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ENVIRONMENTAL PROTECTION AGENCY **6560-50-P**

[EPA-HQ-OAR-2015-0293; FRL-9935-46-OAR]

Notice of Opportunity to Comment on an Analysis of the Greenhouse Gas Emissions Attributable to Production and Transport of Jatropha Curcas Oil for Use in Biofuel Production

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice.

SUMMARY: The Environmental Protection Agency (EPA) is inviting comment on its analysis of the greenhouse gas emissions attributable to the production and transport of *Jatropha curcas* ("jatropha") oil feedstock for use in making biofuels such as biodiesel, renewable diesel, jet fuel, naphtha and liquefied petroleum gas. This notice explains EPA's analysis of the production and transport components of the lifecycle greenhouse gas emissions of biofuel made from jatropha oil, and describes how EPA may apply this analysis in the future to determine whether such biofuels meet the necessary greenhouse gas reductions required for qualification as renewable fuel under the Renewable Fuel Standard program. Based on this analysis, we anticipate that biofuels produced from jatropha oil could qualify as biomass-based diesel or advanced biofuel if typical fuel production process technologies or process technologies with the same or lower GHG emissions are used.

DATES: Comments must be received on or before [**insert date 30 days after publication in the <u>Federal Register</u>**].

ADDRESSES: Submit your comments, identified by Docket ID No. EPA-HQ-OAR-2015-0293 to the *Federal eRulemaking Portal:* http://www.regulations.gov. Follow the online instructions for submitting comments. Once submitted, comments cannot be edited or withdrawn. The EPA may publish any comment received to its public docket. Do not submit electronically any information you consider to be Confidential Business Information (CBI) or other information whose disclosure is restricted by statute. Multimedia submissions (audio, video, etc.) must be accompanied by a written comment. The written comment is considered the official comment and should include discussion of all points you wish to make. The EPA will generally not consider comments or comment contents located outside of the primary submission (i.e., on the web, cloud, or other file sharing system). For additional submission methods, the full EPA public comment policy, information about CBI or multimedia submissions, and general guidance on making effective comments, please visit http://www2.epa.gov/dockets/commenting-epa-dockets.

FOR FURTHER INFORMATION CONTACT: Christopher Ramig, Office of Transportation and Air Quality, Transportation and Climate Division, Mail Code: 6401A, U.S. Environmental Protection Agency, 1200 Pennsylvania Avenue, NW, 20460; telephone number: (202) 564-1372; fax number: (202) 564-1177; email address: *ramig.christopher@epa.gov*.

SUPPLEMENTARY INFORMATION:

I. General Information

A. *Submitting CBI.* Do not submit this information to EPA through www.regulations.gov or e-mail. Clearly mark the part or all of the information that you claim to be CBI. For CBI information in a disk or CD ROM that you mail to EPA, mark the outside of the disk or CD ROM as CBI and then identify electronically within the disk or CD ROM the specific information that is claimed as CBI). In addition to one complete version of the comment that includes information claimed as CBI, a copy of the comment that does not contain the information claimed as CBI must be submitted for inclusion in the public docket. Information so marked will not be disclosed except in accordance with procedures set forth in 40 CFR part 2.

B. *Tips for Preparing Your Comments.* When submitting comments, remember to:

- Identify the rulemaking by docket number and other identifying information (subject heading, Federal Register date and page number).
- Follow directions - The agency may ask you to respond to specific questions or organize comments by referencing a Code of Federal Regulations (CFR) part or section number.
- Explain why you agree or disagree; suggest alternatives and substitute language for your requested changes.
- Describe any assumptions and provide any technical information and/or data that you used.
- If you estimate potential costs or burdens, explain how you arrived at your estimate in sufficient detail to allow for it to be reproduced.
- Provide specific examples to illustrate your concerns, and suggest alternatives.
- Explain your views as clearly as possible, avoiding the use of profanity or personal threats.
- Make sure to submit your comments by the comment period deadline identified.

This notice is organized as follows:

II. Introduction

As part of changes to the Renewable Fuel Standard (RFS) program regulations published on March 26, 2010[1] (the "March 2010 RFS rule"), EPA specified the types of renewable fuels eligible to participate in the RFS program through approved fuel pathways. Table 1 to 40 CFR 80.1426 of the RFS regulations lists three critical components of an approved fuel pathway: (1) fuel type; (2) feedstock; and (3) production process. Fuel produced pursuant to each specific combination of the three components, or fuel pathway, is designated in the Table as eligible to qualify as renewable fuel. EPA may also approve additional fuel pathways not currently listed in Table 1 to 40 CFR 80.1426 for participation in the RFS program, including in response to a petition filed pursuant to 40 CFR 80.1416 by a biofuel producer seeking EPA evaluation of a new fuel pathway.

EPA's lifecycle analyses are used to assess the overall greenhouse gas (GHG) impacts of a fuel throughout each stage of its production and use. The results of these analyses, considering uncertainty and the weight of available evidence, are used to determine whether a fuel meets the necessary greenhouse gas reductions required under the Clean Air Act (CAA) for it to be considered renewable fuel or one of the subsets of renewable fuel. Lifecycle analysis includes an assessment of emissions related to the full fuel lifecycle, including feedstock production,

[1] See 75 FR 14670.

feedstock transportation, fuel production, fuel transportation and distribution, and tailpipe emissions. Per the CAA definition of lifecycle GHG emissions, EPA's lifecycle analyses also include an assessment of significant indirect emissions such as emissions from land use changes, agricultural sector impacts, and production of co-products from biofuel production.

EPA received a petition submitted pursuant to 40 CFR 80.1416 from Global Clean Energy Holdings ("GCEH" or the "GCEH petition") and Emerald Biofuels, LLC, submitted under a claim of confidential business information (CBI), requesting that EPA evaluate the lifecycle GHG emissions for biofuels (biodiesel, renewable diesel, jet fuel and naphtha) produced from the oil extracted from *Jatropha curcas* (hereafter referred to as "jatropha" or "jatropha oil"). The petition also requested EPA provide a determination of the renewable fuel categories, if any, for which such biofuels may be eligible under the Renewable Fuel Standard (RFS) program. The Agency also received a separate petition from Plant Oil Powered Diesel Fuel Systems, Inc., submitted under a claim of CBI, requesting that EPA evaluate the lifecycle GHG emissions for the use of neat jatropha oil as a transportation fuel, and that EPA provide a determination of the renewable fuel categories, if any, for which such neat jatropha oil fuel may be eligible.[2]

EPA has conducted an evaluation of the GHG emissions associated with the production and transport of jatropha oil when it is used as a biofuel feedstock, and is seeking public comment on the methodology and results of this evaluation. In this document, we are describing EPA's evaluation of the GHG emissions associated with the feedstock production and feedstock

[2] There are no further references in this Notice to Plant Oil Powered Diesel Fuel Systems, Inc., as they did not agree to waive CBI claims to the data/information contained in their petition and supporting documentation submitted to EPA pursuant to 40 CFR 80.1416, or references thereto.

transport stages of the lifecycle analysis of jatropha oil when it is used to produce a biofuel, including the indirect agricultural and forestry sector impacts. We are seeking public comment on the methodology and results of this evaluation. For the reasons described in Section III below, we believe that it is reasonable to apply the GHG emissions estimates we established in the March 2010 rule for the production and transport of soybean oil to the production and transport of jatropha oil.

If appropriate, EPA will update its evaluation of the feedstock production and transport phases of the lifecycle analysis for jatropha oil based on comments received in response to this action. EPA will then use this feedstock production and transport information to evaluate facility-specific petitions, received pursuant to 40 CFR 80.1416, that propose to use jatropha oil as a feedstock for the production of biofuel. In evaluating such petitions, EPA will consider the GHG emissions associated with the production and transport of jatropha oil feedstock. In addition, EPA will determine – based on information in the petition and other relevant information, including the petitioner's energy and mass balance data – the GHG emissions associated with petitioners' biofuel production processes, as well as emissions associated with the transport and use of the finished biofuel. We will then combine our assessments into a full lifecycle GHG analysis and determine whether the fuel produced at an individual facility satisfies CAA renewable fuel GHG reduction requirements.

III. Analysis of Greenhouse Gas Emissions Associated with use of Jatropha Oil as a Biofuel Feedstock

EPA has evaluated the GHG emissions associated with the production and transport of jatropha oil for use as a biofuel feedstock, based on information provided in the GCEH petition and other data gathered by EPA. Section III-A includes an overview of our GHG analysis of jatropha oil production and transport. Section III-B describes jatropha oil and available information about the growing conditions suitable for commercial-scale production. Section III-C explains our analysis of the GHG emissions attributable to growing and harvesting jatropha seeds. Section III-D describes our analysis of the land use change and other agricultural sector emissions, including significant indirect emissions, attributable to producing jatropha oil for use as a biofuel feedstock. Section III-E explains our assessment of the GHG emissions associated with feedstock transport and processing, including oil extraction and pre-treatment. Section III-F discusses the potential invasiveness of jatropha. Section III-G summarizes GHG emissions from jatropha oil production and transport. Section III-H discusses how EPA intends to consider the GHG emissions associated with fuel production and distribution when evaluating facility-specific petitions from biofuel producers seeking to generate renewable identification numbers (RINs) for non-grandfathered volumes of biofuel produced from jatropha oil.

This Notice explains and seeks comment on each component of EPA's GHG assessment of jatropha oil production and transportation. We also discuss and seek comment on potential invasiveness concerns for jatropha as they relate to GHG emissions. In this Notice we compare our assessment of jatropha oil to our previous evaluation of soybean oil for the March 2010 RFS rule because jatropha oil and soybean oil can be used in the same types of production processes to produce biodiesel, renewable diesel, jet fuel, and other similar types of biofuels. In the March 2010 RFS rule, EPA determined that several renewable fuel pathways using soybean oil feedstock meet the required 50% lifecycle GHG reduction threshold under the RFS for biomass-based diesel and advanced biofuel.[3]

A. Summary of Greenhouse Gas Analysis

Based on the limited data available on where jatropha will be produced at commercial scale for use in making biofuels for the RFS program, we evaluated a number of scenarios with different assumptions about where jatropha will be grown and what type of land jatropha plantations will use. This section briefly discusses the two main scenarios that we evaluated and our overall findings based on these analyses.

As explained in more detail in Section III-B below, based on information in the GCEH petition and other data gathered by EPA through literature review and expert consultations, we believe that southern Mexico (specifically the states of Yucatan, Oaxaca and Chiapas) and northeastern Brazil[4] are the likely locations for commercial-scale production of jatropha for use in making biofuels for the RFS program. Given the limited amount of available data, these are the two countries where we found reliable evidence on jatropha production that could supply significant volumes of qualifying biofuel feedstock under the RFS program. In the first scenario that we evaluated, we assume that jatropha production will occur on grassland in southern Mexico and northeastern Brazil that is not currently being used for crop production or pasture use. As explained more below, we estimate that on average the GHG emissions attributable to

[3] These pathways included biodiesel produced from soybean oil through a transesterification production process, and renewable diesel, jet fuel and heating oil produced from soybean oil through a hydrotreating production process.
[4] Specifically the regions of Brazil that encompasses the following provinces: Alagoas, Bahia, Ceara, Maranhao, Paraiba, Pernambuco, Piaui, Rio Grande do Norte, Sergipe, Tocantins.

jatropha oil extracted from jatropha seeds grown on unused grasslands in southern Mexico are 951 kilograms of carbon dioxide-equivalent emissions (kgCO_2e) per tonne of jatropha oil that has been harvested, extracted, pre-treated to lower acidity and delivered to a biofuel producer ("delivered jatropha oil"), compared to 1,425 kgCO_2e per tonne of delivered soybean oil. If jatropha is grown on grassland in northeastern Brazil that would not otherwise have been used for crop production or grazing, we estimate that the GHG emissions would be 1,858 kgCO_2e per tonne of delivered jatropha oil. Land use change emissions are higher in northeastern Brazil than in Mexico because, on average, grasslands in northeastern Brazil sequester significantly more carbon than grasslands in southern Mexico.[5] Since we think it is likely that jatropha will be grown in both locations, we believe it is appropriate to evaluate a scenario in which we assume an equal amount of growth on grasslands in southern Mexico and northeastern Brazil. In this scenario, the GHG emissions are 1,404 kgCO_2e per tonne of delivered jatropha oil, which is lower than the emissions attributable to delivered soybean oil.

In a second scenario, we considered the possibility that jatropha will be grown on land that would have otherwise been used for agriculture (crop production or grazing/pasture). For this analysis we used the Food and Agricultural Policy and Research Institute international models as maintained by the Center for Agricultural and Rural Development at Iowa State University (the FAPRI-CARD model),[6] that has been used for a number of previous RFS rulemakings, including the March 2010 RFS rule. We conducted two analyses within this

[5] Based on our assessment of land use change emissions factors for previous RFS rules, on average grasslands in Mexico sequester approximately 15 tonnes CO_2e per hectare compared to 40 tonnes CO_2e per hectare in northeastern Brazil.

[6] For more information on the FAPRI-CARD model see the March 2010 RFS rule and associated Regulatory Impact Analysis: Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. EPA-420-R-10-006. http://www.epa.gov/oms/renewablefuels/420r10006.pdf

scenario: one where we assumed that jatropha will displace crops (predominantly corn) in Mexico, and one where jatropha is grown on cropland in Mexico and on agricultural land in Brazil (with the model choosing what land to displace in Brazil). The second scenario, where jatropha is grown on land otherwise used for agricultural production, evaluates the impacts associated with jatropha displacing crop and pasture land, including evaluating whether and where increased crop production or pasturage would occur in other regions to compensate for the jatropha displacement. In both of these analyses the GHG emissions attributable to the production of jatropha oil are much lower than the corresponding emissions for soybean oil. Specifically, for the Mexico cropland analysis we estimated GHG emissions of negative 721 kgCO_2e per tonne of delivered jatropha oil. As explained more below, the net GHG emissions in this analysis are negative primarily because jatropha sequesters more carbon than the cropland it displaces and the indirect emissions are relatively small because the displaced corn production is backfilled by higher yield producers (e.g., corn production in the United States). For the Mexico and Brazil analysis, the net GHG emissions are 128 kgCO_2e per tonne of delivered jatropha oil, which is also significantly less than the emissions per tonne of delivered soybean oil.

Based on the two scenarios described above, we believe it is reasonable, as a conservative approach, to apply the GHG emissions estimates we established in the March 2010 rule for the production and transport of soybean oil to jatropha oil when evaluating future facility-specific petitions from biofuel producers seeking to generate RINs for volumes of biofuel produced from jatropha oil.[7] The following sections and supporting documentation in the public docket

[7] The purpose of lifecycle assessment under the RFS program is not to precisely estimate lifecycle GHG emissions associated with particular biofuels, but instead to determine whether or not the fuels satisfy specified lifecycle GHG emissions thresholds to qualify as one or more of the four types of renewable fuel specified in the statute. If the record demonstrates that the GHG emissions associated with the use of jatropha oil are at least as low as those of

provides more details on the scenarios and analyses described above. We welcome public comments on all aspects of our assessment.

B. Feedstock Description and Growing Conditions

Jatropha is a deciduous, perennial shrub or tree species belonging to the Euphorbiaceae family that grows approximately 8 to 15 meters tall. Experts agree that jatropha is native to the American tropics; however there is disagreement in the literature regarding its origin and the borders of jatropha's native range.[8] However, it is naturalized throughout Latin America, including Mexico, Central America and the Caribbean, and to a lesser extent in Argentina, Bolivia, Brazil, Colombia, Ecuador, Paraguay, Peru and Venezuela.[9] Traditionally, it has been grown in tropical and sub-tropical regions in Africa, Asia and Latin America as a hedge and ornamental plant. Jatropha is adapted to arid and semi-arid conditions and high temperatures, and it has been found to be very frost intolerant. In its Latin American range, it is common in deciduous forests and open spaces including grassland-savannah and scrub forests. It prefers low altitudes, well drained soils and good aeration. It is adapted to marginal lands with low nutrient content, but commercial production has been unsuccessful in these conditions. Jatropha fruit, similar in appearance to a walnut, can be harvested at least once per year, though multiple harvests are possible as mature jatropha plants flower throughout the year. The fruit has a thick

soybean oil (which meets the most stringent, 50%, lifecycle GHG reduction threshold specified for non-cellulosic feedstocks) then EPA can conclude that where comparable biofuel production methods are used that jatropha oil-based biofuels will qualify in the same manner as soybean oil-based biofuels. In some cases, as here, this comparative approach simplifies EPA's assessment, and allows relevant conclusions to be drawn despite uncertainty that may be associated with an attempt to determine a more precise lifecycle GHG assessment. Similarly, where there are a range of possible outcomes and the fuel satisfies GHG reduction requirements for the optimum RFS renewable fuel qualification when "conservative" assumptions are used, then a more precise quantification of the matter is not required for purposes of a pathway determination.

[8] CABI Jatropha Curcas Data Sheet, http://www.cabi.org/isc/datasheet/28393

[9] Ibid.

outer covering called a husk. Each fruit contains one to three seeds, each with a durable outer shell and a softer oil-bearing inner kernel. The seeds are 25-50 percent oil by mass. When oil is extracted from the kernel the remaining material forms a seedcake (also known as press cake or meal cake) that contains curcin, a highly toxic protein. Although the oil and seedcake are toxic to humans and livestock, the oil has good properties for use as a biofuel feedstock to produce fuels such as biodiesel, renewable diesel and jet fuel, and the seedcake can be used as fertilizer or as fuel for process heat.

Jatropha does not have a long history as a planted crop. As a result, empirical data on crop yields, crop inputs, and other key agricultural characteristics are not readily available. In order to fill these knowledge gaps to the greatest extent possible, EPA conducted a literature review of agronomic and lifecycle GHG analysis studies of jatropha.[10] We sought input on a draft of the literature review from a wide array of stakeholders, including academics, environmental organizations, industry groups and the parties who submitted petitions involving the use of jatropha oil feedstock. The comments we received were considered in preparing the revised document available in the public docket associated with this Notice.

Several past efforts to cultivate jatropha for biofuel use attempted, without commercial success, to produce jatropha on marginal agricultural land with minimal inputs.[11] By contrast, the petitioners and others working to commercialize jatropha more recently have utilized higher quality agricultural land and have made much more extensive use of fertilizer, irrigation, and

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[10] See “GHG Assessments of Jatropha Oil Production: Literature Review and Synthesis” in Docket EPA-HQ-OAR-2015-0293.

[11] Kant, P. and S. Wu. 2011. “The Extraordinary Collapse of Jatropha as a Global Biofuel.” Environmental Science & Technology 45(17):7114-7115. doi: 10.1021/es201943v.

other agricultural inputs. Therefore, for purposes of this assessment, we assume that jatropha grown for use as a biofuel feedstock will be grown as a planted crop under normal agricultural conditions. In other words, we expect jatropha to be grown by farmers on arable land with the use of fertilizer, pesticides, irrigation where necessary, and other crop inputs. Our projection that jatropha grown for biofuel feedstock targeted to the U.S. market will be cultivated on agricultural-quality land also aligns with the definition of renewable biomass at 40 CFR 80.1401, which specifies that planted crops must be grown on existing agricultural land cleared or cultivated prior to December 19, 2007.

Based on conversations with researchers at the United States Department of Agriculture Agricultural Research Service (USDA-ARS) and other organizations, we determined that jatropha is unlikely to be commercially grown in the United States because of its high intolerance to frost.[12] USDA and several university research groups have attempted to grow jatropha in the United States, including projects in Arizona, California, and Florida. To date, no one has demonstrated that jatropha would be a viable commercial-scale crop in the United States due primarily to its extreme frost intolerance.[13] Even in the southernmost reaches of the country, occasional frosts have proven too severe for the plant to be viable. For these reasons, EPA's analysis does not consider jatropha production in the United States.

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[12] Telephone conversations with Terry Coffelt (USDA-ARS), Terry Isbell (USDA-ARS), Roy Scott (USDA-ARS), Dan Parfitt (University of California-Davis), Wagner Vendrame (University of Florida), Jaime Barton (Hawaii Agricultural Research Center), Bob Osgood (HARC), Richard Oguchi (University of Hawaii), Robert Bailis (Yale).
[13] Ibid.

Projecting where jatropha will be produced is difficult, as evidenced by previous government projects to support the expansion of jatropha production that did not materialize.[14] Given the poor track record of pronouncements about future jatropha development, we focused our analysis on regions where we could find evidence of current production at commercial scale. Through literature review and conversations with researchers and industry experts, we found evidence of significant commercial jatropha production in Mexico and Brazil. In contrast, although large areas of Asian jatropha production were planned and reported in global surveys, EPA was not able to verify the existence of successful commercial scale plantations in these regions. While there is potential for jatropha cultivation in India and Africa, it remains uncertain whether jatropha oil grown in those locations would be exported to the United States or whether it would qualify as renewable biomass as defined in the CAA and implementing RFS regulations.[15] The scenarios we evaluated looked only at jatropha production in Mexico and Brazil, because, as discussed in more detail below, these are the two countries where we found reliable evidence on jatropha production that could supply significant volumes of qualifying biofuel feedstock under the RFS program.

Mexico and Brazil offer hospitable environments for jatropha. Both countries are part of jatropha's naturalized range, and several efforts to commercialize jatropha have been reported there.[16] In the GEXSI jatropha market survey of Latin America, Mexico and Brazil were the

[14] See "GHG Assessments of Jatropha Oil Production: Literature Review and Synthesis" on Docket EPA-HQ-OAR-2015-0293.
[15] For example, recent trade data shows that in general the U.S. receives substantially more agricultural imports from Mexico and Brazil than from Africa and India. For example, in Fiscal Year 2014, the U.S. imported over 22.5 billion dollars of agricultural products from Mexico and Brazil, compared to approximately 5.7 billion dollars from Africa and India. Source: USDA Economic Research Service and Foreign Agricultural Service. 2015. Outlook for U.S. Agricultural Trade, AES-89, August 27, 2015.
[16] CABI Jatropha Curcas Data Sheet, http://www.cabi.org/isc/datasheet/28393

only countries classified as having "strong commercial activities."[17] The global survey completed by Leuphana in 2012 also identified Mexico and Brazil as the dominant jatropha producers in Latin America with area planted of 8,000 and 3,100 hectares respectively.[18] These survey results are supported by other studies in the literature and information gathered by EPA.[19] According to the GCEH petition, GCEH recently established a jatropha plantation in the Yucatan Peninsula encompassing several thousand hectares, with plans for expansion in the same region. Furthermore, the Mexican government has supported jatropha through the ProArbol program of the National Forestry Commission of Mexico (CONAFOR) that provides subsidies for the promotion of jatropha as a form of reforestation.[20] Bailis and Baka, for their study on using jatropha oil to produce jet fuel, focused on Brazil because its position as a major biofuel and commercial agricultural exporter makes it a potential site for large-scale jatropha production.[21] As another reason for focusing on Brazil as a growth region for jatropha, Bailis and Baka cited the major push by EMBRAPA, the federal agricultural research and support organization, to develop the crop. Furthermore, our literature review identified additional studies that reported commercial scale jatropha production in Mexico and Brazil.[22]

There have been several efforts to commercialize jatropha in other parts of the world, including Sub-Saharan Africa, India, East Asia, Southeast Asia, and Oceania. However, the

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[17] The Global Exchange for Social Investment (GEXSI). 2008. Global Market Study on Jatropha. Final report. Available at: http://www.jatropha-alliance.org/fileadmin/documents/GEXSI_Global-Jatropha-Study_FULL-REPORT.pdf.
[18] Wahl et al. 2012. Insights into Jatropha Projects Worldwide. Leuphana University.
[19] See "GHG Assessments of Jatropha Oil Production: Literature Review and Synthesis" on Docket EPA-HQ-OAR-2015-0293.
[20] Skutsch, M., E. de los Rios, S. Solis, E. Riegelhaupt, D. Hinojosa, S. Gerfert, Y. Gao, and O. Masera. 2011. "Jatropha in Mexico: Environmental and Social Impacts of an Incipient Biofuel Program." Ecology and Society 16(4):11. doi:10.5751/ES-04448-160411.
[21] Bailis, R.E. and J.E. Baka. 2010. "Greenhouse Gas Emissions and Land Use Change from Jatropha Curcas-Based Jet Fuel in Brazil." *Environmental Science & Technology* 44(22):8684-8691. doi:10.1021/es1019178.
[22] See "GHG Assessments of Jatropha Oil Production: Literature Review and Synthesis" on Docket EPA-HQ-OAR-2015-0293.

commercial scale viability of jatropha farms in all of these regions is currently uncertain. The global surveys conducted by GEXSI and Leuphana reported that the vast majority of jatropha being cultivated worldwide was being grown in Southeast Asia, including India, China and Indonesia. The most recent of these surveys collected data in 2011.[23] However, after reviewing these surveys carefully and discussing their results with experts in industry and the USDA, we determined that practically all of the reported jatropha plantations in Asia were aspirational and have not resulted in commercially significant volumes of jatropha oil. EPA has not been able to locate any information that confirms the presence of the large scale Asian projects reported in the GEXSI and Leuphana surveys, and there does not appear to be any official data confirming their existence.[24] These surveys relied on data that were self-reported and in many cases were based on goals rather than outcomes.[25] A 2012 report by the USDA Foreign Agricultural Service (FAS) confirms the very small scale of commercial jatropha oil production in India.[26] More recently, multiple companies working to commercialize jatropha in parts of Asia also confirmed that, while several large projects were planned in Southeast Asia, they have all since been scaled back to pilot projects or abandoned for funding and other reasons.[27] For these reasons, our analysis of the GHG emissions attributable to jatropha oil produced as biofuel feedstock for the RFS program does not project jatropha oil production from Asia.

[23] Wahl et al. 2012.
[24] Letter from Cosmo Biofuels Group, "Jatropha RFS2 Pathway Petition Insights Into Jatropha Projects Worldwide." February 7, 2014
[25] For example, a review of jatropha promotion in India is provided in Kumar, S., Chaube, A., Jain, S., K. 2012. "Critical review of jatropha biodiesel promotion policies in India. Energy Policy, 41: 775-781.
[26] USDA-FAS. 2012. India Biofuels Annual. Global Agricultural Information Network. GAIN Report Number: IN2081.
[27] Letter from BEI International, LLC, "Jatropha RFS2 Pathway Petition Insights Into Jatropha Projects Worldwide." January 9, 2014.

Africa is another region with significant potential for jatropha production. However, we decided not to model jatropha oil from Africa in our analysis. First, there is uncertainty about whether African jatropha oil production would qualify as renewable biomass, because it is not clear that the land where it would be grown could be considered existing agricultural land, as required in the CAA to qualify as renewable biomass.[28] Furthermore, according to one agricultural trade expert, it is viewed as unlikely for economic reasons that Africa would be a significant exporter of jatropha oil to the United States by the year 2022, in part because it would require the development of a new and potentially costly infrastructure to grow, process, and transport the feedstock or fuel to the United States.[29] For these reasons, our analysis of the GHG emissions attributable to jatropha oil produced as biofuel feedstock for the RFS program does not project jatropha oil production from Africa, and we seek comment on this approach.

Although we are specifically modelling jatropha growth and transport in Mexico and Brazil, and expect most jatropha oil used as renewable fuel feedstock for the RFS program to be grown in those countries, we intend to apply our analysis of the GHG emissions attributable to jatropha oil production and transport when evaluating facility-specific petitions that propose to use jatropha oil as biofuel feedstock, regardless of the country of origin where their jatropha oil feedstock is grown. In the future, some jatropha oil feedstock used to produce biofuels for the RFS may be sourced from countries other than Mexico and Brazil, but this would be unlikely to change our overall assessment of the aggregate GHG impacts from growing and transporting jatropha oil. Consistent with EPA's approach for previous RFS pathway analyses, we will periodically reevaluate whether our assessment of GHG impacts will need to be updated in the

[28] See the definition of renewable biomass at 40 CFR 80.1401.
[29] Conversation with Bruce Babcock, January 8, 2013.

future based on new information or a new methodology that has the potential to significantly change our assessment.

C. Cultivation and Harvesting

Our assessment includes the GHG emissions attributable to growing and harvesting jatropha seeds, including field preparation, planting, annual inputs and harvesting, and replanting. We also estimate the average yields, in terms of tonnes of dry jatropha seed per hectare, in both Mexico and Brazil. The GHG emissions associated with cultivation and harvesting are the same, per tonne of delivered jatropha oil, in both of the main scenarios that we evaluated, as the type of land converted is not expected to impact the emissions from these stages of jatropha oil production. The data for our evaluation of these stages of jatropha oil production came from the GCEH petition, as well as EPA's literature review and our previous lifecycle GHG assessments for the RFS program. The values and calculations in our analysis are discussed briefly here and in more detail in a technical memorandum to the docket.[30]

Seed and Oil Yields. For the purposes of this analysis, we project that in 2022, on average, one hectare of jatropha in southern Mexico will yield five tonnes of dry jatropha seeds per year, while one hectare in Brazil will yield four tonnes per hectare. For Mexico, five tonnes per hectare reflects a middle to upper bound estimate of recorded yields in the literature, and is also supported by information provided in the GCEH petition for current yields. We view five tonnes per hectare as a conservative estimate of yields in the year 2022 because intensive jatropha cultivation is relatively new, with significant room for potential advances through

[30] For more details see "Jatropha Supporting Data and Assumptions" in Docket EPA-HQ-OAR-2015-0293.

genetics, breeding and improved agronomic practices. There are fewer recorded observed yields in northeastern Brazil; however, based on evidence from our literature review of environmental and climate characteristics, we expect jatropha yield in this region will be somewhat lower than yields in southern Mexico.[31] Given the potential for scientific breakthroughs to produce yield improvements for jatropha, we also consider this a conservative projection for 2022 yields in Brazil.

Based on the information discussed in Section III-E below, we assume that after crushing, pre-treatment and transport, each tonne of dry jatropha seeds yields 0.26 tonnes of jatropha oil delivered to a biofuel production facility. (This figure is used to convert cultivation and harvesting GHG emissions from $kgCO_2e$ per hectare of jatropha production to $kgCO_2e$ per tonne of delivered oil.)

Preparation and Planting. When jatropha is first planted, chemical and energy inputs are required. For our analysis, we used average inputs of nitrogen, phosphate, potassium, herbicide, and diesel use from data in the GCEH petition, as shown in Table III-1.[32] In Brazil, lime is also added as a soil amendment during preparation and planting, [33] although it is not required in many parts of southern Mexico.[34] While there is relatively little data available on the inputs and energy requirements for the preparation and planting stages of jatropha, the values provided in

[31] See for example Trabucco et al. 2010.
[32] Table III-1 shows the average results for a scenario with equal amounts of jatropha output (by mass) in Mexico and Brazil.
[33] Bailis, R. E. and J. E. Baka. 2010. Greenhouse gas emissions and land use change from *Jatropha curcas*-based jet fuel in Brazil. Environmental Science and Technology, 44(22) 8684-8691.
[34] Lime is required in Brazil because the soils there are highly acidic, but it is not required in southern Mexico where the native soil pH is well-suited for jatropha.

the GCEH petition were within the range of other values that we found through literature review.[35]

We assumed that jatropha has a 20 year crop cycle, meaning that every 20 years the existing jatropha plants are removed and the crop is replanted.[36] Therefore, the GHG emissions associated with preparation and planting occur every 20 years. Annualized emissions from preparation and planting are shown in Table III-1. We estimate total GHG emissions from jatropha preparation and planting of 66.6 kilograms of carbon dioxide-equivalent emissions ($kgCO_2e$) per ton of jatropha oil that has been harvested, extracted, pre-treated to lower acidity and delivered to a biofuel producer ("delivered jatropha oil").

Table III-1—Annualized GHG Emissions from Preparation and Planting

($kgCO_2e$ per tonne of delivered jatropha oil)

	Inputs per Hectare	**GHG Emissions**
Nitrogen fertilizer	0.07 kg	0.01
Phosphorus fertilizer	0.02 kg	0.001
Potassium fertilizer	0.09 kg	0.003
Herbicide	1.2 gal	1.8
Lime	1.1 tonnes	21.3
Diesel	79.3 gal	43.5
Total Annualized Emissions		**66.6**

Annual Inputs and Harvesting. After the jatropha fields are prepared and planted, there are annual GHG emissions associated with applying crop inputs and harvesting the jatropha seeds. To estimate the average annual emissions from these activities we assumed an average twenty year replanting cycle, meaning that in any given year five percent of the jatropha fields

[35] We consider the crop input data used in our assessment to be conservative because they result in greater estimate GHG emissions per tonne of oil produced than most of the other data we reviewed.
[36] For more details see "Jatropha Supporting Data and Assumptions" in Docket EPA-HQ-OAR-2015-0293.

will be in the replanting stage, and therefore have zero emissions associated with annual crop inputs and harvesting. Table III-2 summarizes the emissions from these activities.

Annual Fertilizer and Pesticide Inputs. The GCEH petition states that some of the husks from the jatropha fruits are used for fertilizer. In addition, the seedcake produced after pressing oil from the seeds can be used as an organic fertilizer. We assumed that fertilizer inputs would have to at least make up for nutrients lost from harvesting the jatropha fruits.[37] Using literature values for nitrogen, phosphorous and potassium in jatropha fruits, husks, and seedcake,[38] and our projected seed yield, we determined that the jatropha husks and seedcake have nearly enough nutrients to replace the nutrients lost from harvesting the seed fruit. We assume that growers will apply 9.3 kilograms per hectare of additional inorganic fertilizer to replace the lost nutrients from harvesting, which is within the range of literature values and similar to the data provided by GCEH. We also assumed use of small amounts of pesticide, herbicide and insecticide based on information from the peer reviewed literature.[39] The GHG emissions associated with fertilizer and pesticide use were estimated using the methodology developed for the March 2010 RFS rule.[40] Table III-2 shows the GHG emissions from annual fertilizer and pesticide use, not including nitrous oxide emissions that occur after they are applied to the field (which is discussed separately, below).

[37] Bailis and Baka 2010 used the same approach to estimate fertilizer requirements.
[38] Bailis, R. E. and J. E. Baka. 2010. Greenhouse gas emissions and land use change from *Jatropha curcas*-based jet fuel in Brazil. Environmental Science and Technology, 44(22) 8684-8691.
[39] Bailis, R. E. and J. E. Baka. 2010. Greenhouse gas emissions and land use change from *Jatropha curcas*-based jet fuel in Brazil. Environmental Science and Technology, 44(22) 8684-8691.
[40] See Section 2.4.3.1 of the Regulatory Impact Analysis for the March 2010 RFS rule.

Annual Energy Use. In addition to chemical inputs, energy will be used annually for irrigation, and to power equipment used for field maintenance and harvesting. For the annual diesel, gasoline and electricity inputs, we used values provided in the GCEH petition, which are within the range of values EPA found through literature review.[41]

Table III-2 GHG Emissions from Annual Inputs and Harvesting
($kgCO_2e$ per tonne of delivered jatropha oil)

	Inputs (per ha)	**GHG Emissions**
Nitrogen fertilizer	9.3 kg	27.8
Phosphorus fertilizer	9.3 kg	9.5
Potassium fertilizer	9.3 kg	6.3
Herbicide	0.5 kg	11.5
Fungicide-Bacteriocide	0.02 L	0.01
Pesticide	0.06 L	0.7
Diesel	15.6 gal	162.5
Gasoline	1.6 gal	14.8
Electricity	184 kWh	40.9
Total		**274.0**

Annual Nitrous-Oxide Emissions. Nitrous oxide (N_2O) is emitted from nitrogen fertilizer and from parts of the jatropha plant that are left on the field to decay or applied as fertilizer ("jatropha residues"). The jatropha residues can be divided into three categories: 1) husks that are applied to the field as fertilizer, 2) seedcake that is applied to the field as fertilizer, and 3) above and below ground biomass from the jatropha plant (e.g., the trunk, branches, leaves, and roots). The above and below ground biomass from the jatropha plant becomes a plant residue every 20 years, when the old plants are removed and new plants are planted. For each of these categories of jatropha residues, we used equations and factors from the United Nations Intergovernmental Panel on Climate Change (IPCC) to calculate direct and indirect N_2O

[41] Supporting Documentation for Jatropha Oil Production and Transport GHG Emissions, Air and Radiation Docket EPA-HQ-OAR-2015-0293.

emissions, and we annualized them by dividing by 20.[42] Estimated annual emissions from fertilizer and plant residues are shown in Table III-3.

Table III-3—N_2O Emissions from Fertilizer and Jatropha Residues

($kgCO_2e$ per tonne of delivered jatropha oil)

	GHG Emissions
Fertilizer, direct	37.4
Fertilizer, indirect	12.2
Husks, direct	51.5
Husks, indirect	11.6
Seedcake, direct	281.7
Seedcake, indirect	63.4
Above and below ground biomass, direct	204.7
Above and below ground biomass, indirect	46.0
Total	**709.4**

Table III-4 provides a summary of the average GHG emissions attributable to growing and harvesting jatropha in southern Mexico and northeastern Brazil. Each of the emissions categories listed in the table are explained above in this section.

Table III-4 GHG Emissions Attributable to Growing and Harvesting Jatropha

($kgCO_2e$ per tonne of delivered jatropha oil)

Emissions Category	**GHG Emissions**
Preparation and Planting	67
Annual Inputs and Harvesting	274
Nitrous Oxide Emissions	709
Total	**1,050**

[42] Direct emissions are emitted from the jatropha plantation, whereas indirect emissions occur for material that has moved to another location (e.g., through leaching or runoff) before it produces N_2O or a pre-cursor of N_2O. For crop residues, such as above and below ground biomass, direct emissions occur when the plant material decays.

D. Land Use Change and Agricultural Sector Emissions

As explained in Section III-B, above, we believe that southern Mexico and northeastern Brazil are the most likely locations for commercial-scale production of jatropha for use in making biofuels for the RFS program. According to the GCEH petition, there are large areas of grasslands in southern Mexico that are suitable areas for jatropha production. These areas were used for crop production or pasture, but they are now fallow or used for very low intensity grazing. For example, Skutsch et al. evaluated jatropha land use change impacts in Yucatan, Mexico and found two plantations that had been planted on estates that had previously been used for low-intensity grazing.[43] There are also grasslands in northeastern Brazil that are suitable for jatropha production, although much of this land may currently be in use as pasture. For example, Bailis and Baka surveyed jatropha producers in northeastern Brazil and found that the producers they approached had primarily planted their jatropha on pasture land.[44]

Based on this information, the first scenario we evaluated for land use change emissions considers jatropha production on grasslands that would otherwise not be used for crops or pasture. In a second scenario, we used economic modeling to look at the potential land use change and agricultural sector emissions (including indirect emissions) of growing jatropha on land that would otherwise be used for crops or pasture.

Jatropha on Currently Unused Grassland Scenario. Analyzing the land use change emissions associated with growing jatropha on grassland that is not currently being used for

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[43] Skutsch, M., E. de los Rios, S. Solis, E. Riegelhaupt, D. Hinojosa, S. Gerfert, Y. Gao, and O. Masera. 2011. "Jatropha in Mexico: Environmental and Social Impacts of an Incipient Biofuel Program." Ecology and Society 16(4):11. doi:10.5751/ES-04448-160411.

[44] Bailis, R.E. and J.E. Baka. 2010. "Greenhouse Gas Emissions and Land Use Change from Jatropha Curcas-Based Jet Fuel in Brazil." *Environmental Science & Technology* 44(22):8684-8691. doi:10.1021/es1019178.

agricultural purposes requires estimates of the carbon sequestered by the jatropha plantations, as compared to the grasslands they would replace. We estimated the average amount of biomass carbon sequestered by jatropha plantations in southern Mexico and northeastern Brazil, projected out to 2022. Jatropha biomass carbon stocks were estimated using available scientific information from the literature. Reinhardt et al. measured basic data about jatropha plants, such as root to shoot ratios and biomass carbon content. Bailis and Baka used the data from Reinhardt et al. to estimate biomass carbon stocks for different jatropha yield scenarios. Using our projected jatropha yields of 5 and 4 tonnes per hectare per year for Mexico and Brazil respectively (the basis for these projections is discussed above), we used the Bailis and Baka approach to estimate average biomass carbon stocks of 8.9 and 8.1 tonnes per hectare for ten year old jatropha plantations in Mexico and Brazil, respectively. Per the methodology developed for the March 2010 RFS rule, we translated these estimates into average biomass carbon stocks over 30 years. Assuming linear growth rates, a 20 year replanting cycle and pruning of any growth after 10 years to ensure fruit accessibility, we estimated average jatropha plantation biomass carbon stocks over 30 years to be 6.9 and 6.3 tonnes per hectare for Mexico and Brazil respectively.[45] These values are within the range of estimates in the literature for jatropha plantations in these regions.[46]

For comparison, based on our analysis for the March 2010 RFS rule we estimate that grasslands in Mexico and Brazil contain approximately 4.1 and 10.9 tonnes of carbon per hectare, respectively. For our first scenario, we looked at the land use change and agricultural

[45] For details on this calculation see "Jatropha Oil Production and Transport GHG Calculations" spreadsheet on Docket EPA-HQ-OAR-2015-0293.
[46] For a comparison with other values in the literature see Supporting Documentation for Jatropha Oil Production and Transport GHG Emissions, Air and Radiation Docket EPA-HQ-OAR-2015-0293.

sector emissions associated with growing jatropha on grassland in Mexico and Brazil that would not otherwise be used for crop production or pasture. Comparing the carbon stocks of jatropha and the grassland it replaces, we estimate that growing jatropha on grassland in Mexico results in a net carbon sequestration, or negative emissions, because the jatropha plantation sequesters more carbon on average over thirty years. Conversely, planting jatropha on grassland in Brazil results in a net carbon emission. Specifically, for jatropha grown on otherwise unused grasslands in Mexico and Brazil we estimate land use change emissions of negative 268 and positive 550 $kgCO_2e$ per tonne of delivered jatropha oil, respectively. Looking at a scenario in which we assume an equal amount of growth of jatropha from unused grasslands in Mexico and Brazil results in land use change emissions of 141 $kgCO_2e$ per tonne of delivered jatropha oil. (For comparison, for the March 2010 RFS rule we estimated land use change emissions of 1,158 $kgCO_2e$ per tonne of soybean oil used for biofuel.) In this scenario there are no indirect agricultural sector emissions, such as from indirect impacts on crop or livestock production, because jatropha is not an agricultural commodity, and the displaced land would not otherwise have been used for commodity production.

Jatropha on Agricultural Land Scenario. In the second scenario we evaluated, we assumed jatropha would be grown on land that would otherwise be used to grow crops or for pasture. In this case jatropha production would impact market prices for the crops and livestock it displaces, leading to other indirect effects. For example, one of the likely indirect impacts would be to increase crop and livestock production in other locations to make up for the production displaced by jatropha. As we have done for the other RFS analyses, we estimated the size of these impacts with an agricultural sector model.

For our agricultural sector modeling of jatropha oil, we used a similar approach to the one we used for sugarcane in the March 2010 RFS rule, in which agricultural sector modeling was conducted using only the FAPRI-CARD model, and not the Forestry and Agricultural Sector Optimization Model (FASOM). For other feedstocks (e.g., corn, soybeans, grain sorghum), we used FASOM to model domestic forestry and agricultural impacts in addition to using the FAPRI-CARD model for international impacts. Similar to sugarcane, for jatropha we only used the FAPRI-CARD model because we do not expect jatropha to be grown in the United States as a biofuel feedstock for the RFS program.

To date, jatropha has not achieved a significant presence in global agricultural markets. For example, EPA is not aware that it is traded on any agricultural exchange, and there does not appear to be any publicly available data on jatropha prices or trade flows. These limitations create significant difficulties when attempting to model jatropha in an agro-economic framework, such as the FAPRI-CARD model. The creation of robust assumptions for production costs at various levels of production (i.e., production cost curves), as well as estimates for supply and demand at various prices (i.e., supply curves and demand curves), depends upon these types of historical data. We considered building production cost curves for jatropha oil based on land, crop yield, and crop input data. However, for jatropha, production cost data are limited to a very small number of companies and regions, making it difficult to estimate or project how much jatropha oil could be produced at various production cost levels. We also have limited information to determine the price that jatropha might command on the open market, or the extent to which it might be competitive with other planted crops for acreage. Without this information, it is not possible to form supply and demand curves for jatropha in the FAPRI-CARD model, which the model typically uses for other crops that we have evaluated to project where and in what quantities jatropha will be grown. Because of these limitations, EPA applied a slightly modified methodology in this analysis.

For other crops that EPA has evaluated for the RFS program, we have used the FAPRI-CARD model to project international agricultural sector impacts by running different biofuel volume scenarios and allowing the model to decide where to grow the additional crops needed to produce the biofuel volumes. Because of the data limitations regarding jatropha, the FAPRI-CARD model is not able to decide where to grow jatropha or what other types of land uses to displace for its production. Therefore, to model the agricultural sector impacts of expanding jatropha production, we exogenously specified how much and what types of land it would displace in Mexico and Brazil. The FAPRI-CARD model then estimated how the crops and pasture displaced by jatropha would be made up elsewhere via crop switching, land conversion and other market-mediated effects.

First, similar to our modeling for other feedstocks, we used available information to project the amount of jatropha oil produced as biofuel feedstock for the RFS program in the year 2022. We developed two analyses for the production of 130 million gallons of biodiesel in 2022, one where all of the jatropha oil is produced in Mexico (the "Mexico only case") and one where the jatropha oil production is split evenly between Mexico and Brazil (the "Mexico and Brazil case"). Although there is limited historical data available to use as the basis for formulating jatropha oil volume scenarios for modeling, we believe that a total production level of 130 million gallons of biodiesel in 2022 is sufficiently large to produce robust estimates of agricultural and GHG impacts in the FAPRI-CARD model, while still being feasible. As described elsewhere in this notice, we conservatively project that in 2022 Mexico and Brazil will have delivered jatropha oil yields of 1.3 and 1.0 tonnes per hectare per year, respectively.[47] Based on these oil yields, in the Mexico only case the production of enough jatropha oil feedstock to produce 130 million gallons of biodiesel would require approximately 350 thousand hectares of jatropha production in Mexico. In the Mexico and Brazil case, we modeled approximately 172 thousand hectares of jatropha in Mexico and 216 thousand hectares in Brazil.[48] The results of our modeling are based on a comparison of this jatropha production case to a control case that included no jatropha oil production.

To model the agricultural sector impacts of jatropha production in Mexico, we specified in the FAPRI-CARD model the area and types of crop land that jatropha would displace. Based on the information provided in the GCEH petition and collected through EPA's literature review, jatropha production in southern Mexico will most likely occur in the states of Yucatan, Chiapas and Oaxaca because they offer the most suitable climate conditions and available land. Over 80 percent of the agricultural land in this area is used for corn production, with smaller areas devoted to specialty crops such as fruits, vegetables, herbs and spices.[49] We do not expect jatropha to displace the higher value specialty crops, so we focused our analysis on the land used for commodity crops: corn, grain sorghum, soybeans and wheat. We then specified in the

[47] Based on projected average 2022 dry seed yields in Mexico and Brazil of five and four tonnes per hectare, respectively. We also assume that dry seeds have 35% oil content, 75% oil extraction efficiency and a 1.4 percent loss from oil pre-treatment.
[48] Given the yields for Mexico and Brazil described above, these cultivation areas correspond with 65 million gallons of jatropha oil biodiesel each from Mexican and Brazilian jatropha oil production, for a total of 130 million gallons. The specific underlying assumptions and calculations that produced these figures are available in the docket for this notice at EPA-HQ-OAR-2015-0293.
[49] Mexico Information Service for Agribusiness and Fisheries (SIAP), http://www.siap.gob.mx/

FAPRI-CARD model that jatropha will displace these staple crops based on their current share of land used for commodity crops: 96 percent corn, two percent grain sorghum, and one percent each of soybeans and wheat.

For Brazil we used a slightly different approach to take advantage of the fact that the FAPRI-CARD model for Brazil is significantly more detailed than the Mexico module. As explained above, based on EPA's literature review we determined that jatropha production in Brazil would predominantly occur in the northeastern part of the country, which correlates with the Northeast Coast and North-Northeast Cerrados regions in the FAPRI-CARD Brazil module. Unlike the Mexico part of the FAPRI-CARD model, the Brazil module includes crop and pasture land, and allows for switching between the two. Instead of specifying how much of each type of crop and pasture to displace with jatropha, we specified the area needed for jatropha production and allowed the FAPRI-CARD model to project the land used for jatropha production.

Table III-5 summarizes the land use changes projected in our modeling. We evaluated two cases: one involving jatropha production only in Mexico, and the other involving production in both Brazil and Mexico. In both cases, the land use impacts in Mexico are the replacement of other crops (primarily corn) with jatropha. In the Brazil and Mexico case, jatropha is planted on roughly three-quarters pasture and one-quarter crop land in Brazil. In both cases, the rest of the world (outside of Mexico and Brazil) increases its crop area. However, globally the total area devoted to non-jatropha crops and pasture decreases. Overall, the rest of the world expands their agricultural land (the sum of crop and pasture land including jatropha), meaning that other types of land, including unmanaged grassland and forest, are converted for agricultural uses.

Table III-5—Projected Land Use Changes by Case in 2022 (thousand hectares)[50]

	Crop Land			
	Jatropha	Other Crops	All Crops	Pasture
Mexico Only Case				
Mexico	345	(345)	0	0
Brazil	0	9	9	(5)
Rest of World	0	114	114	(63)
Total	345	(222)	123	(68)
Brazil and Mexico Case				
Mexico	172	(172)	0	0
Brazil	216	(62)	154	(154)
Rest of World	0	81	81	(49)
Total	388	(153)	235	(203)

Table III-6 summarizes the projected changes in the production of corn, soybeans and sugarcane, the crops with the largest changes in the cases we simulated. In both cases, there is a reduction in the total area of corn but an increase in the amount of corn produced. This is the result of corn production shifting to regions with higher yields, particularly the United States. In both cases, there is a reduction in the area and production of soybeans and sugarcane. All of these changes are less than 0.1% of projected crop production in 2022.

Table III-6—Projected Crop Production Changes by Case in 2022 (thousand metric tonnes)

	Corn	Soybeans	Sugarcane
Mexico Only Case			
Mexico	(1,151)	(9)	0
Brazil	292	103	(51)
United States	738	(97)	5
China	115	(1)	(7)

[50] For the tables in this Notice, the numbers in parentheses are negative and the totals may not sum due to rounding.

Rest of World	185	(8)	(4)
Total	178	(12)	(58)
Mexico and Brazil Case			
Mexico	(578)	(4)	0
Brazil	110	22	(300)
United States	375	(37)	2
China	62	1	(2)
Rest of World	101	1	54
Total	70	(18)	(246)

Table III-7 summarizes the projected impacts on global meat production. In both of the cases, meat production declines. These changes are on the order of approximately 0.01%, or less, of projected global livestock production in 2022.

Table III-7—Changes in Global Meat Production by Case in 2022 (thousand metric tonnes)

	Mexico Only Case	Brazil and Mexico Case
Beef	(0.4)	(4.1)
Pork	(9.4)	(5.7)
Poultry	(10.0)	(5.8)

Overall, the projected agricultural sector impacts in 2022 of growing jatropha on agricultural land in Mexico and Brazil in the two cases we evaluated can be summarized as a reduction in crop and pasture land in Mexico and Brazil which triggers an increase in crop area in other countries. Just over half of the increase in crop area in other countries comes at the expense of pasture land, with the rest coming from other types of land, including unmanaged grassland and forest. Globally, corn production increases, while soybean, sugarcane and meat production declines. Detailed modeling results and further explanation are provided in the docket for this notice,[51] and we welcome comments on all aspects of our analysis.

To estimate the GHG emissions associated with the land use changes summarized in Table III-5, EPA used the same methodology as developed for the March 2010 RFS rule. Per this methodology, the crop and pasture area changes in 2022 derived from the FAPRI-CARD model were evaluated with Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data to project what types of land (e.g., grassland, savanna, forest) would be converted to agricultural land (crops and pasture) in regions where the FAPRI-CARD model projected agricultural expansion. For these projections we used the satellite data to determine what types of land have been converted to crops and pasture in each region, and then applied those land use change patterns to the agricultural changes projected by the FAPRI-CARD modeling. Land use change GHG emissions were then estimated over 30 years using emission factors derived from various data sources accounting for average carbon stocks on eight types of land in 755 distinct regions.[52]

The land use change GHG emissions are summarized in Table III-8, including results for both the Mexico only and Mexico and Brazil cases. The results are broken out regionally by Mexico, Brazil, and Rest of World, because as discussed above, the great majority of land use change impacts came from Mexico and Brazil. Table III-8 also includes the total emissions for the low and high ends of the 95% confidence range for land use change GHG emissions, based

[51] Supporting Documentation for Jatropha Oil Production and Transport GHG Emissions, Air and Radiation Docket EPA-HQ-OAR-2015-0293.
[52] See Section 2.4 of the Regulatory Impact Analysis for the March 2010 RFS rule, http://www.epa.gov/otaq/renewablefuels/420r10006.pdf

on the land use change uncertainty analysis methodology developed for the March 2010 RFS rule, which considers the uncertainty in the satellite data and land use change emissions factors used in our assessment.

Table III-8. Land Use Change GHG Emissions by Case in 2022
(kgCO_2e per tonne delivered jatropha oil)

	Mexico Only Case	**Brazil and Mexico Case**
Mexico	(2,795)	(1,397)
Brazil	843	636
Rest of World	569	356
Total (Mean)	(1,383)	(406)
Total (Low)	(3,725)	(1,827)
Total (High)	612	809

In both cases, the mean values suggest negative land use change emissions (net sequestration) associated with growing jatropha on agricultural land. This is due primarily to the net sequestration that we project from replacing corn fields with jatropha plantations in Mexico. Per our analysis for the March 2010 RFS rule, corn in Mexico has average biomass carbon stocks of five tonnes per hectare.[53] In our assessment average jatropha plantation biomass carbon stocks are 6.9 tonnes per hectare, so every hectare of corn replaced by jatropha increases biomass carbon by 1.9 tonnes (including both above- and below-ground biomass). Additionally, converting corn to jatropha results in additional soil carbon sequestration. Due to the reduced tillage and increased biomass returned to the soil for jatropha (tree litter and prunings) compared to corn, we estimate that after 20 years jatropha would add approximately 27.7 tonnes of soil

[53] See Section 2.4 of the Regulatory Impact Analysis for the March 2010 RFS rule, http://www.epa.gov/otaq/renewablefuels/420r10006.pdf

carbon per hectare compared to corn production in Mexico.[54] Therefore, annualized over thirty years we estimate that replacing corn with jatropha in Mexico would result in additional soil sequestration of approximately 1.0 tonnes of carbon per hectare.

In both cases, we project positive land use change emissions in Brazil and other countries. We project land use change emissions in Brazil for a number of reasons. In the Mexico only case, Brazil expands its crop production to backfill for some of the lost production in Mexico. Some of this crop expansion occurs on pasture, which results in net land use change emissions from both biomass and soil carbon, and some of the crop expansion occurs on other types of land, including forests. In particular, the FAPRI-CARD model projects crop and pasture expansion in the Amazon, an area with particularly high carbon stocks, resulting in large emissions per hectare of conversion. In the Brazil and Mexico case, the expansion of jatropha onto corn or soybean land results in a net sequestration, but this net sequestration is smaller than the emissions associated with replacing sugarcane and pasture with jatropha.

In both cases, we also project land use change emissions from the rest of the world (all regions other than Mexico and Brazil). In our modeling the main impact in other countries is increased crop production to respond to higher prices and to backfill for some of the lost production from Mexico and Brazil. The additional cropland replaces some pasture and some other types of land, including unmanaged grasslands and forests, which results in net land use change emissions.

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[54] Based on the methodology developed for the March 2010 RFS rule, the soil carbon stocks reach equilibrium after 20 years.

For this second scenario, our analysis also considers indirect emissions associated with changes in fertilizer, pesticide and energy use for crop production, and methane and nitrous oxide emissions associated with changes in crop production. The sources of indirect livestock emissions include emissions from energy use for livestock production, and methane and nitrous oxide emissions associated with raising cattle, dairy cows, swine and poultry. The emissions for indirect crop production were estimated based on international crop input data and emission factors developed and peer reviewed for the March 2010 RFS rule. The livestock emissions factors are from the IPCC.

In the first main scenario we evaluated, where jatropha production occurs on grassland that is not otherwise used for crop production or grazing, there are no indirect emissions associated with changes in fertilizer, pesticide and energy use for crop production, and methane and nitrous oxide emissions associated with changes in crop production. In the second scenario, where jatropha is grown on agricultural land, there are indirect emissions associated with how the agricultural sector responds to the displacement of crop and grazing land for jatropha. Table III-9 summarizes the indirect crop production and livestock emissions impacts for both of the cases we evaluated for scenario two. Indirect agricultural emissions are negative in both cases, primarily because of emission reductions from decreased corn production in Mexico. Indirect livestock emissions are negative, because as shown in Table III-7, we project reductions in meat production in the cases evaluated.

Table III-9 – Indirect Crop Production and Livestock Emissions by Case in 2022 (kgCO_2e per tonne delivered jatropha oil)

	Mexico Only Case	Mexico and Brazil Case
Indirect Crop Production	(431)	(338)

Indirect Livestock	(125)	(392)

Table III-10 summarizes the land use change, and agricultural sector emissions in the two main scenarios that we evaluated. Note that this table does not include the emissions associated with cultivation and harvesting discussed above in Section III-C.

Table III-10 – Land Use Change and Indirect Agricultural Sector Emissions by Scenario in 2022
(kgCO_2e per tonne delivered jatropha oil)

Scenario	Jatropha Produced on Unused Grassland in Mexico in Brazil	Jatropha Produced on Agricultural Land	
Case		Mexico Only	Mexico and Brazil
Land Use Change	141	(1,383)	(406)
Indirect Crop Production	--	(431)	(338)
Indirect Livestock	--	(125)	(392)
Total	**141**	**(1,940)**	**(1,136)**

E. Feedstock Transport and Processing

Producing fuels from jatropha requires oil to be first extracted from its seeds, and then refined into a finished fuel product. Oil can either be expelled from the seeds by mechanical treatment or extracted using chemical solvents. There are two commonly used types of mechanical expellers, the screw press and the ram press. The screw press is typically used, and is somewhat more efficient at expelling oil (75-80% yield) than the ram press (60-65% yield). Up to three passes is common to achieve these yields. Certain pretreatments of jatropha seeds, such as cooking, can increase the expelled oil yield to 89% after a single pass using a screw press and

91% after a second pass. Chemical extraction can achieve greater oil yields than mechanical expulsion. (The most commonly used chemical extraction method, the n-hexane method, can achieve yields of 99%). However, chemical extraction is capital intensive and only economical at very large scales of production. According to Bailis and Baka, all jatropha oil produced in Brazil is extracted by screw press at one facility. Based on our review of available literature, EPA's evaluation considered oil recovery from jatropha seeds to occur via screw press mechanical expulsion assuming oil yield of 75% and seed oil content of 35%.[55] Based on reported electricity and fuel demands for jatropha oil extraction, we estimate that oil extraction results in emissions of 175 kgCO_2e per ton of delivered jatropha oil.[56]

Our evaluation also considers emissions associated with pretreating the jatropha oil.[57] Based on data provided in the GCEH petition, we evaluated the emissions from jatropha oil pretreatment with chemicals (typically sodium hydroxide) to lower its acid content, and electricity used to heat the reaction.[58] The outputs from the pre-treatment process are pre-treated jatropha oil, soapstock and filter cake. The pre-treated jatropha oil is ready for transport and use as a biodiesel feedstock. The soapstock and filter cake are low value byproducts, and as a conservative approach we model them as resulting in no GHG emissions impacts, i.e., we do not give a displacement credit for these byproducts. We estimate the GHG emissions from pre-treatment are approximately 4.7 kgCO_2e per ton of delivered jatropha oil. Pretreatment may occur at the oil extraction facility or the biofuel production facility, so it may be appropriate for

[55] See "GHG Assessments of Jatropha Oil Production: Literature Review and Synthesis" on Docket EPA-HQ-OAR-2015-0293.
[56] For details on this calculation see the "Jatropha Lifecycle GHG Calculations" spreadsheet on Docket EPA-HQ-OAR-2015-0293.
[57] Other vegetable oils that EPA has approved as feedstocks, including soybean oil, commonly undergo similar pre-treatment before they are converted to biofuels. The oil recovered after pretreatment is still chemically jatropha oil.
[58] The pre-treatment data provided in the GCEH petition is within the range of values EPA found in the literature.

EPA to revise the pre-treatment emissions on a case-by-case basis when evaluating petitions from specific biofuel production facilities.

For our GHG analysis, we assumed that jatropha is produced, and the jatropha oil is extracted and pre-treated in Mexico and Brazil, and that the pre-treated oil is then transported to the United States for use as biofuel feedstock. First, we calculate the emissions associated with transporting the jatropha seed 20 miles by truck to a facility where the crude jatropha is extracted via screw press and then pre-treated. The truck is loaded with kernel shells and seedcake and returns 20 miles to the plantation. The pre-treated jatropha oil is transported 75 miles by truck to a port and then shipped 500 miles by barge to a port in the U.S. Gulf of Mexico. For this scenario we estimate the seed transport emissions to be 24 kgCO_2e/mmBtu and the oil transport emissions to be 10 kgCO_2e/mmBtu. For our analysis, the distances and modes for seed and oil transport are based on data provided in the GCEH petition for jatropha production in Yucatan, Mexico. We believe these values are also reasonable to apply for jatropha production in other regions, including Brazil. This jatropha oil transport scenario was developed based on the best currently-available information, but may need to be adjusted when EPA evaluates individual petitions if the petitioner's jatropha oil feedstocks are delivered via a significantly different route than the one EPA modeled.

F. Potential Invasiveness

Jatropha is not currently widespread in the United States, and is not listed on the federal noxious weed list.[59] A recent weed risk assessment by USDA found that jatropha has a moderate risk of invasiveness in the United States.[60] Its seeds are toxic to animals and humans, and it is considered a weed in anthropogenic production and natural systems. Jatropha is a perennial plant, meaning that if a grove is abandoned, seeds would still be produced. In addition, jatropha can regrow from its roots. For these reasons, and in consultation with USDA, the use of jatropha as a biofuel feedstock raises concerns about its threat of invasiveness and whether its production could require remediation activities that would be associated with additional GHG emissions. Therefore, similar to EPA's actions with respect to other biofuel feedstocks found to present invasiveness risks, such as *Arundo donax* and *Pennisetum purpureum*, EPA anticipates that any petition approvals for renewable fuel pathways involving the use of jatropha oil as feedstock will include requirements related to mitigating risks associated with invasiveness. However, based on our consultations with USDA, EPA does not believe that the requirements for jatropha are likely to be as stringent as those for *Arundo donax* and *Pennisetum purpureum*, because, in the judgment of USDA, the risk of invasiveness for jatropha is likely to be smaller than for these two other feedstocks.[61] A fuel producer may alternatively demonstrate that there is not a significant likelihood of spread beyond the planted area, or that the species will be grown and processed in its native range where no or little risk of impact is expected if it spreads from planting sites. As outlined in the rule published on July 11, 2013 (78 FR 41702) for *Arundo donax* and *Pennisetum purpureum*, the fuel producer would need a letter from USDA that concludes

[59] USDA (2014). "Federal Noxious Weed List." Available at: http://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/weedlist.pdf.

[60] USDA Animal and Plant Health Inspection Service (2015). "Weed risk assessment for Jatropha curcas L. (Euphorbiaceae) – Physic nut." The weed risk assessment classifies jatropha as "evaluate further," which means it poses a moderate risk of invasiveness.

[61] For details on the requirements imposed on *Arundo donax* and *Pennisetum purpureum*, see the rule published on July 11, 2013 (78 FR 41702), http://www.gpo.gov/fdsys/pkg/FR-2013-07-11/pdf/2013-16488.pdf

that jatropha does not pose a spread of risk beyond the planted area. With these requirements in place, we would assume that there are no GHG emissions associated with potential invasiveness when jatropha oil is used as a biofuel feedstock. EPA is taking comment on the invasiveness concerns of jatropha and the appropriateness of the referenced requirements in mitigating those concerns.

G. Summary of GHG Emissions from Jatropha Oil Production and Transport

The results of our analysis of the GHG emissions associated with jatropha oil production and transport are summarized in Table III-11. The table summarizes the results for the two main scenarios that we evaluated: the first scenario where jatropha is grown on unused grassland in Mexico and Brazil and a second scenario where it is grown on agricultural land. For the second scenario, results are summarized for two cases: the first with jatropha production on agricultural land in Mexico, and the second with jatropha production on agricultural land in Mexico and Brazil. For comparison, Table III-11 also includes a summary of soybean oil production and transport GHG emissions as estimated for the March 2010 RFS rule. (Some emissions categories for the soybean results have been combined to align as much as possible with the jatropha results.) The results summarized in Table III-11 show that based on the scenarios we evaluated, the GHG emissions associated with producing and transporting jatropha oil as a biofuel feedstock are less than similar emissions for soybean oil. When evaluating petitions to use jatropha oil as biofuel feedstock we would also consider GHG emissions from fuel production and fuel distribution, in addition to the emissions summarized in Table III-11 (adjusted as appropriate for petitioners' individual circumstances).

The agency also conducted an uncertainty analysis and estimated the 95 percent confidence range for each of the scenarios evaluated. For this evaluation, we used the same methodology and spreadsheet model used for the March 2010 RFS rule. For the unused grassland scenarios we considered the uncertainty in the emissions factors used in our analysis. For the agricultural land scenarios, we considered the uncertainty in both the range of potential values for the satellite data and land use change emissions factors used in our modeling. The low and high ends of the 95 percent confidence range are presented below in Table III-11, with results from the jatropha scenarios displayed along with the results from our soybean oil modeling for the March 2010 RFS rule. The range is narrowest for the unused grassland-only scenario because it does not incur uncertainty associated with using satellite data to project land use change patterns. Comparing the uncertainty estimates for the scenario with jatropha oil produced on agricultural land and the estimates for the soybean oil results, the confidence range is narrower for the soybean results because a greater proportion of the land use change impacts for soybeans are in regions and impact types of land where EPA has better quality data. We invite comment on our analysis and the results presented below.

Table III-11. Production and Transport GHG Emissions for Jatropha Oil ($kgCO_2e$ per tonne of delivered oil)[62]

	Jatropha Oil			
		Produced on Agricultural Land		
Emissions Category	**Produced on Unused Grassland in Mexico and Brazil**	*Mexico Only*	*Mexico and Brazil*	**Soybean Oil**
Land Use Change	141	(1,383)	(406)	1,158
Preparation and	67	40	67	(3)

[62] Totals may not sum due to rounding. The "Total" results represents our mean estimates, and the "Low" and "High" results represent the low and high ends of the 95 percent confidence range.

Planting				
Annual Cultivation	983	964	983	
Indirect Crop Production	--	(431)	(338)	
Indirect Livestock	--	(125)	(392)	(291)
Oil Extraction	175	175	175	
Oil Pre-Treatment	5	5	5	470
Seed Transport	24	24	24	
Oil Transport	10	10	10	91
Total	**1,404**	**(721)**	**128**	**1,425**
Low	1,217	(3,063)	(1,293)	470
High	1,590	1,273	1,342	2,580

Based on the results summarized in Table III-11, we believe it is reasonable, as a conservative approach (and subject to confirmation upon review of individual petition submissions), to apply the GHG emissions estimates we established in the March 2010 rule for the production and transport of soybean oil to jatropha oil when evaluating future facility-specific petitions from biofuel producers seeking to generate RINs for volumes of biofuel produced from jatropha oil. While it is possible that jatropha could be grown on other types of land, such as shrubland or secondary forest, that would result in higher GHG emissions than the scenarios we evaluated, the RFS program's qualification requirements for renewable biomass would prevent the use of jatropha grown on such lands from use as an RFS renewable fuel feedstock. The renewable biomass definition would not prevent a scenario where jatropha is planted on agricultural land, and the displaced crops or pasturage is then shifted to shrubland or forestland. However, as discussed above, our modeling suggests that this scenario is not expected. Therefore, we believe it is reasonable to conclude that the overall emissions attributable to the production and transportation of jatropha oil used to produce biofuels for the

RFS program will be equal to or less than the same types of emissions attributable to soybean oil. We welcome public comments on all aspects of our assessment.

H. Fuel Production and Distribution

Jatropha oil is suitable for the same conversion processes as soybean oil and other previously approved feedstocks for making biodiesel, renewable diesel, jet fuel, naphtha and liquefied petroleum gas. In addition, the fuel yield per pound of oil is expected to be similar for fuel produced from jatropha oil and soybean oil through these processes. Jatropha may also be suitable for other conversion processes and types of fuel that EPA has not previously evaluated. After reviewing comments received in response to this action, we will combine our evaluation of agricultural sector GHG emissions associated with the use of jatropha oil feedstock with our evaluation of the GHG emissions associated with individual producers' production processes and finished fuels to determine whether any proposed pathway satisfies CAA lifecycle GHG emissions reduction requirements for RFS-qualifying renewable fuels. Each biofuel producer seeking to generate RINs for non-grandfathered volumes of biofuel produced from jatropha oil will first need to submit a petition requesting EPA's evaluation of their new renewable fuel pathway pursuant to 40 CFR 80.1416 of the RFS regulations, and include all of the information specified at 40 CFR 80.1416(b)(1). Because EPA is evaluating the greenhouse gas emissions associated with the production and transport of jatropha oil feedstock through this action and comment process, petitions requesting EPA's evaluation of biofuel pathways involving jatropha oil feedstock will not have to include the information for new feedstocks specified at 40 CFR

80.1416(b)(2).[63] Based on our evaluation of the lifecycle GHG emissions attributable to the production and transport of jatropha oil feedstock, EPA anticipates that fuel produced from jatropha oil feedstock through the same transesterification or hydrotreating process technologies that EPA evaluated for the March 2010 RFS rule for biofuel derived from soybean oil and the March 2013 RFS rule for biofuel derived from camelina oil would qualify for biomass-based diesel (D-code 4) RINs or advanced biofuel (D-code 5) RINs.[64] However, EPA will evaluate petitions for fuel produced from jatropha oil feedstock on a case-by-case basis.

IV. Summary

EPA invites public comment on its analysis of GHG emissions associated with the production and transport of jatropha oil as a feedstock for biofuel production. EPA will consider

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[63] For information on how to submit a petition for biofuel produced from jatropha oil see EPA's web page titled "How to Submit a Complete Petition" (http://www.epa.gov/otaq/fuels/renewablefuels/new-pathways/how-to-submit.htm) including the document on that web page titled "How to Prepare a Complete Petition." Petitions for biofuel produced from jatropha oil should include all of the applicable information outlined in Section 3 of the "How to Prepare a Complete Petition" document, but they do not need to provide the information outlined in section 3(F)(2) (Information for New Feedstocks).

[64] The transesterification process that EPA evaluated for the March 2010 RFS rule for biofuel derived from soybean oil feedstock is described in section 2.4.7.3 (Biodiesel) of the Regulatory Impact Analysis for the March 2010 RFS rule (EPA-420-R-10-006). The hydrotreating process that EPA evaluated for the March 2013 rule for biofuel derived from camelina oil feedstock is described in section II.A.3.b of the March 2013 rule (78 FR 14190).

public comments received when evaluating the lifecycle GHG emissions of biofuel production pathways described in petitions received pursuant to 40 CFR 80.1416 that use jatropha oil as a feedstock.

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Office of Transportation and Air Quality,
Office of Air and Radiation.

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