RCN Conference on Pan American Biofuels & Bioenergy Sustainability

Golden Tulip Recife Palace, Recife, Brazil
July 22-25, 2014

Technical Program
Thursday, July 24, 2014: 01:00 PM - 04:00 PM

Thursday, July 24, 2014: 01:00 PM - 04:00 PM, Boa Viagem Room
NGO-Government Perspectives on Biofuel and Bioenergy
Chair: Dulce Benke, Conservation International, Americas
Co-Chair: Andre Guimaraes, Conservation International, Brazil

Session Overview:
This session seeks abstracts on case studies or other projects involving non-governmental organizations (NGOs), government organizations, or collaborative actions to address biofuel and bioenergy sustainability.

1:00 PM	Activists Follow As Markets and States Transnationalize Northeast Brazilian Sugarcane, 1954-1989 . **R. Pinto**
1:25 PM	Assessing the Sustainability of Ethanol Production in Mexico from Three Crops . **C. García**
1:50 PM	Sustentability: socioeconomic and environmental considerations . **R. Frazao**
2:15 PM	Market mechanisms for sustainable production . **G. Nardelli**
2:40 PM	Future scenarios for the expansion of bioenergy and its potential impacts . **M. Moreira**
3:05 PM	Roundtable Discussion of Key Research Issues and Challenges

1:00 PM Voluntary Certification: Market Mechanism for Responsible Production
Aurea Maria Brandi Nardelli, Roundtable on Sustainable Biomaterials, Belo Horizonte e Região, Brazil

Abstract:
Certification is a set of activities performed for verifying if a process or product meets the requirements of a standard. It is a mechanism widely used in many sectors of industry. The objective is to provide independent confirmation that defined standard is being achieved. The evaluation process usually results in certified products, which can be labeled and recognized in the market.
The demand for sustainability certification is growing in many sectors. Particularly after 2007, biofuels and biomaterials are being asked to implement standards for responsible production. This is a result of new regulations, in special in Europe and US markets, and also a demand of many other stakeholders. Buyers, investors, workers, communities and customers are concerned about the negative impacts of the production and use of bioenergy and biofuels and are requiring additional guarantees that all operators along the supply chain, from field to final user, are applying responsible practices.

The objective of this presentation is to contribute to the understanding of voluntary certification schemes as a mechanism to improve responsible practices in bioenergy and biofuels sector. Sustainability standard, when effectively implemented by the organizations, is a powerfull tool to consolidate a management system that guarantees best social, environmental and social performance.

The Roundtable on Sustainable Biomaterials (RSB) is an international multi-stakeholder initiative that brings together farmers, companies, non-governmental organizations, experts, governments, and inter-governmental agencies concerned with ensuring the sustainability of biomass and biomaterial production and processing. Its certification system is based on sustainability standards encompassing environmental, social and economic principles and criteria. Originally set up in 2007 to ensure the sustainability of liquid biofuels for transport, the RSB expanded its scope in 2013 to cover biomaterials.

1:25 PM Activists Follow As Markets and States Transnationalize Northeast Brazilian Sugarcane, 1954-1989
Rodrigo Pinto, James Madison College of Public Affairs, Michigan State University, East Lansing, MI

Abstract:
History not only repeats itself in patterns that are again evident in the recent expansion of bioenergy production, but also informs current perspectives of key cause-oriented organizations such as the Pastoral Land Commission (CPT—*Comissão Pastoral da Terra*), whose office for Northeast Brazil remains based in the same city of Recife where this conference takes place. Examples of these historical patterns include commonalities in how Peasant Leagues opposed the expansion of sugarcane production for sugar, alcohol and ethanol during the 1950s-1964 period on the one hand and in how the CPT sharply opposed the recent expansion of sugarcane for ethanol on the other. Both the distant and the recent oppositions are mainly based on a sense that the expansion of sugarcane production has an indirect negative impact on land redistribution. As for how the past informs the present, two terms used in the title of this conference serve to exemplify those historical legacies: CPT's well-known preference to frame bioenergy as 'agro-energy' as well as its distinctively third worldist understanding of 'Pan American.'

Briefly and transnationally, this presentation analyzes how markets and states shaped an activist campaign that shares historical patterns and legacies with more recent bioenergy campaigns following

its own 1954-1989 timing. The campaign initially mobilized after world sugar prices rose in 1945 such that as of the early 1950s landowners increasingly maximized their sugarcane output by pressuring their wage laborers to produce more and by converting to sugarcane land that had previously been allotted or rented to peasant sharecroppers or tenants. Next, the struggle cohered in 1955 during the 1st Peasants' Conference of Pernambuco (*1º Congresso de Camponeses de Pernambuco*) with support from the chairperson of the United Nations Food and Agricultural Organization (FAO)—namely, Josué de Castro. The campaign subsequently grew more intense between a 1959 Cuban revolution that brought foreign communist support to the struggle, a U.S.-supported invasion of Cuba in 1961 that instilled in campaigners the fear of a similar invasion into Brazil, and a U.S.-backed 1964 Brazilian regime transformation—from democracy to autocracy—that demobilized the campaign. The campaign then shrank in quantity and moderated in quality through exile and/or U.S.-funded repression and cooptation of the relatively more radical activists. It later reinvigorated with Brazilian expansion of bioenergy production in response to the 1973 oil shock, eventually leading to the foundation of the aforementioned CPT in the late 1970s. The campaign ultimately dissolved with the 1989 disbanding of the Soviet Union. The northeast Brazilian city of Recife, which harbors the port from which most Brazilian sugar was exported abroad during the campaign, remained the campaign epicenter from 1954 to 1964 and an important campaign hub throughout the 1954-1989 period. This centrality is evident in the prominent international visitors that Recife hosted during these years, including U.S. Secretary of State Henry Kissinger, U.S. politician Edward Kennedy, U.S. bureaucrat Sargent Shriver, U.S. activist Ralph Nader, Pan-American Che Guevara's mother, and fatefully not U.S. president John Kennedy—whose assassination brought to an end plans honoring the statesman's wish to visit Recife in the heart of what he had famously described as "the most dangerous area in world."

The presentation focuses on process-tracing how markets and states shape cause-oriented action in transnational relations. It traces market and state causalities through two processes: one variously known as internalization or defensive transnationalism and to a lesser extent another known as radiation from supply chains certified to be socio-environmentally responsible. These process-tracings tend to feature the activisms of cause-oriented actors such as CPT and sugarcane labor unions getting themselves into some tension with one another.

1:50 PM Assessing the Sustainability of Ethanol Production in Mexico from Three Crops
Carlos García, Environmental Sciences, Escuela Nacional de Estudios Superiores Unidad Morelia-UNAM, Morelia, Mexico

Abstract:
The Mexican transportation sector is the largest energy consumer in the country and depends mostly on gasoline. One of the promising alternative fuels according to the experiences of other countries is ethanol. Despite the increasingly important use of ethanol as an alternative fuel, criticisms have arisen production as researchers have warned of negative effects such as CO_2 emissions, biodiversity loss , high use of water resources, and food security. To study aspects of the sustainability of ethanol production in Mexico, a Sustainabilty Index (ISUS) was defined using the following indicators: GHG reduction, water use, land use, number of jobs created, and economic costs involved in the lifecycle of each ethanol production modality. Then, calculation of ISUS was performed using the named indicators, previously normalized and applied to three different feedstocks, sugar cane, maize and sorghum. Results show that the best option in terms of sustainability was the production of ethanol from sugarcane direct juice with export of electricity.

Thursday, July 24, 2014: 01:00 PM - 04:00 PM, Candeias Room
Brazilian Biofuel and Bioenergy Sustainability Issues and Case Studies
Chair: Arnaldo Walter, University of Campinas-Unicamp, Campinas, SP, Brazil

1:00 PM	Biofuel in Brazil: Soybean and Palm Oil Impacts on Socioecological Systems . **F. Martinelli**, **T. Martins**, and R. Medeiros
1:20 PM	Process Integration Case Study for the Second Generation Ethanol Production . S. Rouzinou, **P. Brito**, and V. Pylkkanen
1:40 PM	Bioenergy Production through Microalgae in Brazil: An Activity Joint with Ethanol Plants of the Country . **L. R. Holanda** and F. S. Ramos
2:00 PM	Socioeconomic Aspects of Sugarcane Producing Municipalities in Brazil . **P. Gerber Machado Sr.**
2:20 PM	Analysis of the Viability of Ethanol Production in Brazil: Economical, Social & Environmental Implications . **I. Alvarez Murillo**
2:40 PM	Socioenvironmental Aspects of the Palm Oil for Biodiesel Production in the Center of Endemism Belém - Brazil . **G. S. Pereira**, **R. Medeiros**, **B. H. Coutinho**, and **T. Martins**
3:00 PM	Roundtable Discussion of Key Research Issues and Challenges

1:00 PM Biofuel in Brazil: Soybean and Palm Oil Impacts on Socioecological Systems

Fernanda Martinelli, Sustainable Development Practices Graduate Program, UFRRJ/ Conservation International Brasil, Rio de Janeiro, Brazil, Tatiana Martins, Sustainable Development Practices Graduate Program, UFRRJ/ International Center of Studies in Sustainable Development, CIEDES, Rio de Janeiro, Brazil and Rodrigo Medeiros, Department of Environmental Sciences, Federal Rural University of Rio de Janeiro / Conservation International, Americas Center for Sustainability

Abstract:
The increasing concern about global warming and the uncertainty of oil prices have generated much interest in alternative fuel sources to petroleum, especially biofuels. Biofuels are liquid fuels produced from biomass, and ethanol and biodiesel are the world primary liquid biofuels used for transportation. In Brazil, more than 70% of biodiesel production is from soybean crops, which is currently the only oil crop available for large-scale biodiesel production. The Brazilian soybean expansion started in the early 1970s driven by global market forces that lead government to heavily subside this crop and invest in transportation infrastructure needed. Since then, Brazil has invested in soybean production and became the world's second biggest producer. Although it brought countless economic benefits, it also ended up in significant impact on biodiversity and ecosystem services, especially if plantations replace Cerrado or Amazon rainforest. Further, highly mechanized large-scale industrial soybean plantations might lead small-scale farmers' displacement into Amazon forested areas to use them for agriculture or cattle ranching

In order to promote rural social and environmental development, government has enacted political measures to support different sources for biodiesel, and oil from palms has the potential to be a major contributor. Although Brazil has not yet reached full-scale production, the country has followed the global trend and doubled its production area during 2001-2009, from 46 to 109 thousand ha and projected scenarios predict major expansion in the next few years. In order to avoid the same impacts of past large-scale soybean expansion, two important measures were set: the Social Fuel Seal Program and the Zoning for palm oil in Amazon. The Seal Program has encouraged partnerships between biodiesel companies and small scale farmers by contractual agreements, where biodiesel refineries buy at least 15% of their total palm oil from small-scale farmers. SFS companies receive tax benefits and priority in biodiesel auctions. The Brazil's agro-ecological zoning for palm oil limits production only to degraded lands without environmental legal restrictions, and the removal of native vegetation for planting palm oil crop is forbidden. From this restriction, suitable areas for oil palm went down from 2.32 million to 704.066 km^2 which represents 14% of Legal Amazon.

Although legal regulation and tax incentives are important to promote a sustainable biodiesel production, they might not achieve the targets they were supposed to. The world biggest palm oil producers Indonesia and Malaysia's experiences suggest that Brazil should expect land use changes challenges and unanticipated effects. Some effects might come from the remoteness for supervision of palm production poles, displacement of farmers who do not accept palm crop, as well as environmental consequences for communities regardless indirect and illegal direct deforestation.

Because soybean and oil palm are most intensively cultivated in high biodiversity sites, any future intensification of these crops without proper mitigation guidelines will likely further threaten the high concentrations of globally endangered species in these areas. Our paper intent to compare soybean and palm oil production impacts on biodiversity, ecosystem services and local community by evaluating 1) Land use change, 2) Agrochemicals use, 3) Soil, Water use and GHG emissions, and 4) Job creation and inclusive growth. These indicators were assessed in a literature-based inventory of the sustainability of

major biofuel production systems, based on current certification and production practices (RSB, RSPO, RTRS) in major production areas.

Since soybean is a consolidated crop in Brazil and the impacts are widely known, we can anticipate the future impacts and promote a more sustainable large-scale palm oil production in Amazon and help stakeholders to set better production practices for both soy and palm. This comparison was taken from available published data through literature research. We analyzed impacts of soybean and palm oil biofuel production systems in different tropical regions where these crops are relevant.

1:20 PM Process Integration Case Study for the Second Generation Ethanol Production

Sophia Rouzinou, American Process Inc, Athens, Greece, **Paulo Brito**, Granbio, Sao Paulo, Brazil and Vesa Pylkkanen, American Process Inc., Atlanta, GA

Abstract:
Co-location and integration of sugar mills and first generation ethanol mills with flexible bio-refineries can enhance biofuel and biochemical's production sustainability. Integrating second generation biorefineries to existing sugarcane mills represents a promising opportunity to reduce both capital and product cost.
The decisions of converting an existing plant to a second generation biorefinery or the optimum configuration of a green field integrated biorefinery should be a strategic decision. Biorefinery options include synergistic parallel facility, byproduct utilization and holistic production process realignment. Because of site consideration, a different approach may be necessary in each plant. Energy consumption implications are critical. Furthermore, integration of the new process with the existing equipment plays a key role for a successful implementation.
Application of Process Integration techniques and Pinch technology are therefore essential for early evaluation and design of novel biorefinery process concepts. Process Integration and Pinch technology combined with simulation modeling are powerful tools for reliable and quick feasibility analysis and techno-economic evaluation of different options. The optimum integration schemes are identified and the process energy consumption is optimized, while concurrently considering the capital cost.
The main principles and methodology of Process Integration and Pinch technology will be presented. An example of feasibility analysis and identification of the best options for a second generation biorefinery integration, with the use of Process Integration and simulation modeling, will be presented.

1:40 PM Bioenergy Production through Microalgae in Brazil: An Activity Joint with Ethanol Plants of the Country

Laryssa R. Holanda, Production Engineering Department, Federal University of Pernambuco - UFPE, Recife, Brazil and Francisco S. Ramos, Economics Department, Federal University of Pernambuco - UFPE, Recife, Brazil

Abstract:
This paper proposes a process for the production of microalgae for electricity generation, regarded as a joint activity with ethanol in order to meet the expected increase in energy demand caused by economic growth in Brazil. Microalgae are efficient in generating electricity, as by burning a ton of the biomass are generated 8.12 MWh. The production of this alternative energy source in conjunction with an ethanol plant maximizes the production of both, as it reduces the costs of production of microalgae using waste from the ethanol plant and the reduction of idleness of its equipments, furthermore brings benefits the

environment, with the microalgae capturing the carbon dioxide emitted by the ethanol plant. The production process proposed sum revenue from carbon credits, selling oxygen and electricity.

2:00 PM Socioeconomic Aspects of Sugarcane Producing Municipalities in Brazil
Pedro Gerber Machado Sr., FEM, UNICAMP, campinas, Brazil

Abstract:
Government policies to support the production of ethanol from sugar cane , large availability of land and a favorable climate , ie tropical, with good rainfall and temperatures , have made Brazil a global leader in this field . In 2009, Brazil accounted for 33 % of global production of ethanol and was also the largest exporter (HERRERAS, 2013). The importance of the sector to the economy has taken large proportions, especially in the last four decades. In 2008 participation in the Brazilian GDP reached 2 %, generating more than 1,280,000 formal jobs (UNICA, 2011). The number of plants in 2010 was 413, with 103 producing only ethanol, 11 producing sugar and 297 mixed (MAPA, 2010).
The scale of production of sugarcane and ethanol, as well as the growth of consumption, which is a consequence of the introduction and success of flex vehicles in the Brazilian fleet, justifies the analysis not only of environmental aspects, but also social and economic issues, including its contribution to the development of the country and the regions in which it operates
This article aims to analyze the socio-economic aspects associated with the production of sugarcane in two major producing states: São Paulo, the largest producer in the Center-South region, and in the country, and Alagoas, the largest producer in the Northeast. To do so, regularly compiled municipal indicators were used and disclosed by official Brazilian government agencies. The cluster method was used to separate in a non-biased way two groups: with higher and lower socioeconomic indicators.

2:20 PM Analysis of the Viability of Ethanol Production in Brazil: Economical, Social & Environmental Implications
Isabel Alvarez Murillo, Rotary International, Montreal, QC, Canada

Abstract:
The global dependency on fossil fuels as energy sources has encouraged many countries to look for different renewable alternatives. Some have come to consider biofuel production as the ‘solution’ to the oil dependency. The leaders of ethanol production in the world are the United States and Brazil. This paper will focus on ethanol production in Brazil, outlining its development through Brazil’s history as well as the advantages and the negative impacts of such a market. The importance of this energy source in Brazil’s economy and the possible future outcomes of Brazil’s biofuel dependency will be discussed. Three different aspects of primary impacts will be highlighted: economic, environmental and social. The effects of the new advancements in emerging biofuels will be discussed as they pertain to the current market for first-generation biofuels. An analysis of the economic impacts of ethanol will concentrate on the influence of the American ethanol market and its policies on Brazil. The environmental impacts of land use change, with a focus on soil, water and biodiversity, will also be reviewed. Likewise, the social impacts associated with food security, sugarcane workers and indigenous peoples’ rights will be discussed. An overall view of the repercussions of biofuel production will be presented and questions regarding the viability of the biofuel market in Brazil will be addressed.

2:40 PM Socioenvironmental Aspects of the Palm Oil for Biodiesel Production in the Center of Endemism Belém – Brazil

Gustavo Simas Pereira[1], **Rodrigo Medeiros**[2], **Bruno Henrique Coutinho**[3] and **Tatiana Martins**[4], (1)IFRJ/RJ and UFRRJ/IF/DCA, IFRJ and UFRRJ, Rio de Janeiro, Brazil, (2)Conservation International, RIO DE JANEIRO, Brazil, (3)UFRJ, Rio de Janeiro, Brazil, (4)UFRJ and CI, Rio de Janeiro, Brazil

Abstract:
In Brazil the use of biofuels to replace the fossil fuels is not new. According Gazzoni (2013), the country search for oil sources for power generation (biodiesel) since 1920. Recently, the National Program for Production and Use of Biodiesel (NPPB), created in 2004 by the Brazilian government, has the objective to increase the production of biodiesel from oilseed crops, including palm oil (*Elaeis guineensis*), in the North and Northeast regions, against the Brazilian biodiesel production focused on soybean in the central west region (ANP, 2012). The program is an attempt to associate the production of renewable sources with socioeconomic development and environmental protection.

In order to include the small farmer (out of soy) (NPPB) set different taxes depending on the origin of the raw material, with the biggest discount to that produced by small farmers in the North and Northeast regions of Brazil. The biodiesel producer to receive the tax benefits in the selling price in the auction, must possess the Social Fuel Seal (established by Decree No. 5,297 of December 6, 2004). The seal is a guarantee that the producer buys its raw materials from family farmers - framed in the National Program for Strengthening Family Agriculture (PRONAF) - with the purchase and sale contracts, with fair price, in percentage established by the Brazilian government and offering technical assistance and training to this population.

The NPPB, has the legal apparatus the Law No 11.097 of 2005 (BRAZIL, 2005), which introduced the biodiesel into the Brazilian energy matrix and established the mandatory use of 2% biodiesel blended with petroleum diesel, with increases gradual coming to current levels (2014) of 7% of the total volume. Thus, the Brazilian government created a demand for this biofuel, causing between 2005 and 2011 biodiesel production jumped from 736 m3 to 2.6 million m3. During this period the acreage of soybeans increased by 29.4% bringing the total to 24 million hectares, producing over 75 million tons of grain.

However, soy failure to meet inclusion of family agriculture, one of the goals of PNPB, due your characteristic of a culture whose production is highly mechanized. In this sense, a culture that has great potential to include smallholders in the supply chain is the palm oil.

One of the possibilities to increase biodiesel production is the use of already degraded areas in the Amazon, where they could be used for growing perennial oilseed species such as palm oil. This possibility is indicated in the study conducted by Embrapa, the Agro-Ecological Zoning Palm oil / AZP (EMBRAPA, 2010), which identified more than 700.000 km² with a good possibility for biodiesel generation in order to ensure its sustainable expansion. This area is equivalent to about 14% of the Legal Amazon. It is noteworthy that these areas indicated by AZP are within the same regions identified in the National Agro-Energy Plan (PNA, 2011), who identified the regions in Brazil that have characteristics suitable agricultural production focused on power generation.

In the Brazil we can identify that the production of biodiesel (with the palm oil) is concentrated in the states of Pará and Bahia, that the area under cultivation increased by 39% and 18% respectively since 2011. During 2001, the crop intended the palm oil occupied a total of 85,240 hectares, mainly in the North and Northeast regions. In 2011, the area under cultivation reached 109,080 hectares, equivalent to about 30% increase when compared to 2001. Pará state has the largest city in Brazil with dedicated to the cultivation of Elaeis guineensis, Tailândia area with 20,893 hectares, that between the years 2001 and 2011 increased your area of palm oil by 34% (following the state average). Another highlight (among the 21 municipalities) is the city of Moju who increased by 270% to your area, reaching a total of 7,093 hectares.

The Amazon Rainforest is a mega-diverse environment that has a large territory with about 6,5 million km², housing almost 20% of existing species on the planet. Many of the species found in the Amazon do not exist elsewhere on the planet. These are called endemic species and are located in certain geographical regions with their own characteristics. Given these unique characteristics and using the great water courses, different authors (CRACRAFT, 1994; HAFFER & PRANCE 2001; SILVA et al, 2005) classified the Amazon biome in eight centers of endemism: Napo; Imeri; Guiana; Inanbari; Rondônia; Tapajós; Xingu and Belém. Among the centers of endemism, the Belém (CEB) has the highest deforestation rate, with almost 70% of its impacted area, a situation which is explained by higher occupancy and urban density in this region (ALMEIDA & VIEIRA, 2010).

The present work aims to identify areas for expansion of palm oil (*Elaeis guineensis*), in the Amazon, in particular Center of Endemism Belem and present an socioenvironmental characterization of the micro-region Tomé-Açú, focused on the expansion of palm oil region. The growth areas were identified based on the results published by other authors through literature to scientific articles, theses, legal documents and other publications relevant to the topic search. The socioenvironmental characterization was carried out from the base of the Brazilian Institute of Geography and Statistics (IBGE) and the National Institute for Space Research (INPE) where forest cover data were analyzed; degraded areas; farms; protected areas; agricultural settlements; deforestation; among others. ArcGis10.1 using the program, data were compared with the Agro-Ecological Zoning of Palm oil in order to verify the impact generated by palm oil cultivation in the region.

According to Sakamoto (2013), within the CEB, in the state of Pará, are found some of the main units of production of biodiesel from vegetable oil using the Palm oil as feedstock. This production is being held in an area of approximately 140,000 hectares, reaching almost 470,000 hectares in the coming years, after the consolidation of expansion projects by 2020. Besides the large and medium-sized companies, palm oil production has the participation of local community in nuclei of family farmers in area a nearby 20 thousand hectares (to year 2010). Between 2010 and 2012 over 581 families (in 5,810 ha) were added to the partnership programs of Amazônia Bank (BASA) for the production of palm oil.

It is estimated that for the 2012/2013 crop the Amazônia Bank have the partnership with over 1,610 contracts in an area of 15,300 ha to the palm oil. This expansion of palm oil enabled the inclusion of 2,191 new families (in 21,110 hectares) in the last three years. On average each family occupies 10 hectares and can get an average of R $ 2,000 monthly between the fifth and eighteenth year of life of the palm oil when it reaches the height of its productivity, totaling R$ 24,000 per year (SAKAMOTO, 2013).

With indications that the state of Pará has a prominent role in the production of palm oil and also has a set of degraded with potential for cultivation of palm oil (identified by AZP), was determined the regions with the greatest potential for socioenvironmental development of palm oil plantations. Thus, was highlighted the micro-region of Tomé-Açú (five municipalities: Acará; Concórdia do Pará; Moju; Tailândia and Tomé-Açú) with great aptitude expansion of palm oil plantations.

Thursday, July 24, 2014: 01:00 PM - 04:00 PM, Piedade Room
Industry-Government Perspectives on Biofuel and Bioenergy
Chair: Abraham Sicsu, General Office of Science and Technology, Recife Brazil

Session Overview:
This session seeks abstracts on industry and government initiatives and project on biofuel and bioenergy sustainability.

1:00 PM	Bioenergy and Biofuels: Presentation . **A. Sicsú**
1:20 PM	Commercial Experience of Rapid Thermal Processing (RTP) of Sustainable Biofuels . **M. J. Cleveland** and D. Szeezil
1:40 PM	The Sustainability of Biofuels in Brazil . **S. T. Coelho** and J. Goldemberg
2:00 PM	Bioethanol Industry Perspectives in Brazil . **J. G. Eugenio de França**
2:20 PM	Bioenergy in Northeastern Brazil: Opportunities and Challenges . **R. S. Cezar Menezes** and C. de Lima Júnior
2:40 PM	Forest Biomass Harvesting and Site Productivity: Is Policy Ahead of Science? . **E. D. Vance**, W. M. Aust, B. D. Strahm, R. E. Froese, R. B. Harrison, and L. A. Morris
3:00 PM	Roundtable Discussion of Key Research Issues and Challenges

1:00 PM Bioenergy and Biofuels: Presentation
Abraham Sicsú, UFPE, Recife, Brazil

Abstract:
The proposal of this specific table of discussion on Government and Industry interface for Bioenergy and Biofuels on the view that the action of the state in regulating and supporting the sector in Brazil has always been strategic and essential to the definition of a pattern of sectorial development. In this direction, as political issues for the feasibility of public and private investment; impacts in relation to the environment; labor relations; government regulation for the production and trading of electricity; promotion of research; agricultural zoning are the key points. The table was structured with the following proposal: a brief opening presentation. Eric will make a presentation of the important international experience in the commercial exploitation of energy forests and debate on ethanol and biodiesel. Suani also doing a presentation on biofuel sustainability in various aspects. As the topic of debate is vast it seems that will focus on the possibilities of introduction of raw materials and innovations that increase productivity and reduce the differences in agricultural productivity in certain regions. The need for public policies to support the development of supply chains is another important point. It seems very unlikely that the operation of the market alone would reach these guidelines. Geraldo Eugenio will put in context the perspective of the Ethanol Industry in Brazil, including the outputs of the current crisis and Marcelo Guerra, with a practical view of those who follow the daily lives of the sector, will present the view of the productive sector about the current situation and Brazilian prospect. Romulo Meneses will report on recent studies on the potential for energy recovery from biomass sources in the Northeast region with emphasis on biodiesel. He will present the reality of this specific sector and its prospects, including the technological stand point. In this debate four strands emerge as guiding practices. Agronomic Technology and agro-climatic conditions defined for the type of crop or raw material being used; agro industrial and industrial technology established and developed for production in small, medium and large scale; logistics and infrastructure for the production and circulation of goods in the economic production chain; the minimum scale of production, complementarity in production processes and simultaneity of production shares. All this items will be discussed for the development of an institutional arrangement that is being built between the State and Industry as effective partnerships.

1:20 PM Commercial Experience of Rapid Thermal Processing (RTP) of Sustainable Biofuels
Michael J. Cleveland, UOP LLC, A Honeywell Company, Honeywell do Brasil, Rio de Janeiro, Brazil and Dan Szeezil, Envergent Technologies LLC

Abstract:
Envergent Technologies is a biofuels technology licensor and equipment producer for RTP™ Rapid Thermal Processing, a proven route to convert low-value biomass residues into a high-value liquid biofuel. RTP Green Fuel production is cost-effective, virtually carbon-neutral and sustainable and can be used for renewable heat, power and, ultimately, transportation fuels.

Backed by Honeywell-UOP, a leader in the refining and petrochemical industries for nearly 100 years, and Ensyn, developer of the RTP technology with 20 years of commercial experience, Envergent offers a low-risk, high-reward solution for renewable fuels production.
The proposed presentation will cover the RTP technology highlighting the following:
Benefits of RTP Green Fuel

- RTP technology can utilize a wide range of biomass from eucalyptus and other trees to residues that are readily available such as bagasse and agricultural remains.

- RTP Green Fuel is a light, pourable clean-burning liquid that contains little sulfur and reduces greenhouse gas emissions by 70-90% compared to fossil fuels, depending on application
- RTP Green Fuel can be co-processed in a petroleum refinery FCC unit to produce a blended renewable fuel for transportation use
- RTP technology is virtually self-sustaining, using the co-products to generate much of the heat and power required to run the unit
- RTP technology provides biomass conversion into a liquid fuel that can be transported & stored for future use, fully decoupling the feedstock source from energy usage.
- Low risk, modular construction allows efficient site selection and accelerated commissioning

1:40 PM The Sustainability of Biofuels in Brazil
Suani Teixeira Coelho, University of Sao Paulo, Sao Paulo, Brazil and José Goldemberg, University of Sao paulo

Abstract:
The concept of sustainability has evolved considerably in the 20th century. Initially it was focused on the conservation of the landscape and biodiversity mainly in the advanced industrialized countries. The rapid growth of the world population and greater access to material goods in former undeveloped countries put strong pressures on mineral resources, leading to scarcity and increased environmental problems, such as urban air pollution and global warming. Sustainability concerns focused then on using such resources in a more rational fashion, ranging from increased efficiency to shifting the resources used, and privileging the use of renewable resources, particularly in the case of energy. The emphasis in this case is to find substitutes for the use of fossil fuels. One of them corresponds to the liquid biofuels, in which Brazil in the United States are the main producers. However, liquid biofuels sustainability is still seen as a controversial issue considering environmental and social aspects. Several studies have already discussed these issues with different points of view but today is a consensus that "bioenergy is not bad or good" but it depends on how it is produced. Contributing to this discussion, The Global Bioenergy Partnership (co-chaired by Brazil and Italy) has developed together with FAO (Food and Agriculture Organization) and UNEP (United Nations Environmental Program) a set of 24 bioenergy sustainability indicators (environmental, social and economic), accepted by all its member countries. Several if these countries are already implementing this methodology in Europe, Africa and Latin America for different types of bioenergy. Brazil had not yet applied it but now a new study is starting to be developed for sugarcane ethanol mills in São Paulo State by the University of São Paulo, funded by the Government of Italy/Forum of the Americas with the support of the Brazilian Federal Government and the Secretariat for Environment of São Paulo. In this presentation a general overview of sustainability issues for sugarcane ethanol in Brazil will be presented, as well as the general context and background of the GBEP indicators to be applied in Brazil. Despite the fact that there are several certifications schemes already in place, it appears that this GBEP indicators methodology is a consensus among the governments members of GBEP and could be a good experience for comparing bioenergy among the countries.

2:00 PM Bioethanol Industry Perspectives in Brazil
José Geraldo Eugenio de França, The Technological Institute of Pernambuco, Recife, Brazil

Abstract:
Brazil has a long history of biofuel production and use, and is the country that first developed a large scale program aiming the use of ethanol as an automotive fuel. The main feedstock for the Brazilian

ethanol industry is sugarcane, a traditional crop in the country since the XVI century. In the last ten years the country witnessed a boom in ethanol use, especially due to the development and marketing of the flexfuel (gasoline and ethanol) vehicles in 2003. By 2009, 90% of the new automobiles in Brazil were flexfuel what illustrates the effectiveness of this technology adoption. It is common sense that the economics effective ratio of the ethanol vs gasoline prices is 10 to 7. However in the last 4 years particularly due the high sugar prices in the international market the ethanol has shown a higher ratio and the consumers have dropped remarkably the use of pure ethanol preferring the use of gasoline that in Brazil is a mixture with 25% of ethanol. There has been a lot of discussion in the last few months on how the government can work with the sugarcane industry in order to reconquer the Brazilian market. It looks something interesting since in 2013/2014 the Brazilian industry has used 65% of its 9,3 million hectares of cultivated sugarcane for producing ethanol instead of sugar. After few years with the ethanol production stalled around 23 to 24 billion liters a year, the last year have witnessed a surge in the ethanol production reaching 28 billion liters. The country has also observed that a reasonable portion of this production has been sold abroad, what makes the local market extremely vulnerable and open for the outside competitors, particularly the corn ethanol industry of the USA. For a long term perspective it is clear that the ethanol industry has to use the bagasse for producing second generation ethanol even though this feedstock has become very valuable for energy production through cogeneration or as row material for sugar high valuable derivatives. The country still has an edge in ethanol production comparable with most competitors however it will be extremely indispensable to invest in research, development and innovation in its sugarcane industry as well as to update the research agenda on the production of biofuels from agricultural, industry and urban residuals since although the sugarcane acreage has increased it will not be enough to fulfill the local and international demand for sugar, ethanol and energy.

2:20 PM Bioenergy in Northeastern Brazil: Opportunities and Challenges

Rômulo Simões Cezar Menezes, Nuclear Energy Department, Universidade Federal de Pernambuco, Recife, Brazil and Claudemiro de Lima Júnior, Universidade de Pernambuco

Abstract:
The use of biomass sources for energy purposes is very relevant in Brazil. The same importance is observed in the NE region of Brazil, but there are regional sources that are still underutilized. Therefore, this subject deserves more attention from researchers and government officials to point the potential opportunities for the industry and other sectors. We have recently completed the "Atlas of Bioenergy in NE Brazil", in which we quantified the annual production of the main biomass sources with potential for energy recovery, for each municipality of the region. We also calculated the primary energy content of each biomass source. Similarly to the rest of Brazil, sugarcane bagasse, ethanol, firewood and charcoal were the sources with highest primary energy production. Several other sources with potential energy contribution are underutilized or are not used for energy purposes, such as the organic fraction of municipal solid waste, sugarcane vinasse, coconut shells and animal manure. Biomass conversion through anaerobic biodigestion, particularly in decentralized micro generation systems, could improve the energy recovery of several of these regional biomass sources. However, the region lacks the human resources and infrastructure to develop and support this route on a large scale. Information on the spatial distribution of these potential sources available, routes for energy recovery and suggestions of public policies to stimulate the use of these sources will be discussed.

2:40 PM Forest Biomass Harvesting and Site Productivity: Is Policy Ahead of Science?

Eric D. Vance, National Council for Air and Stream Improvement, Inc. (NCASI), Research Triangle Park, NC, W. Michael Aust, Department of Forest Resources and Environmental Conservation, Virginia Tech, Blacksburg, VA, Brian D. Strahm, Department of Forest Resources and Enviornmental Conservation, Virginia Tech, Blacksburg, VA, Robert E. Froese, School of Forest Resources and Environmental Science, Michigan Technological University, Houghton, MI, Robert B. Harrison, School of Environmental and Forest Sciences, University of Washington, Seattle, WA and Larry A. Morris, Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA

Abstract:
Emerging bioproduct and energy markets provide incentives for harvesting greater quantities of biomass at shorter intervals and have raised environmental concerns, including effects on the productive capacity of forested sites. In response to these concerns, governments and non-governmental organizations have developed biomass harvesting guidelines (BHGs) with provisions for retaining specific proportions or quantities of biomass on site and restricting harvests on sites deemed sensitive. These guidelines are largely voluntary but may be incorporated in some form into forest practice mandates and certification systems. BHGs are well intentioned and based on a reasoned, conceptual understanding of the role of harvest residues in sustaining soil organic matter, nutrient availability, and future site productivity. Management restrictions come with economic and environmental costs, however, and the science supporting them deserves greater scrutiny. Field experiments show that forest responses to biomass harvesting vary widely and are often counterintuitive. With site-specific data lacking, BHGs tend to rely on default assumptions supported by best professional judgment. These include (i) the natural or unmanaged state is an ideal frame of reference, (ii) conventional harvesting retains and distributes most residues across the site, (iii) biomass harvesting removes virtually all residues, (iv) decomposing residues always enhance soil C and site productivity, (v) biomass harvesting is conducted without operational practices that alleviate site deficiencies and sustain productivity, and (vi) changes in forest state are equivalent to changes in forest function. While harvesting-induced nutrient deficiencies can be prevented or corrected with fertilizers or other soil amendments, soil disturbance and exposure may warrant greater attention. Effective BHGs are science-based, operationally feasible, and protect values of interest while allowing managers the flexibility to prevent or mitigate potential impacts within constraints imposed by existing forest practice rules, best management practices, and forest certification provisions.

Thursday, July 24, 2014: 01:00 PM - 04:00 PM, Imperial Room
Industry-Academic Perspectives on Biofuel and Bioenergy Sustainability
Chair: M. Regis L.V. Leal, Brazil Bioethanol Science and Technology Lab, Campinas Brazil
Co-Chair: Hayri Önal, Department of Agricultural and Consumer Economics, University of Illinois, IL, USA

Session Overview:
Industry and Academia are forming partnerships to address challenges and opportunities in biofuel production and sustainability. This session welcomes abstracts from research, demonstration, and commercialization projects from the Pan American region.

1:00 PM	Sustainability in Biofuel and Bioenergy Sectors: The Role of Public Policy . **H. Önal**
1:18 PM	Biofuels and Bioenergy Sustainability Assessment Methods . **D. Schuster** and L. Alexander
1:36 PM	Biogas Generation from Sanitary Landfill Leachate . **V. Mello**, V. Lima, S. Holanda, J. Ferreira, J. F. Jucá, and M. Motta Sobrinho Sr.
1:54 PM	The Potential Use of Waste Stabilization Ponds for Biofuel Production By the Microalgae Biomass . **M. Paiva**
2:12 PM	The Sustainability of Brazilian Sugarcane Ethanol: The Contribution of the Brazilian Bioethanol Science and Technology Laboratory (CTBE) . **M. R. L. V. Leal**
2:30 PM	Comparison of Acid and Enzymatic Hydrolysis of Jerusalem Artichoke Tubers for Fermentative Butanol Production . **T. Sarchami**
2:48 PM	Understanding Concentration and Pressure Changes during Ultrasonication-Enhanced Blending of Petrol-Ethanol Blended Fuel . **D. Nkazi**, M. O. Daramola, and S. E. Iyuke
3:06 PM	Roundtable Discussion of Key Research Issues and Challenges

1:00 PM Sustainability in Biofuel and Bioenergy Sectors: The Role of Public Policy
Hayri Önal, Department of Agricultural and Consumer Economics, University of Illinois, Urbana-Champaign, IL

Abstract:
I will give an overview of the existing policies and the development of the biofuel and bioenergy sectors in the US and summarize the empirical findings of a large-scale economic simulation model we developed for the US agriculture and biofuel/bioenergy sectors. The talk will focus on the role of alternative policy designs, in particular the RFS blending mandates, subsidies, and trade policies. The model includes a Brazil component similar to the US component and we have conducted some analyses for the Brazil ethanol industry as well (impacts of ethanol pipelines, changes in gasoline pricing and blending mandates, etc.).

1:18 PM Biofuels and Bioenergy Sustainability Assessment Methods
Darlene Schuster, Institute for Sustainability, An AIChE Technological Community, New York, NY and Lucy Alexander, Institute for Sustainability, AIChE, New York, NY

Abstract:
This presentation from AIChE's Institute for Sustainability will explore biofuels and bioenergy sustainability assessment methods, focusing on supply chain and value chain, and safety, economic, social, and environmental concerns. Various popular methods will be compared on the basis of cost- and time-effectiveness, ease of use, flexibility, clarity of results, and other strengths and weaknesses. Also discussed will be the needs for and benefits of such assessments for bioenergy producers and users. The presentation will identify areas where more research is needed and what challenges exist for implementing assessment methods across the supply chain. Applicability will be compared for different types of energy producers, and specific recommendations will be made based on size, feedstock, location, process, products, and resource availability. The ways in which these factors are likely to affect attitudes, operations, impacts from a sustainability standpoint will be explored.

This paper will come from educational materials offered as part of the AIChE Credential for Sustainability Professionals.

1:36 PM Biogas Generation from Sanitary Landfill Leachate
Victor Mello[1], Valmir Lima[2], Sávio Holanda[3], Joelma Ferreira[3], José Fernando Jucá[4] and Mauricio Motta Sobrinho Sr.[5], (1)Engenharia Civil, Universidade federal de Pernambuco, Recife, Brazil, (2)Universidade Federal de Pernambuco, Recife, Brazil, (3)Universidade federal de pernambuco, Recife, Brazil, (4)Universidade federal de pernambuco, recife, Brazil, (5)Universidade federal de Pernambuco, recife, Brazil

Abstract:
The use of alternative sources of energy not only contributes to environmental sustainability and for diversifying the energy matrix, which in the case of Brazil , has a high renewable portion (45%). The possibility of obtaining energy when treating an effluent has been a current focus of fundamental and applied research, and the last developed by companies or partnerships with research institutions. The anaerobic degradation process generates a blend rich in methane (70 to 50%) to degrade solid or liquid contaminants. The generation of biogas from landfills is already a reality, with several installations in

operation in the country. However the treatment of leachate (liquid derived from the anaerobic degradation diluted in water from the landfill itself) is one of the main barriers to the installation of this type of disposal for waste, for its complexity , toxicity and recalcitrance. To estimate the potential for generation of biogas from waste is generally used the BMP test (Biochemical Methane Potential), which assesses the biodegradability of waste from the total production of biogas (containing mainly CH_4 and CO_2) under controlled conditions, knowing the initial composition of the waste and the conditions they are subjected to biodegradation (ALVES, 2008). However, the increase of pressure inside the bottle can shift the equilibrium of the reaction, underestimating the generation of biogas. It is noteworthy that the ratio F:M. (organic load/microorganism), the head-space of the bottle and the pH (which should be close to neutrality) may influence the production of biogas. Consequently, this study aimed to evaluate the influence of parameters mentioned in the production of biogas through a 2^3 full factorial design in BMP trials. All experiments were performed in triplicate. The leachate used was collected from the landfill leachate treatment unit of Muribeca and presented a COD of 3,066 $mgO_2.l^{-1}$, and pH of 8.3, which was adjusted according to the planning (6.0, 7.5, 8.5). The anaerobic sludge was provided by Brazil Kirin brewery (Guabiraba - PE). In parallel, a blank experiment, with only a white sludge, was realized to evaluate the biogas production with the organic matter of the sludge itself. In order to minimize the pressure effect, every time that it reached 0.8 bar, there was release of the bottle. Under the condition of 50 ml of sludge (VSS = 152.27$g.L^{-1}$) leached in 50 ml of pH 7.5, the production rate was 9.7 $ml.d^{-1}$and the total volume of biogas generated was 277 ml. The methane concentration in the biogas from leachate was 67% and in the bottle with only anaerobic sludge was 55%.

1:54 PM The Potential Use of Waste Stabilization Ponds for Biofuel Production By the Microalgae Biomass
Marcella Paiva, Civil engineering, UFPE, Olinda, Brazil

Abstract:
In the work the performance of a real scale polishing pond treating domestic wastewater in Rio Formoso city Southern coast of Pernambuco State, Brazil was evaluated. The principal objective was investigate the the potential use of waste stabilization ponds for biofuel production by the microalgae biomass Samples were taken monthly at two different times (2h and 14h) comprising a period of six months (from Janury till June of 2011) covering the rainy and dry seasons. It was observed that the phytoplankton community was represented by 40 taxa belonging to divisions Cyanophyta, Chlorophyta and Euglenophyta, being the Cyanophyta the most representatives comprising (45% from total). We found that the higher and lower biomass density was observed during January and June in both periods (diurnal and nocturne) These months represents respectively the dry and rainy periods in the region, showing that a higher sunlight penetration promote a higher algae growth on the water column. By the diagnosis of the potential use of algae growing in the polishment pond from Rio Formoso WWTP, it was possible to observe the biomass concentration, and to propose ways to optimize the biomass growth for an efficient and sustainable biodiesel production.

2:12 PM The Sustainability of Brazilian Sugarcane Ethanol: The Contribution of the Brazilian Bioethanol Science and Technology Laboratory (CTBE)
M. Regis L.V. Leal, Brazil Bioethanol Science and Technology Lab, Campinas, Brazil

Abstract:

The Brazilian Bioethanol Science and Technology Laboratory (CTBE) was created in 2010 by the Ministry of Science, Technology and Innovation (MCTI) as a research institution to fill the gaps in science and technology that had been identified in the production chain of sugarcane ethanol. As a national laboratory it is open to receive outside researchers, from universities, research centers and private companies, to use its facilities and staff expertise. The handling of the key technology gaps had been distributed in five divisions working in close association and focusing on improving the sustainability of our main biofuel:

- Biomass Production: designing a new concept of agricultural mechanization for sugarcane to reduce the production costs, negative impacts on the soil, greenhouse gas emissions and use of fertilizers and chemicals.
- Biomass Processing: develop the complete processing chain of sugarcane residues to second generation ethanol (2G), counting on a very flexible pilot plant and several supporting laboratories; the 2G ethanol is expected to decrease the production costs and land demand.
- Functional Biology, Biotechnology, and Biophysics: understanding the sugarcane plant physiology, cell wall structure and deconstruction and enzyme production.
- Integrated Evaluation of Biorefineries: process simulation for 1G/2G ethanol and other products from sugarcane.
- Sustainability of the Production of Biomass and Bioenergy: GHG emissions Lifecycle Analysis, land use change dynamics, soil carbon stock and emissions, impacts on water availability and quality, biodiversity and socioeconomic issues.

As a young institution CTBE has already been able to demonstrate that it is possible to bring the private sector and academia together in the search for more sustainable alternatives of bioenergy production from sugarcane. The mains projects in development will be briefly presented as well as the main partnerships with universities and private companies.

2:30 PM Comparison of Acid and Enzymatic Hydrolysis of Jerusalem Artichoke Tubers for Fermentative Butanol Production

Tahereh Sarchami, Chemical and biochemical engineering, University of Western Ontario, London, ON, Canada

Abstract:
In this study, a central composite design and response surface methodology were used to study the effect of various hydrolysis variables on both acid and enzymatic hydrolysis of Jerusalem artichoke-derived inulin. It was found that quadratic model was able to predict inulin conversion as a function of all investigated factors in both types of hydrolysis. The models were confirmed by additional experiments and via analysis of variance (ANOVA). Subsequently, numerical optimization was used to maximize the inulin conversion (94.5% in enzymatic hydrolysis and 96% in acid hydrolysis) of Jerusalem artichoke powder within the experimental range. The optimum conditions for enzymatic inulin conversion were a temperature of 48°C, pH of 4.8, substrate concentration of 60 $g.l^{-1}$, and enzyme loading of 10 unit. $g^{-1}_{substrate}$ in 24 hours. For acid hydrolysis using Sulphuric acid as catalyst, the optimum conditions were achieved at a temperature of 97°C, pH of 2.0, and in 35 minutes.

The hydrolysates of Jerusalem artichoke were fermented via solventogenic clostridia to acetone-butanol- ethanol (ABE). ABE yields of 0.33 $g.g^{-1}$ and 0.31 $g.g^{-1}$ were obtained using enzymatic and acid hydrolysates of Jerusalem artichoke, respectively. Acid hydrolysis produced HMF as fermentation inhibiting byproduct resulting in a lower yield compared to enzymatic hydrolysis. Therefore, enzymatic

hydrolysis of Jerusalem artichoke was found to be a more effective method of hydrolysis for butanol production.

2:48 PM Understanding Concentration and Pressure Changes during Ultrasonication-Enhanced Blending of Petrol-Ethanol Blended Fuel

Diakanua Nkazi, Michael O Daramola and Sunny E Iyuke, School of Chemical and Metallurgical Engineering, University of the Witwatersrand, Johannesburg, South Africa

Abstract:
Increasing global energy demand as well as air quality concerns have in recent years led to the search for alternative clean fuels to replace fossil fuels. One such alternative is the blending of petrol (gasoline) with ethanol, which has numerous advantages such ethanol's ability to act as oxygenate thus reducing the carbon monoxide emissions from the exhaust of internal combustion engines of vehicles. However, the hygroscopic nature of ethanol could cause phase separation of the blended fuel and this is a major concern in obtaining a perfectly homogenized petrol-ethanol fuel. Phase separated petrol-ethanol fuel could cause irreversible damages to internal combustion engines. Formation of perfectly homogenized petrol-ethanol blend is the key to solving the problem [1] and this depends on molecular diffusion and eddy diffusion in the vertical and horizontal direction during the process. Several mixing methods such as impinging-jet micro-mixing, high-pressure homogenization techniques have been proposed as a measure to overcome the problem [2], but ultrasonication is the most promising of all.

Ultrasonic cavitation generated during ultrasonication is an effective type of dynamic agitation due to the growth and implosive collapse of bubbles in liquid as a result of ultrasonic vibration [3]. Also designing a blender to achieve perfectly homogenized petrol-ethanol fuels via ultrasonication-enhanced blending depends on the in-depth understanding of concentration and pressure changes during the mixing. Therefore in this study, investigation was conducted to investigate effect of the position of ultrasonicator's horn on the concentration and pressure changes during ultrasonication-enhanced blending of petrol-ethanol fuels. Understanding the concentration and pressure changes during the process could pave a way for the design of a blender to achieve a perfectly homogenized petrol-ethanol blend.

Petrol-ethanol mixtures were prepared and the ethanol concentrations in the mixtures were 10%, 20% and 30% v/v. A 2.5 l-beaker of diameter 1400 mm was using the blending. During the blending, the position of ultrasonicator's horn was fixed in the beaker and the concentration and pressure were measured at distance ranging from 10 mm to 40 mm away from the position of the horn to understand effect on the homogenization of the mixture. The measurement was conducted at both horizontal and vertical distance away from the horn. The pressure during the ultrasonication-enhanced blending was measured with an oscilloscope and the ethanol and petrol concentrations in the samples withdrawn at time intervals during the mixing were analysed with a pre-calibrated high performance liquid chromatography (HPLC).

Concentration gradient, energy gradient (indicated by pressure) and diffusion rates were higher in the vertical direction when compared to the behaviour in the horizontal direction, therefore making the diffusion in the horizontal direction a rate-limiting step. This suggests that the dimensions of the blender that will ensure perfectly homogenized mixture should have larger height-to-diameter ratio. In addition, the results reveal variation of pressure with time due to the changes in the ultrasound energy at different vertical and horizontal distances away from the fixed position of the horn. Between 120 and

360 seconds of the ultrasonication-enhanced blending, the pressure gradient became zero (a plateau), indicating a constant distribution of ultrasound energy, hence perfectly homogenization of the petrol-ethanol blend. The concentration profile with distance during the blending follows a wave function but the concentration of ethanol as a function of time in the mixture remained constant in the both horizontal and vertical distance away from the fixed position of the horn of the ultrasonicator. The observed behaviour could be exploited towards designing a blender with high efficiency for ultrasonication-enhanced blending of petrol-ethanol fuels.