS2 calls for an increasing portion of fuel sold nationwide to be renewable (cellulosic, advanced, or non-advanced) through 2022 and beyond, and that the renewable fuel meets certain GHG-reduction targets. This means that over time, the baseline GHG-intensity of transportation fuel in NY will become lower than that of current gasoline (which was the fuel used as the baseline in the Roadmap LCA assessment), so future GHG reductions of New York Roadmap biofuel (compared to a baseline of gasoline actually being used at that time) could be overestimated.

Second, Plevin's (2010) critiques of the RFS2 LCA assessment bring attention to a common assumption in biofuel LCA analyses: that electricity produced in cellulosic ethanol biorefineries displaces electricity with a carbon intensity equal to the average grid. The Roadmap LCA analysis assumed that NY average grid electricity was displaced. Plevin believes a more accurate approach would be to examine the marginal electricity displaced. This is one possible approach that may have relevance with respect to New York's deregulated electricity markets, but the issue is complex and other factors including policies or future regulations for toxic air emissions must also be considered. Further, it is unclear whether electricity generated by biorefineries would actually displace electricity on a one-to-one basis. Some think electricity consumption would increase due to increased supply, while others believe an increased supply of renewable electricity would result in reduced electricity from dirtier sources. The issue is further complicated by differing assumptions regarding what timeframe is being considered. As electricity co-production has been identified as a key factor in LCA GHG emissions estimates (the removal of the credit can result in net GHG emissions greater than conventional fuels), special attention should be paid to the method and assumptions used to calculate this credit.

USDA Roadmap

On June 23, 2010, the USDA released a study entitled "A USDA Regional Roadmap to Meeting the Biofuels Goals of the Renewable Fuels Standard by 2022." In this report, the USDA examined the current state of the nation's biofuel production in terms of achieving the ambitious goal of producing 36 billion gallons of bio-based fuels by 2022. It concluded, among other things, that while the current and anticipated production of corn ethanol should be sufficient to meet the 15 billion gallons of conventional biofuels permitted under the RFS, the 20 billion gallons of cellulosic/advanced biofuels will be more difficult to obtain. Based on certain assumptions, the USDA determined that in order to achieve the 20 billion gallons goal, 527 biorefineries would need to be built, and this would cost $168 billion (USDA, 2010).[5]

Of relevance to the Roadmap are the assumptions the study made regarding estimated percentages of advanced biofuels each region of the U.S. will be able to produce. For the Northeast, the study estimates that, on 639,150 acres of dedicated bioenergy crops (perennial grasses) plus 1.7 million acres of harvested logging residue/year, it will only be able to produce 2.0%, or 0.43 billion gallons, of the roughly 20 billion gallons needed by 2022 (USDA, 2010). The Roadmap, however, estimated a potential for between one million and 1.68 million acres of non-forest land to be used for bioenergy feedstock production in New York alone and, of the State's forest lands, nearly 15.8 million acres is producing or is capable of producing woody biomass (NYSERDA, 2010 (b)).

While the USDA study focuses on the Northeast region and established estimates based on production required by 2022, the comparison between the two studies is significant. For example, the USDA estimates that only 639,150 acres are available for dedicated bioenergy crops in the entire Northeast, while the Roadmap estimates between one and 1.68 million acres are available in New York alone. One reason for the large discrepancy in part has to do with the definitions set forth in the Energy Independence and Security Act (EISA). The USDA study focused on determining how the nation will meet the RFS2 goal of 36 billion gallons of bio-based fuels by 2022, as stated above. The EISA provides specific and relatively restrictive definitions of agricultural cropland as compared to definitions under, for example, the Farm Bill. Because of these specific definitions, the USDA was unable to include certain land types common in the Northeast. In addition, the Roadmap estimated land use through the National Land Cover Database, a source that was not apparently used in the USDA study.

Light-Duty and Heavy Duty Vehicle Rules

On May 21, 2010, President Obama issued a Presidential Memorandum requesting that action be taken to encourage the development of clean vehicles, with the ultimate goals of promoting energy security, job creation, and American manufacturing competitiveness. He said that the United States "has the opportunity to lead the world in the development of a new generation of clean cars and trucks through innovative technologies and manufacturing that will spur economic growth and create high-quality domestic jobs, enhance our energy security, and improve our environment" (Office of the Press Secretary, 2010).

Prior to the issuance of this memorandum on April 1, 2010, the U.S. Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA, on behalf of the U.S. Department of Transportation) finalized a joint rule establishing greenhouse gas (GHG) emission and fuel economy standards for model year (MY) 2012-2016 passenger cars, light-duty trucks, and medium-duty passenger vehicles (USEPA & USDOT, 2010 (a)). The standards established under this rule address carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4)

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[5] Footnote to these numbers states that "This figure comes from the analysis of USDA received applications for funding biorefineries that average the cost of building the biorefinery divided by the projected plant capacity."

emissions. This program is designed to provide both the consumer and manufacturers with flexibility and options. For example, the EPA has established several credit provisions, such as flex-fuel and alternative fuel vehicle credits, providing auto manufacturers with flexibility in terms of how they can meet these new standards (USEPA, 2010 (a)). The EPA, DOT and the State of California are currently working together to develop GHG and fuel economy standards for MY 2017-2025, and the proposed standards are expected to be released by September 30, 2011 and finalized by July 31, 2012 (USEPA, 2010 (b)).

On November 20, 2010, EPA and the NHTSA issued a Notice of Proposed Rulemaking (NOPR) where the proposed rules would establish GHG and fuel efficiency standards for heavy-duty vehicles (USEPA & USDOT, 2010 (b)). The NHTSA fuel consumption standards and EPA carbon dioxide (CO_2) standards would be specifically developed for (1) combination tractors; (2) heavy-duty pickup trucks and vans; and (3) vocational vehicles. The EPA is also developing standards for hydrofluorocarbon, N_2O and CH_4 emissions. They would generally apply to MY 2014-2018 vehicles weighing at least 8,500 lbs, and similarly include flexibility provisions for manufacturers as they work toward meeting these standards.

As we strive to improve future alternative fuels, reduce the pollution associated with fossil fuel, and develop engines and vehicles that are more fuel efficient, or clean-burning, parallel efforts are inevitable. All of these options have the capacity to lead to improved air quality, a reduced carbon footprint, and fewer negative impacts to the environment.

2012 Farm Bill

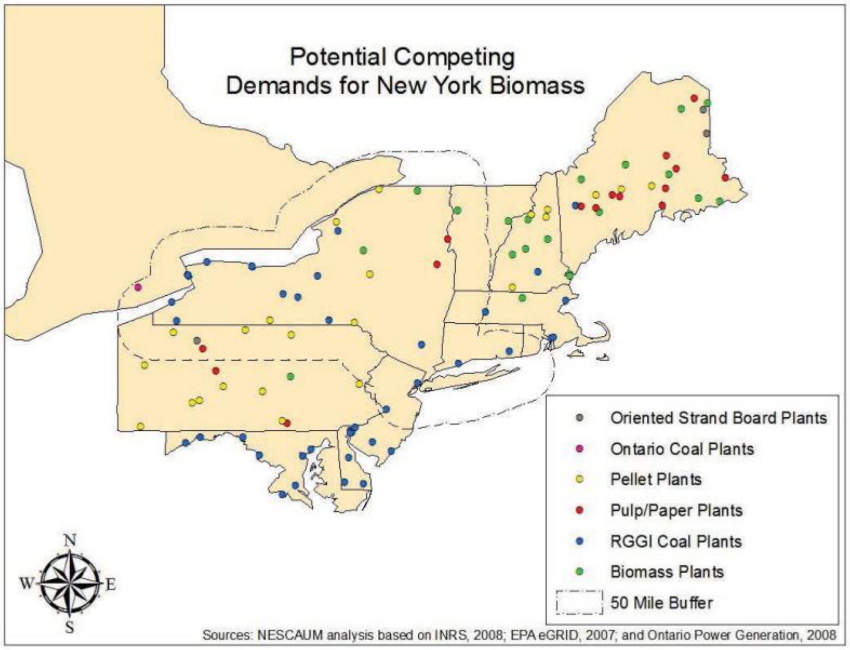
With the 2008 Farm Bill set to expire in 2012, it is important to see how much of a role energy will play in the successive 2012 Farm Bill. Two particular programs in the 2008 Farm Bill Energy Title are of note: the Biomass Crop Assistance Program (BCAP) and the Rural Energy for America Program (REAP). BCAP is a program designed to make it more financially viable for farmers to grow advanced bioenergy crops by providing them with grant money. It can be difficult for farmers to grow these crops because with few or no advanced conversion facilities, there is often no demand for them. At the same time developers are reluctant to construct conversion facilities unless they know there will be a steady supply of energy crops. The BCAP grants provide the financial security for farmers to produce crops that could encourage investment in advanced conversion facilities. To help promote renewable energy and energy efficiency in rural areas, REAP connects project developers and lenders who can provide loans to support these projects, and the USDA guarantees these loans up to 85%. The USDA also recently clarified that REAP assistance applies to the installation of blender pumps (also known as flex fuel pumps) which dispense E85, and it is hoped that this will provide people with greater fuel choices at the pump (USDA, 2011 (a)).

The future of BCAP and REAP, however, is uncertain. Over the past few months, the USDA has announced projects on nearly 70,000 acres in Arkansas, Pennsylvania, Ohio, Kansas and Missouri which would take advantage of the BCAP grants to establish dedicated bioenergy crops (USDA, 2011 (b)). Despite the establishment of these projects, on May 24, 2011, the U.S. House of Representatives' Agriculture Appropriations Subcommittee voted to eliminate both BCAP and REAP funding for 2012. This elimination of funding does not necessarily mean that both programs will be excluded from the 2012 Farm Bill. There will likely be strong support for the Farm Bill's energy provisions, including REAP, which has been considered to be largely successful to both producers and policymakers. BCAP, on the other hand, has been met with some frustration, fairly or unfairly, because the development of advanced biofuel conversion facilities has been slow.

Department of Defense

On June 14, 2011, the Department of Defense (DoD) issued an operational strategy intended to address the amount and sources of energy it uses on the battlefield. "Energy for the Warfighter: Operational Energy Strategy," the first such document issued by the DoD to focus on military energy use, identifies three specific target areas: reducing energy demand, diversifying energy supply, and integrating energy issues into future planning (Department of Defense, 2011; Snider, 2011). Among the alternative energy sources the DoD is considering are biofuels and local energy crops (Department of Defense, 2011; Snider, 2011). More details of the plan are expected to be developed over the next three years (Snider, 2011).

The Following Figure (denoted as Figure ES-6 in the Executive Summary, Figure 2-5 in the Roadmap, and as Figure O-2 in Appendix O) and Table (denoted as ES-1 in the Executive Summary and Table 4-1 in the Roadmap) are updated from the original versions in the 2010 Roadmap.



Potential Competing Demands for New York Biomass

Sources: NESCAUM analysis based on INRS, 2008; EPA eGRID, 2007; and Ontario Power Generation, 2008

TABLE ES-1 AND 4-1

Attributes	Scenario 1	Scenario 2	Scenario 3
Human Values Emphasized			
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)	N/A	x[a]	x[a]
Centralized, larger scale production	x	x	
Distributed, smaller scale production as a goal[b]			x
State of Conversion Technology			
Ready in near term	x		
Advanced technologies (ready in mid-term)		x	x
Land Resources (million acres)			
[Non-forest] land used for lignocellulosic feedstocks	0.98	1.68[a]	1.68[a]
Biomass Feedstock Resource Inputs (Mdt)			
Lignocellulosic feedstocks (at $3 wholesale gge)	4.2	14.5	14.5
Lignocellulosic feedstocks (at $4 wholesale gge)	9.4	14.6[c]	14.6[c]
Total production of corn grain, soybean, and yellow grease (current baseline)[d]	1.9	1.9	1.9
Lignocellulosic Feedstock Types (Mdt)[e]			
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
Capacity of Existing Biorefineries in Year 2020 (MGY)			
Two grain ethanol plants (current nameplate capacity)	154	154	154
Biodiesel production ($4 wholesale gge case)	30	30	30
New Biorefineries and Feedstock Sheds			
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[f]	5.6 %	16%	16%
Economic Factors			
Investment capital from investors[g]	60%	60%	50%
Transportation Factors			
Average distance fuel is transported to blending terminals (miles)	28.1	27.0	24.5

[a] 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.
[b] May not be an economical or practical choice for all technologies.
[c] For Scenarios 2 and 3, higher price brings little to no increase in production because the availability of New York biomass becomes limited.
[d] Corn grain and soy are measured in dry tons. Yellow grease is measured in tons.
[e] Scenario 1 lignocellulosic feedstock type production levels correspond to $4 wholesale gge.
[f] Assumes that all sustainably available biomass is used for ethanol production. Figure intended as "upper boundary" of feasible biofuel production.
[g] Percentage of total biorefinery capital costs that are supplied by private investment.

References

Al-Riffai, P., B. Dimaranan, et al. (2010). Global Trade and Environmental Impact Study of the EU Biofuels Mandate, International Food Policy Institute (IFPRI).

Babcock, B. A. and J. F. Fabiosa (2011). The Impact of Ethanol and Ethanol Subsidies on Corn Prices: Revisiting History CARD Policy Briefs. Ames, Iowa, Iowa State University.

Brune, D. E., Lundquist, T.J. and Benemann, J. R. (2009, November) Microalgal biomass for greenhouse gas reductions: Potential for replacement of fossil fuels and animal feeds. *Journal of Environmental Engineering,* 135 (11), 1136-1144.

California Air Resources Board. "Table 6. Carbon Intensity Lookup Table for Gasoline and Fuels that Substitute for Gasoline." February 2011. http://www.arb.ca.gov/fuels/lcfs/010611lcfs_lutables.pdf.

Cherubini, F. and A. H. Strømman (2011). "Life cycle assessment of bioenergy systems: State of the art and future challenges." Bioresource Technology **102**: 437–451.

Cherubini, F. and S. Ulgiati (2010). "Crop residues as raw materials for biorefinery systems - A LCA case study." Applied Energy **87**: 47-57.

Dale, B., B. D. Bals, et al. (2010). "Biofuels Done Right: Land Efficient Animal Feeds Enable Large Environmental and Energy Benefits." Environmental Science & Technology **44**(22): 8385-8389.

Delucchi, M. A. (2010). "Impacts of biofuels on climate change, water use, and land use." Annals of the New York Academy of Sciences **1195**(1): 28-45.

Department of Defense. June 15, 2011. "Energy for the Warfighter: Operational Energy Strategy." June 2011. http://energy.defense.gov/OES_report_to_congress.pdf

Gawel, E. and G. Ludwig (2011). "The iLUC dilemma: How to deal with indirect land use changes when governing energy crops?" Land Use Policy **In Press, Corrected Proof**.

Hertel, T. W., A. A. Golub, et al. (2010). "Effects of US Maize Ethanol on Global Land Use and Greenhouse Gas Emissions: Estimating Market-mediated Responses " Bioscience **60**(3): 224-231.

Hsu, D. D., D. Inman, et al. (2010). "Life Cycle Environmental Impacts of Selected U.S. Ethanol Production and Use Pathways in 2022." Environmental Science & Technology **44**(13): 5289-5297.

IEA Bioenergy. (2010). "Algae - The Future for Bioenergy? Summary and conclusions from the IEA Bioenergy ExCo64 Workshop, from http://www.ieabioenergy.com/MediaItem.aspx?id=6517.

Kollaras, A., J. M. Kavanagh, et al. (2011). "Techno-economic implications of improved high gravity corn mash fermentation." Bioresource Technology **In Press, Accepted Manuscript**.

Lankoski, J. and M. Ollikainen (2011). "Biofuel policies and the environment: Do climate benefits warrant increased production from biofuel feedstocks?" Ecological Economics **70**: 676-687.

Lywood, W. (2010). Issues of concern with models for calculating GHG emissions from indirect land use change, Ensus.

McKone, T. E., W. W. Nazaroff, et al. (2011). "Grand Challenges for Life-Cycle Assessment of Biofuels." Environmental Science & Technology **45**: 1751–1756.

Misra, R. D. and M. S. Murthy (2011). "Blending of additives with biodiesels to improve the cold flow properties, combustion and emission performance in a compression ignition engine--A review." Renewable and Sustainable Energy Reviews **15**(5): 2413-2422.

Mullins, K. A., W. M. Griffin, et al. (2010). "Policy Implications of Uncertainty in Modeled Life-Cycle Greenhouse Gas Emissions of BiofuelsâŠ¥." Environmental Science & Technology **45**(1): 132-138.

NYSERDA (2010) (a). New York State Climate Action Plan Interim Report Albany, NY, New York State Energy Research and Development Authority.

NYSERDA (2010) (b). "Renewable Fuels Roadmap and Sustainable Biomass Feedstock Supply for New York State." New York State Energy Research and Development Authority, from http://www.nyserda.org/publications/renewablefuelsroadmap/Report_10_05_Renewable%20Fuels%20Roadmap.pdf.

Office of the Press Secretary. "Improving Energy Security, American Competitiveness and Job Creation, and Environmental Protection Through a Transformation of Our Nation's Fleet of Cars And Trucks,'' Issued May 21, 2010, published at 75 FR 29399, May 26, 2010.

Oladosu, D. and K. Kline (2010). Decomposition Analysis of U.S. Corn Use for Ethanol Production from 2001-2008. California Air Resources Board (CARB) Low Carbon Fuel Standard Expert Workgroup Meeting Sacramento, CA, U.S. Department of Energy Oakridge National Laboratory.

Plevin, R. J. (2010). "Review of final RFS2 analysis ", from http://plevin.berkeley.edu/docs/Plevin-Comments-on-final-RFS2-v7.pdf.

Plevin, R. J., M. O'Hare, et al. (2010). "Greenhouse Gas Emissions from Biofuels' Indirect Land Use Change Are Uncertain but May Be Much Greater than Previously Estimated." Environmental Science & Technology **44**: 8015-8021.

Rajagopal, D., G. Hochman, et al. (2011). "Indirect fuel use change (IFUC) and the lifecycle environmental impact of biofuel policies " Energy Policy **39**: 228-233.

Searchinger, Timothy, et al. "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change." February 2008. Science Express.

Snider, A. "DEFENSE: Battlefield energy plan aims to spark major changes in the Pentagon." http://www.eenews.net/Greenwire/2011/06/15/12.

Spatari, S., D. M. Bagley, et al. (2010). "Life cycle evaluation of emerging lignocellulosic ethanol conversion technologies." Bioresource Technology **101**(2): 654-667.

Spatari, S. and H. L. MacLean (2010). "Characterizing Model Uncertainties in the Life Cycle of Lignocellulose-Based Ethanol Fuels." Environmental Science & Technology **44**(22): 8773-8780.

Tyner, W. E., F. Taheripour, et al. (2010). Land Use Changes and Consequent CO_2 Emissions due to US Corn Ethanol Production: A Comprehensive Analysis, Purdue University Department of Agricultural Economics.

U.S. Department of Agriculture. June 23, 2010. "USDA Regional Roadmap to Meeting the Biofuels Goals of the Renewable Fuels Standard by 2022."

U.S. Department of Agriculture. (a) April 8, 2011. "USDA Program Provides Consumers More Choices at the Pump With Flex-Fuel Options." Release No. 0158.11. http://usda.gov/wps/portal/usda/!ut/p/c5/04_SB8K8xLLM9MSSzPy8xBz9CP0os_gAC9-wMJ8QY0MDpxBDA09nXw9DFxcXQ-cAA_1wkA5kFaGuQBXeASbmnu4uBgbe5hB5AxzA0UDfzyM_N1W_IDs7zdFRUREAZXAypA!!/dl3/d3/L2dJQSEvUUt3QS9ZQnZ3LzZfUDhNVlZMVDMxMEJUMTBJQ01IMURERDFDUDA!/?contentidonly=true&contentid=2011%2f04%2f0158.xml

U.S. Department of Agriculture, Farm Service Agency. (b) June 15, 2011. "USDA Announces Projects to Provide Increased Renewable Energy Production, Reduce Reliance on Foreign Oil." Release No. 0254.11. http://disaster.fsa.usda.gov/FSA/mobileNewsReleases?area=newsroom&subject=landing&topic=ner&newstype=newsrel&type=detail&item=nr_20110615_rel_0254.html

U.S. Department of Energy. (2010). "National Algal Biofuels Technology Roadmap." Office of Energy Efficiency and Renewable Energy, Biomass Program.

U.S. Environmental Protection Agency. (a) April 2010. "EPA and NHTSA Finalize Historic National Program to Reduce Greenhouse Gases and Improve Fuel Economy for Cars and Trucks."

U.S. Environmental Protection Agency. November 2010. (b) "EPA and NHTSA Issue a Supplemental Notice in the Process for Setting Future Greenhouse Gas and Fuel Economy Standards for Passenger Cars and Light Trucks." http://www.epa.gov/otaq/climate/regulations/420f10059.pdf.

U.S. Environmental Protection Agency, U.S. Department of Transportation. (a) "Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule." 75 Fed. Reg. 25324. May 7, 2010.

U.S. Environmental Protection Agency, U.S. Department of Transportation. (b) "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles." 75 Fed. Reg. 74152. November 30, 2010. http://www.gpo.gov/fdsys/pkg/FR-2010-11-30/pdf/2010-28120.pdf

Venkatesh, A., P. Jaramillo, et al. (2010). "Uncertainty Analysis of Life Cycle Greenhouse Gas Emissions from Petroleum-Based Fuels and Impacts on Low Carbon Fuel Policies." Environmental Science & Technology **45**(1): 125-131.

Wang, M., H. Huo, et al. (2010). "Methods of dealing with co-products of biofuels in life-cycle analysis and consequent results within the U.S. context." Energy Policy **In Press, Corrected Proof**.

Wang, M. Q., J. Han, et al. (2011). "Energy and greenhouse gas emission effects of corn and cellulosic ethanol with technology improvements and land use changes." Biomass and Bioenergy **35**(5): 1885-1896.

Zhu, X., X. Li, et al. (2011). "Challenges and models in supporting logistics system design for dedicated-biomass-based bioenergy industry." Bioresource Technology **102**: 1344-1351.

Zilberman, D. et al. 2010. "Indirect Land Use: One Consideration Too Many in Biofuel Regulation." Agricultural and Resource Economics, Giannini Foundation of Agricultural Economics, University of California. V. 13 no. 4, Mar/Apr 2010.

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