CATF WHITE PAPER:
CORN STOVER AND THE
PACE OF CELLULOSIC ETHANOL COMMERCIALIZATION

April 2013

Corn stover (stalks, leaves and cobs) is the largest existing resource of cellulosic feedstock now available in the United States. The US Department of Energy estimates that by 2030, 180 million dry tons of cellulosic feedstock could come from agricultural crop residues, the bulk of it from corn stover.[1]

DOE projects that up to 500 million dry tons of cellulosic feedstock could be harvested in 2030, mainly in the form of dedicated energy crops such as switchgrass and Miscanthus.[2] However, these crops have not been widely established and cultivated and the present economics of doing so are unfavorable. In addition, the full range of environmental impacts arising from conversion of fallow land into energy cropland has not been defined and quantified. Looking to stover as near term feedstock makes sense, given that corn is already grown, and the stover already produced as a by-product.

There are several factors that should be considered, however, when estimating how much stover might reasonably be available, and under what circumstances.

Stover now provides much of the organic material being re-incorporated into the soil where corn is cultivated continuously or where corn and soybeans are rotated. Removing too much stover could lead to deterioration of soil quality, loss of soil carbon, and increased sediment runoff and associated water pollution. These concerns can broadly be classified as environmental.

Stover is dispersed widely over the landscape. The USDA predicts that 97 million acres of corn will be planted in 2013, about the same as 2012.[3] This is up from around 80 million acres planted in 2003. The business of harvesting, transporting and storing stover presents significant challenges, most of which have yet to be addressed. This is especially so when one considers that grain and stover need to be harvested simultaneously or nearly so. These concerns can be broadly classified as logistic.

Building biorefineries and associated infrastructure to produce the 16 billion gallons of cellulosic ethanol required under the RFS2 is also a substantial task. A biorefinery processing one million tons of stover annually would produce about 80 million gallons per year (GPY) of ethanol. Two hundred such biorefineries would be needed to produce 16

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[1] USDOE, U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry" 67 (2011) (http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf).
[2] *Id.* at 130-131.
[3] USDA National Agricultural Statistics Service, Quick Stats ("USDA Quick Stats") (http://www.nass.usda.gov/Quick_Stats/).

billion gallons. Although it is difficult to estimate the capital costs of fully commercial facilities, recent proposals for smaller refineries in the 25-30 million GPY range have estimated costs from $200 to $400 million.[4] It is not unreasonable to assume that an 80 million GPY facility would cost between $500 million and $1 billion. The total capital required to build a 16 billion gallon industry could be as high as $200 billion. These concerns can be broadly classified as infrastructural.

Environmentally Available Stover Resource

In 2012, the 87 million acres of corn harvested (10 million acres were lost to the drought) produced about 11 billion bushels of corn. This translates into about 300 million tons of stover. If all of this stover were available, and could be economically harvested, transported, stored and converted, it would produce about 24 billion gallons of ethanol. However, environmental limitations will reduce the amount of stover available for cellulosic ethanol.

Agronomists and soil scientists now estimate that about 3.5 tons of stover should be left on each acre of cropland to maintain fertility, soil carbon, tilth, and to prevent runoff.[5]

The following bar chart presents national stover production versus environmentally available stover (*i.e.*, total stover –[acres harvested *3.5]) for the period 2003-2012.[6] On average for the period considered, 53 million tons of stover were available annually for ethanol production. This would yield about 4 billion gallons of cellulosic ethanol, about one-quarter of the amount required by RFS2 in 2022.

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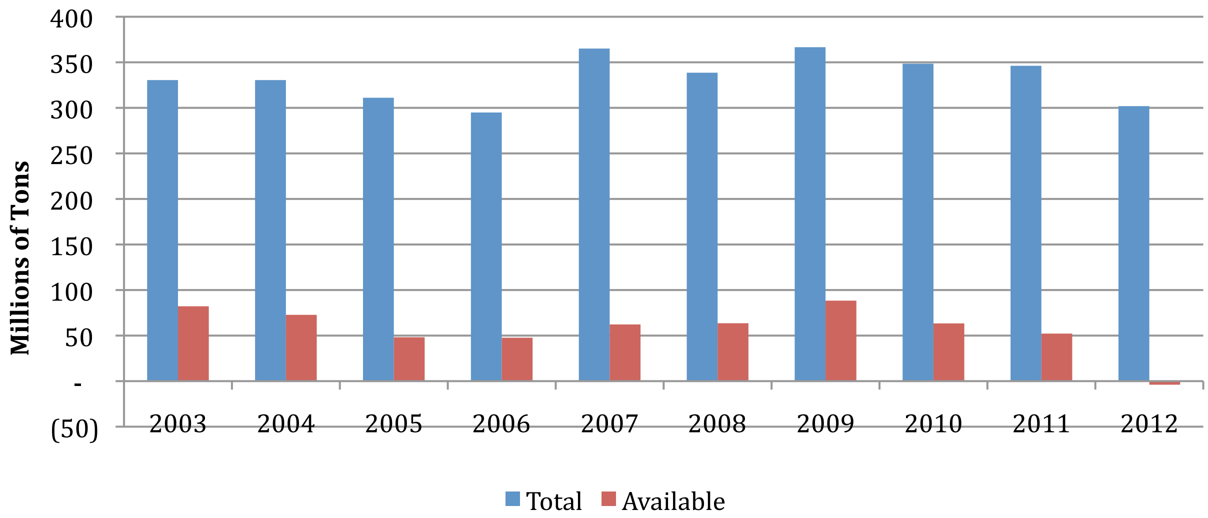
[4] *See* "Dupont Builds Giant Cellulosic Ethanol Biorefinery in Iowa," ENVIRONMENT NEWS SERVICE (December 12, 2012) (http://ens-newswire.com/2012/12/12/dupont-builds-giant-cellulosic-ethanol-biorefinery-in-iowa/); Dan Campbell, "Switchgrass Plant Switches On," RURAL COOPERATIVES 14 (May/June 2011) (http://www.generaenergy.com/wp-content/uploads/Genera_RuralCooperativesMag1.pdf)

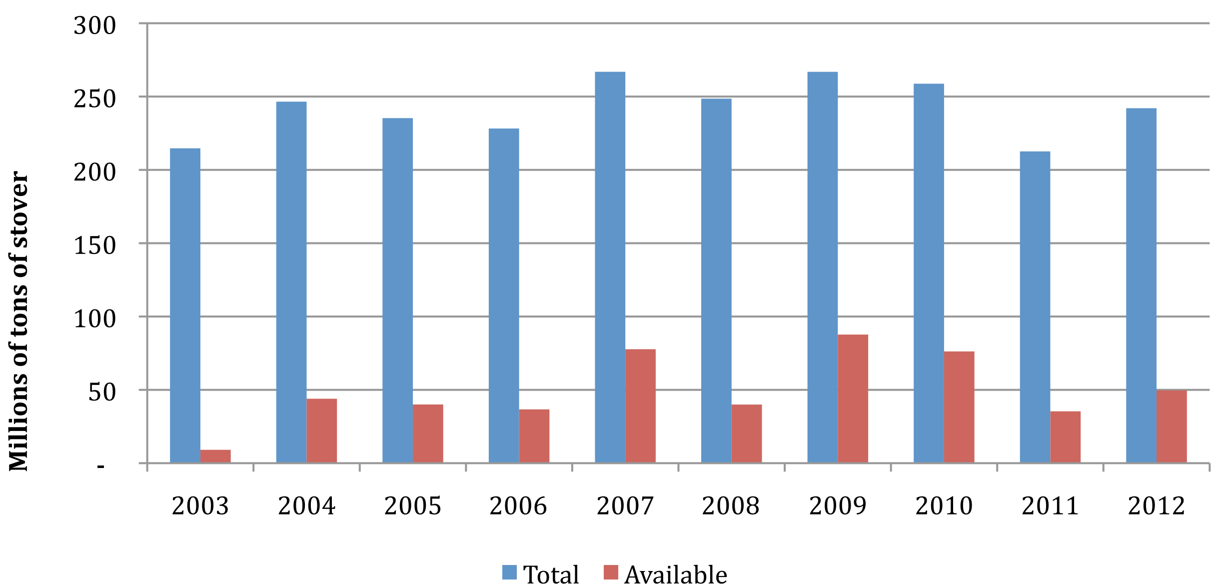
[5] Greg Roth *et al.*, *Corn Stover for Biofuel Production*, EXTENSION (March 30, 2012) (http://www.extension.org/pages/26618/corn-stover-for-biofuel-production); *see also* Steve Brick, *Harnessing the Power of Biomass Residuals: Opportunities and Challenges for Midwestern Renewable Energy* (The Chicago Council on Global Affairs, 2011) (http://www.thechicagocouncil.org/UserFiles/File/Globalmidwest/Harnessing_the_Power_of_Biomass_Residuals.pdf).

[6] USDA Quick Stats.



These national data are misleading, however, because they include all the corn producing acreage in the country. Much of this corn (perhaps a third) is far from the areas of highest production in the nation's Corn Belt, the most likely location for stover-based biorefineries.

The following chart presents total and available stover for the highest corn producing states (NE, MN, IA, WI, IL, MI, IN, OH) for 2003-2012.[7] On average 50 million tons of stover are available during the period analyzed, just short of the national total of 53 million. This is because the Corn Belt contains the highest yielding acreages, both in terms of grain and stover.



[7] USDA Quick Stats.

Nonetheless, the considerable year to year variability in stover availability should be noted—a down year would have a significant effect on a stover-based industry. The average density of available stover in the Corn Belt is about 0.82 tons per acre; in 2012, this density was 0.09. On average, it takes the stover from 1.2 million acres to supply an 80 million GPY plant. In 2012, it would have taken the stover from 11 million acres—and it most likely would not have been cost effective to try and collect most of that stover.

Some recent studies suggest that stover removal should only occur on corn lands that produce in excess of 175 bushels per acre. This is a more protective standard, and reduces the amount of stover available significantly.

Counties in the Corn Belt that average more than 175 bushels per acre are few. Wisconsin, Indiana, Ohio and Michigan would be excluded from stover harvest by these criteria.

The average available stover for the remaining states is presented in the following table:

State	**Stover available**
MN	1,800,000
IA	3,500,000
IL	500,000
NE	2,600,000
Total	8,400,000

This would yield about 670 million gallons of ethanol, or about four percent of the 2022 RFS2 goal.

Bounding our analysis by these two figures suggests that the near term (through 2020) potential for production of ethanol from corn stover should be pegged between 670 million and 4 billion gallons. In other words, in the most optimistic scenario, corn stover might be used to produce about one-fourth of the cellulosic requirement of the RFS2 by 2020.

Logistic Concerns

The logistics of coordinating the harvest and transport of stover with that of the grain have not been fully addressed. For the foreseeable future, grain will continue to be the most valuable part of the corn plant, and the farmer will remain focused first on growing and harvesting corn grain.

Combined systems (where grain and stover are harvested simultaneously) are one possible means of bringing stover to market. Stover is much less dense than grain, and optimizing combines and associated wagons for both grain and stover will be needed. Machines that harvest both grain and stover will be larger and heavier than those dedicated to grain only. Such equipment will increase soil compaction and be more difficult to maneuver in the field. In addition, farmers will have to purchase new equipment suited to both grain and stover, the cost of which could be a significant obstacle.

Sequential systems (where grain is harvested first and stover second) are also possible. In such a model, stover harvest would wait until after grain was taken. The party harvesting the stover would not necessarily be the party who harvested the corn. Sequential systems would double the traffic on the field, increasing soil compaction and potentially worsening soil loss.

In northern parts of the Corn Belt, grain harvest often pushes up against freezing and snow; significant snowfall could prevent stover harvest altogether, or cause the quality of stover to degrade. Such late season loss of stover is another risk to the market.

Transporting stover to storage facilities will increase traffic on rural roads, many of which are already congested during harvest time. For example, a biorefinery designed to process 1 million tons of stover annually would need to receive, store and handle 1.6 million large round bales (1,200 lbs) of stover per year. If stover delivery were concentrated with 60 days of corn harvest, this would mean delivery of about 25,000 bales per day, or about 1,200 bales per hour, around the clock. Fully loaded semi-trailers could perhaps transport as many as 50 large bales of stover (60,000 lbs); this would mean that 24 such trucks would be unloaded per hour, 24 hours per day during the harvest window.

Working out the logistic details and understanding the full impacts of various harvest and transport models will be necessary before a fully-fledged stover market can develop.

Infrastructural Concerns

Producing 16 billion gallons of cellulosic ethanol per year from stover will require around two hundred 80-million-GPY biorefineries. Based on the cost estimates for smaller facilities currently under development, the projected cost of the 80-million-gallon refineries is between $500 million and $1 billion each.

If this construction were spread out smoothly between 2013 and 2022, 22 new biorefineies would need to be completed each year. Given the immaturity of the basic cellulosic technology, we can confidently say that this pathway is not possible (five such refineries would had to have broken ground in the first three months of 2013 to stay on this schedule; this has not happened).

It is not clear how long it will take for the cellulosic technology to fully mature, but it is clear that progress has been extremely slow since President George W. Bush committed to commercializing the technology by 2012.

But what about the other scenario detailed above, where 50 million tons of stover are used to produce 4 billion gallons of cellulosic ethanol per year? If 2013 were a breakthrough year from a technology standpoint, how long would it take for the industry to ramp up?

Based on other capital-intensive endeavors like petroleum refineries and electric generating units, we estimate that it would take six months for project design, six months for permitting and financing, and twelve months for construction of a large biorefinery. If the technology is fully commercialized by January 2014, it will be January 2016 before a full-scale biorefinery is operating. To take advantage of all the optimistically available stover (50 million tons per year), biorefineries with a capacity of 50-80 million GPY would be needed. This would mean a minimum of seven refinery starts per year beginning in 2014 to develop enough capacity to convert the stover to ethanol.

Conclusions

- Reasonable estimates for corn stover availability between the present and 2022 should be pegged at between 8 and 50 million tons per year; this would produce between 640 million and 4 billion gallons of cellulosic ethanol annually.
- Stover harvest and transport logistics are not well understood, and the problem of coordination with grain harvest is significant.
- Building sufficient biorefinery capacity to convert available stover to meet the RFS2 mandates is challenging, both from an engineering standpoint and from a financial standpoint.
- It is likely that the US will continue to fall far short of the cellulosic ethanol mandates contained in RFS2, and that EPA will continue to revisit this issue for the foreseeable future.

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