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Catching-up with the Ethanol Opportunity:
The Emergent Ethanol Industry in Honduras

Master of Science [Management and Economics of Innovation]

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Göteborg, Sweden, 2007
ISSN 1404-8167

ESA-Report No. 2007-17
ISSN 1404-8167

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Executive Summary

Currently petroleum is considered to be the most important energy source around the world; allegedly by its high energy density, easy transportability and relative abundance (which has been recently challenged). Recently the world has experienced many crises directly related to oil supply and increasing concern about climate change strongly linked with the use of fossil fuels. Uncertainty about future oil supply and the effects that CO2 emissions are having over the environment are the two main drivers that are encouraging the emergence of different energy alternatives.

Biofuels – fuels derived from biomass- appear as a promising alternative. Ethanol is an alcohol that in water-free form can be blended with gasoline and used as an energy source to power engines. A considerable world movement towards its promotion is perceivable. Until recently, most of the biofuel programs were created as part of agricultural-support policies; but today, many governments are extending such programs for energy security and economic and environmental reasons. Several developed and developing countries have established regulatory frameworks for biofuels such as blend targets and consumption level, and providing subsidies and incentives to support nascent biofuel industries.

The purpose of this master's thesis is to analyze the emergent ethanol industry in Honduras and identify the main blocking and enhancing mechanisms that will be faced in order to facilitate its further development. To do so, an innovation system approach was applied to the Honduran case. This framework was selected on the basis that it provides a systematic model based on the perception that the innovation process is not limited to individual firms, but to several related firms that are embedded within an IS that guides, aids and constrains them.

To perform this thesis, a brief analysis of ethanol technologies and the global ethanol landscape was performed in order to gain a fair understanding of the ethanol market, and identify important trends that could influence the Honduran IS. The main sources considered were: governmental reports, international organization reports, newspaper articles, Chalmers e-journal database (Elsevier Science, Research Policy, etc.), PhD and Masters Theses. After this, the thesis focused in the Honduran case. First, the

structure of the Honduras system was defined; second, its performance was described and evaluated; and third, several blocking and enhancing mechanisms were identified as the result of the system's assessment. The data for this analysis was obtained from local governmental reports, web pages of different local organizations and companies involved in the ethanol supply chain. Semi-structured interviews with actors involved in the nascent ethanol industry complemented this data.

Ethanol is currently produced from sugar and starchy crops – first generation- such as sugar cane or corn. Higher oil prices and lower production cost from advances in conversion technologies has made ethanol more competitive with oil-based fuels. While sugar cane ethanol competes effectively with conventional fuels, corn ethanol does not without subsidies. First generation ethanol presents environmental benefits in comparison with oil fuels. However, there is still concern regarding the effects on land use and displacement of food needs. Other promising biomass as cellulosic materials, which require more complex conversion technologies, can permit biofuels to play a more important role in the long term.

At the moment, the international trade of ethanol has remained low, but most of the forecasts show the production and use of ethanol will increase. Developed countries have limited land availability and ethanol production costs are higher than tropical and subtropical developing countries. The experience of Brazil in the development of an ethanol industry has pulled other developing countries in the Latin American region to engage in biofuel programs. They want to catch-up the opportunities of serving this increasing demand, reduce their dependence on fossil fuel and diversify its agriculture industries. There is window of opportunity to continue exploiting the advantages of the sugar cane to ethanol technology, since no breakthrough is expected in the next 10 years. In this context, Honduras has given the first steps toward the creation of a biofuel industry.

The Honduran ethanol innovation system is very young and there is still no commercial production of ethanol; but yet, several signals of structural development and dynamism can be spotted. First of all, there are several actors within the system that are already interacting between each others. This has created a number of networks, both learning and political, that have started to mobilize knowledge and

influence across the system. There are also some initiatives regarding the establishment of an institutional framework that would dramatically help the system to further develop.

As the system is going through a systematization phase, the interactions between the components of the system are already taking the first steps of functional development. *Knowledge Development and Diffusion* is been performed fairly well. An important generation of knowledge related to the production of feedstock for biofuels is happening and is likely to become more active. The system is taking advantage of the core capability of the country, which is agricultural expertise. The system is likely to strongly pursue to sugar cane as the primary feedstock used for ethanol production. *Market Formation* in the international landscape looks very promising. In the national context, the formation of an initial nurturing market is almost entirely dependant on the establishment of a mandatory blend through the approval of the so expected "Biofuels Law". Although non tangible ethanol production projects have actually started, *Entrepreneurial Experimentation* can be considered to be somewhat positive. This is due to the many motions and expectations from investors and entrepreneurs that are interested in the industry. *Resource Mobilization* has started with a number of investment projects announcements, both from national and international sides. This gives the system some important initial dynamism, but any entrepreneurial initiative is considerably discouraged by the absence of a positive national institutional framework. An opportunity for Honduras to diversify its agricultural sector and mitigate the heavy burden of petrol imports have also contributed to create *Legitimacy* over ethanol.

Several enhancing mechanisms that provide positive dynamism to the system were identified. Nevertheless, a "Weak Advocacy Coalition" and an "Unclear Governmental Position and Support" are two critical issues present in the system that are negatively affecting it. The lack of strong connections between key actors and the ambiguous position that the government is portraying are two main challenges that need to be overcome in order to develop the industry. Sugar producers have maintained a rather independent and leader position that has actively ignited the whole biofuels movement in the country. However, they have failed to create strong liaisons with other important actors, situation that has deteriorated their bargaining

power over time. The main challenge for the private sector is to work together with other actors, such as fuel distributors, financers and the government. Its goal is to create a strong coalition that would allow them to exercise pressure over the governmental institutions involved in the creation of the institutional framework.

The "Unclear Governmental Position and Support" is another identified critical blocking mechanism. While the executive government, through the Presidential Special Projects Office, shows a strong commitment to biofuels; the legislative government seems to have forgotten about the subject. This situation brings important instability to the system creating an uncertainty that investors are afraid of and, spurs other actors' reluctance. The challenge for the government is to define a joint strategy where the involved governmental entities delineate their roles and commit to the subject. In this way, a more stable situation can be perceived by entrepreneurs and investors that would encourage them to move resources in a certain field.

At this early stage these are two of the main challenges for the actors; however, as the system evolves over time, many other implications will arise, creating more different challenges. The Honduran ethanol industry has promising development expectations. Honduras has the possibility of becoming one important actor by catching-up with the ethanol opportunity.

Resumen Ejecutivo

Actualmente el petróleo es considerado una de la fuentes energéticas mas importantes en el mundo, debido a su alto contenido energético, fácil transportabilidad y relativa abundancia. Recientemente se han experimentado varias crisis directamente relacionadas con su abastecimiento. Otro problema importante es la creciente preocupación en torno al cambio climático, la cual se encuentra directamente relacionada con el uso de combustibles fósiles. La incertidumbre acerca de las reservas de petróleo y los efectos de las emisiones de CO2 sobre el medio ambiente son los puntos centrales que impulsan el desarrollo de energías alternativas.

Los biocombustibles – aquellos derivados de biomasa- surgen como una prometedora alternativa. El etanol es un alcohol que puede ser mezclado con gasolina cuando está libre de agua y usado como fuente de energía para motores. Un considerable movimiento mundial ha favor de la promoción de biocombustibles esta siendo percibido. Inicialmente la mayoría de los programas de biocombustibles fueron creados para fomentar el desarrollo agrícola, sin embargo hoy, muchos gobiernos han extendido estos programas por razones de seguridad energética, económicas y medio ambientales. Varios países desarrollados y en vías de desarrollo han establecido marcos reguladores para promover los biocombustibles, como metas en las mezclas obligatorias y niveles de consumo, además de proporcionar incentivos monetarios para apoyar esta naciente industria.

El objetivo de esta tesis es analizar la emergente industria del etanol en Honduras e identificar los principales mecanismos de bloqueo y fomento que esta industria enfrentara para facilitar su desarrollo futuro. Con este objetivo, se ha aplicado el marco conceptual de sistema de innovación (SI) al caso de Honduras. Este enfoque fue seleccionado debido a que provee un modelo sistemático basado en la idea que el proceso de innovación no se limita a empresas individuales, sino a varias empresas relacionadas integradas en un SI que las guía, asiste y limita.

Para realizar esta tesis fueron analizadas las tecnologías asociadas con la producción de etanol y el panorama mundial de este biocombustible, con el objetivo de identificar importantes tendencias que puedan influir en el SI hondureño. La principales fuentes

utilizadas fueron: reportes gubernamentales, reportes de organizaciones internacionales, artículos de diarios, bases de datos electrónicas de publicaciones de Chalmers (Elsevier Science, Research Policy, etc.), tesis doctorales y de magíster. El paso siguiente fue focalizar el estudio en el caso hondureño. Primero, la estructura del sistema fue definida y segundo su funcionamiento fue descrito y evaluado, dando como resultado la identificación de varios mecanismos de bloqueo e impulso. Los datos para este análisis fueron obtenidos de reportes gubernamentales locales, paginas web de diversas organizaciones locales y compañías relacionadas en la cadena de producción del etanol. También fueron realizada entrevistas con actores involucrados en la emergente industria.

El etanol es actualmente producido de cultivos que contienen azúcar y almidón – primera generación- ejemplos son la caña de azúcar y el maíz. Los altos precios del petróleo y los bajos costos de producción del etanol, debido a los avances en las tecnologías de conversión, han llevado a que el etanol sea competitivo con los combustibles fósiles. Mientras el etanol de la caña de azúcar compite efectivamente, el etanol de maíz no puede hacerlo sin subsidios. La primera generación de etanol presenta beneficios medio ambientales en comparación con combustibles convencionales. Sin embargo, existen preocupaciones acerca de los efectos en el uso de la tierra y el desplazamiento de cultivos para alimentación. Otras biomasas que se muestran prometedoras son los materiales celulosos, que requieren tecnologías de conversión mas complejas y que podrían permitir a los biocombustibles jugar un papel mas importante en el largo plazo.

Aunque el comercio internacional del etanol ha permanecido bajo, la mayoría de pronósticos muestran que su producción y su uso incrementará. Los países desarrollados tienen limitaciones en cuanto a disponibilidad de tierra y los costos de producción son mas altos que en los países en vía de desarrollo con clima tropical y subtropical. La experiencia de Brasil en el desarrollo de la industria del etanol ha atraído a otros países en vías de desarrollo de la región a involucrase en programas de biocombustibles. Estos países quieren aprovechar las oportunidades de servir esta creciente demanda, reducir su dependencia de combustible fósiles y diversificar sus industrias agrícolas. Actualmente existe una ventana de oportunidad para continuar explotando las ventajas de la tecnología del etanol de caña de azúcar, debido a que

ningún avances tecnológico radical se espera para los próximos 10 años. En este contexto, Honduras ha dado los primeros pasos hacia la creación de una industria del biocombustible.

El SI hondureño es bastante joven y aun no existe producción comercial de etanol, sin embargo algunas signos de desarrollo estructural y dinamismo han comenzado. En primer lugar, varios actores dentro del sistema están interactuando, creando un número de redes, eolíticas y de aprendizaje, que han empezado a movilizar conocimiento e influencia a través del sistema. Hay también algunas iniciativas con respecto al establecimiento de un marco institucional que ayudaría dramáticamente al desarrollo del sistema..

A medida que el sistema va avanzando hacia una fase de sistematización, las interacciones entre sus componentes están tomando los primeros pasos hacia al desarrollo funcional. El *Desarrollo de conocimiento y la Difusión* se han realizado bastante bien. La generación de conocimiento relacionado a la producción de materia prima para biocombustibles se está desarrollando y es probable que se vuelva más activa. El sistema está tomando ventaja de la competencia agrícola del país. Es probable que el sistema establezca la caña de azúcar como principal materia prima para la producción del etanol. La *Formación del Mercado* internacional parece muy prometedora. En el contexto nacional, la formación de un mercado inicial es casi completamente dependiente del establecimiento de una mezcla obligatoria a través de la aprobación de la esperada "Ley de Biocombustibles". Aunque ningún proyecto tangible de producción de etanol ha comenzado, la *Experimentación Empresarial* puede ser considerada hasta cierto punto positiva. Debido principalmente a los movimientos y expectativas percibidas por parte de los inversionistas y empresarios en al industria. La *Movilización de Recursos* ha surgido en la forma de varios anuncios de inversiones, nacionales e internacionales, entregándole al sistema un dinamismo inicial importante. No obstante cualquier iniciativa empresarial puede perder poder por la ausencia de un marco institucional nacional concreto que lo fomente. La oportunidad para Honduras de diversificar su sector agrícola y mitigar la pesada carga de importaciones de gasolina también ha contribuido para crear *Legitimidad* en favor del etanol.

Varios mecanismos de fomento que entregan al sistema un dinamismo positivo fueron identificados. No obstante, una "Débil fuerza de Coalición" y una "Confusa Posición y Soporte Gubernamental" son factores críticos que afectan negativamente al sistema. La falta de conexiones robustas entre los actores claves y la ambigua posición del gobierno son los principales desafíos que se necesitan resolver para desarrollar la industria. Los productores de azúcar han mantenido un liderazgo independiente que ha puesto en marcha el movimiento a favor de los biocombustibles. Sin embargo, no han logrado crear fuertes enlaces con otros importantes actores, situación que ha deteriorado su poder negociador a lo largo del tiempo. El mayor desafío para el sector privado es trabajar junto con otros actores, como distribuidores de petróleo, financistas y el gobierno, con el objetivo de crear una coalición sólida que les permita presionar a las instituciones gubernamentales involucradas en la creación del marco institucional.

La "Confusa Posición y Soporte Gubernamental" es otro mecanismo de bloqueo identificado. Mientras el ejecutivo, a través de la Oficina Presidencial de Proyectos Especiales, muestra un fuerte compromiso hacia los biocombustibles, el poder legislativo parece haber olvidado el tema. Esta situación es fuente de inestabilidad en el sistema, creando incertidumbre para los inversores que al mismo tiempo crea reticencia en otros actores. El desafío para el gobierno es definir una estrategia conjunta, donde las entidades gubernamentales involucradas delineen sus roles y se comprometan. De esta forma, una situación mas estable podrá ser percibida por parte del sector privado, que en consecuencia podría inducir al movimiento de recursos.

En esta temprana fase estos son los dos retos centrales que enfrentan los actores, sin embargo, al tiempo que el sistema evolucione otras implicaciones aparecerán, creando diferentes retos. La industria hondureña del etanol presenta prometedoras expectativas y podría permitir a Honduras convertirse en un importante actor si lograr capturar las oportunidades de desarrollo del etanol.

Acknowledgements

We would like to thank our supervisors, Hans Hellsmark and Karl Hillman, for the important support and wisdom they provided to us throughout this thesis project. We would also extend our special thanks to our examiner, Professor Staffan Jacobsson, whose inspiring lectures encouraged us to pursue the realization of this master thesis and deepen our knowledge regarding public policy and innovation systems.

We are very thankful to all the interviewees who provided us with vital information required for the fulfillment of this master thesis's goal.

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Acronyms

ADIHVA	Asociación Hondureña de Distribuidores de Vehiculos Honduras Association of Cars Distributors
AICA	Asociación de Ingenios Centroamericanos Association of Sugar Producers of Central America
APAH	Asociación de Productores de Azucar de Honduras
AHDIPPE	Asociación Hondurena de Distribuidores de Productos del Petroleo Association of Petrol Products Distributors of Honduras
BANADESA	Banco Nacional de Desarrollo Agricola National Bank of Agriculture Development
CABEI	Central American Bank for Economic Integration
EAP	Escuela Agrícola Panamericana Pan-American Agriculture School
ENP	Empresa Nacional Portuaria National Harbor Enterprise
FHIA	Honduran Agricultural Research Foundation
IADB	Inter-American Development Bank
IEA	International Energy Agency
IICA	Inter-American Institute for Cooperation in Agriculture
RFA	Renewable Fuel Association
SAG	Secretaría de Agricultura y Ganaderia Secretariat of Agriculture and Livestock
SERNA	Secretaría de Recursos Naturales y Ambiente Secretariat of Natural Resources and Environment
SIC	Secretaría de Industria y Comercio Secretariat of Industry and Commerce
UNAH	Universidad Nacional Autónoma de Honduras National Autonomous University of Honduras
WWI	World Watch Institute

1 Introduction

Since the industrial revolution in the 18th century, mankind has experienced an ever growing demand for energy. Steam power became one of the most important sources of energy to power machines but, in the early 19th century another source of energy emerged. Driven by the demand for kerosene and oil lamps, petroleum began to gain momentum and in the early 20th century its importance enormously grew because of the introduction of the internal combustion engine. Nowadays, petroleum has become the most important energy source around the world allegedly by its high energy density, easy transportability and relative abundance. This relative abundance has been recently challenged to the point that some organizations have set 2014 as the year where oil demand will surpass oil supply (Campbell, 2003). It is well known that the world has recently experienced many crises directly related to oil supply. There is also another issue that goes by hand with the fossil fuel dilemma and that is, environmental concern. Global warming is a problem that occupies a relevant place around the world and it has been strongly linked with the use of fossil fuels as a primary energy source, especially for the transport sector. Uncertainty about future oil supply and the effects that CO2 emissions are having over the environment are the two main drivers that are encouraging the emergence of different energy alternatives.

In the last few years, the production and use of biofuels has increased. Developed and developing regions are experiencing several movements towards the promotion of biofuels. However, considering the current technology, developed countries will not be able to produce the ethanol required to achieve their oil displacement targets. Latin America[1] and Africa are the regions with the most potential to be able to become the main producers of biofuels. As the worldwide conditions are improving for the commercialization of ethanol, many Latin American nations are keen on following this opportunity; not mainly driven by environmental purposes but for economic development.

Ethanol – a transport fuel from biomass- is a promising biofuel that has generated a lot of attention worldwide, encouraged mainly by the Brazilian experience in the production and use of biofuel. Still, the potential of ethanol has been obscured by

[1] This refers to the Central America and Caribbean countries, and South American countries

several negative circumstances as food competition, energy balance and indirect pollution. If the world decides to establish ethanol fuel as an important energy source, many implications would emerge and some of them will represent tremendous opportunities for some regions.

The purpose of this master's thesis is to analyze the ethanol industry in Honduras and identify the main blocking and enhancing mechanisms that will be faced in order to facilitate its further development. Jacobsson & Bergek (2006) present a Technological Innovation System framework that fitted our expectations and was therefore used as a basis of analysis. This analytical framework is further described in chapter 2. The used methodology is also presented in chapter 3.

Chapter 4 offers a description of the ethanol fuel technologies. It is important to consider the technology that characterizes the industry because it helps to better understand the system that is subject of analysis. It is presented the current biomass-first and second generation- used to obtain ethanol, their respective conversion processes, estimation of ethanol production cost, and finally the environmental impact of producing ethanol.

Chapter 5 presents a brief overview of ethanol fuel worldwide. The Honduran innovation system is emerging as a response to a global opportunity and its performance is influenced by some exogenous conditions. The Global ethanol Landscape portraits the current situation of ethanol fuel regarding production, consumption and public policy; and then, some important trends are identified.

The case of Honduras is presented in chapter 6. First, a brief description of the sugar production history and current situation is presented in order to understand the emergence of an ethanol fuel industry in Honduras. Section 6.2 is divided in three parts: First, the main drivers that have created the initiatives to develop an ethanol industry in the country are presented; then, the identified structure of the system, based on actors, networks and institutions is described; and finally, the dynamics of the system is addressed by describing the situation of the system functions in the Honduran context. The analysis and identified blocking and enhancing mechanisms for the Honduran innovation system are presented and analyzed in Chapter 7.

Some concluding remarks of this study are presented in chapter 8. The Honduran innovation system is still in an early emergent state and there are many challenges that its actors will need to outdo in order to further develop the ethanol industry. Some important enhancing mechanisms such as high oil prices, free trade conditions, technology advantages and private sector leadership were identified. These conditions are creating a fruitful national landscape for the industry to develop. There are still some significant challenges that need to be overcome. The unclear governmental position and support, a weak advocacy coalition, a recent drop in ethanol international price contrasted with a sustained growth of sugar price, and some troubles related to land acquisition are conditions that block the system's development.

2 Analytical Framework

A framework outlining an analytical process to asses the performance of an Innovation Systems (IS) is presented by Jacobsson and Bergek (2006). This scheme of analysis is an updated version of the one proposed by the same authors in 2005, where a 6 steps process was described (Bergek et al, 2005). This framework was selected on the basis that it provides a systematic model based on the perception that the innovation process is not limited to individual firms, but to several related firms that are embedded within an IS that guides, aids and constrains them. Within this IS, firms interact with each other and together – whether they do it consciously or not –, they perform several tasks that ensure the survival and further development of the system and of course, of themselves.

Since the conceptualization of an IS varies among different scholars, a brief discussion aiming to provide a clear reasoning of the selection of the Technological Innovation System (TIS) perspective would be presented in the next section. This is important in order to define the unit of analysis that will be used for this study.

Having defined the type of IS that will be studied, the framework aims to develop an understanding of the key processes that are present during the evolution of a TIS. These processes can be divided in two levels. The first level addresses the structural composition of the system. An emerging TIS involves three structural processes: entry of firms and other organizations, formation of networks and institutional alignment. These processes are important in order to create the three components that made up a

TIS: *Firms and other organizations, Networks and Institutions*. These components are described in section 3.2.

Traditionally, performing a structural analysis of an innovation system was considered to be the most effective way to assess it when the theoretical foundation of intervention rested just on the failure of market mechanisms to achieve an adequate solution to an economic problem. Carlsson (1997) discusses about the dynamic nature of technological systems and how the traditional static approach of market failures is not longer valid to design adequate technological policies. He argues that early policies were based mostly on market failures, i.e., the failures of market mechanisms to reach an optimal solution to an economic problem (caused by the presence of increasing returns to scale and scope, externalities, missing market, coordination problems, uncertainty, etc). But the processes that are executed within an IS are influenced not only by market phenomena or by actors. Institutions and networks also constitute building blocks in that system; so actors/markets, institutions and networks weaknesses can generate 'system failures' as well. Because of these reasons, it is necessary to go further and focus on the dynamics of the system, analyzing the functional performance of a TIS; with the aim of identifying the mechanisms that block or enhance its development. The second level refers to processes that are directly related to the performance of the system. In Section 2.3, the different functions proposed by Jacobsson and Bergek (2006) are described.

2.1 What is an Innovation System?

The concept of Innovation System (IS) has been around for a couple of decades. It is said that the Innovation System approach has been really important, especially for policy makers, when evaluating technological development at an industrial or a higher level. There are many different perspectives on Innovation Systems, mainly because the whole concept leaves room for interpretation due to its intrinsic ambiguity. A system can be defined as a set of different components that are characterized by different attributes and that interact with each other through different relationships. The main perspectives about Innovation Systems can be considered to be: *National, Regional, Sectorial and Technological innovation systems* (Carlsson et al, 2002). Each one of these perspectives take different considerations when defining an Innovation System, but the main issue that accounts for its differences is the way each one

defines the boundaries of the system. Due to this, it is necessary to define each one of the conceptualizations of an IS in order to understand their main implications.

The idea of *National Innovation System* (NIS) was introduced in the mid 1980s and its origin has been debated between academics and policymakers. Disregarding the source of the NIS concept, it is widely accepted that this new economical perspective of technological change was a response of the inadequacy of the neoclassical economic theories (Sharif, 2006). The notion of a NIS centers its attention on the role of nations, where the national geographical boundaries set also the boundaries of the IS and, country specific factors influencing the innovative capabilities of national firms are studied (Edquist, 1997). Both National and Regional perspectives take into consideration the physical or geographical dimensions of the system as the basis for defining its boundaries. The NIS or RIS (Regional Innovation System) consider national or regional borders to be also the boundaries of the Innovation System; and so, all the different companies and institutions that work together through different relationships inside the national or regional borders are the ones that represent the pieces of the IS.

The *Sectorial Innovation Systems* (SIS) perspective defines its boundaries according to a specific industry or sector. The basic idea of this approach is that different industries or sectors function under different technological regimes characterized by particular conditions related to Knowledge, Technology and Economics (Carlsson et al, 2002). Geels (2004) presents an in-depth discussion about the Sectoral level perspective on IS. He also made some contributions to the concept involving the inclusion of the social aspect as a complement of the technological approach, creating a Socio-technical conceptualization. The sectoral innovation system focuses on the firms that are active in the innovation activities of a specific industrial sector. The boundaries of the SIS are set by the specific conditions of each sector, by paying more attention to the sources of knowledge and on the role played by geographical space in the processes of knowledge transfer (Breschi et al, 1997). Sectoral innovation systems can be also related to the "Cluster" conception. A cluster can be defined as geographical concentrations of interconnected companies in a particular field (Porter, 1999).

The perspective on which this study will focus is the *Technological Innovation System* (TIS); because it represents a more versatile conceptualization of the meaning of an IS. Such systems may or may not be geographically and institutionally localized within nations or regions but they may have links to supporting institutions elsewhere (Carlsson, 2005). It's really important to notice that at a certain level the national or even the regional approach might present some limitations for understanding an IS as such. National or regional IS are ever increasing their absorptive capacity and learning to transfer knowledge within their organizations and in the networks and alliances in which they participate, making firms become vehicles for the internationalization of the IS (Carlsson, 2005). A TIS focuses on generic technologies that might have general applications over many industries and sectors (Carlsson et al, 2002). The concept of a TIS centers on the direct influence that the different structural components of the TIS apply over the development and diffusion of a specific technology (Jacobsson et al, 2000).

In order to secure a more understandable and manageable unit of analysis using the technological innovation system approach; in this case the boundaries of the system will also consider national borders. Even though geographical delimitation of a TIS can be useful, is important to notice that its boundaries, in terms of both actors and knowledge, will consequently be altered, sometimes quite fast (Carlsson et al, 2002). Because of this, the global *technological innovation system* will be taken in consideration by developing a general overview of the global ethanol landscape in section 4.

2.2 The Structural Composition of an Innovation System

This study is focused on *Technological Innovation Systems*, and then, it is most relevant to view the system as one of *Firms and other Organizations*, *Networks* and *Institution.*

Firms are all the companies involved in the whole value chain of the system. *Other Organizations* include universities and other academic related institutes and centers, bridging organizations, NGOs, International Cooperation Agencies, government bodies and any other organization that is related to the system. In an innovation system the common components are industries, firms, universities, research institutes

and government agencies (Carlsson et al, 2002). During the formation process of a IS new firms enter into the system bringing new knowledge, capital and other resources that generate benefits for the whole system. Other organizations enter the system as well, improving its performance and enriching even more the pool of resources available. *Firms and other Organizations* can also be referred to as *Actors.* For practical purposes, *Actors* can be organized in different groups according to the activities they perform in the system, following the idea presented by Geels (2004).

Networks describe the relationships through which knowledge is diffused within the system. There are two types of networks identified by IS theory. The first are the Learning Networks; formed to solve technical problems and to improve knowledge transfer in the system, and can be made up by affected firms, users and university-firm collaborations. The second type are the Political Networks, as the name would suggest, formed with those institutions that have influence over the norms and rules that govern the growth of the firms in the IS. Here the concept of advocacy coalitions takes an important role, as it is stated that policy-making takes place within this associations (Jacobsson & Bergek, 2006). As it has been argued before, innovations do not occur within a single firm, and is the reason why *networks* need to be created in order to link all the *Actors* that compose the IS and give the collective a voice in the political arena.

The third component is *Institutions.* This refers to the regulatory regime that governs the system. It represents the set of rules and believes that regulate the firm's behavior, thereby also leading both their growth and future directions. They can also influence the perception of what is possible and desirable. *Institutions* also consider tacit norms and regulations, which can be understood as culture; implying that the social environment also affects the system, not just explicit law (Jacobsson & Bergek, 2006).

2.3 The Dynamics of an Innovation System

Mapping the structure of an IS is important to identify the different *firms and Other Organizations, Networks and Institutions* that shape the system. In order to understand the performance of the systems, we shift focus and pay more attention to the interaction amongst the different actors and how their behavior is affected. The different functions that are performed within an IS become the subject of analysis.

i. Knowledge Development and Diffusion

Knowledge plays a central role in innovation and it differs across institutions, sectors and firms in terms of scientific and technical scope (Malerba, 2002). Individual *Actors* are not capable to manage the whole burden of knowledge development and diffusion alone, thus there is the need of collaboration (Bergek et al, 2007). This function is related to the knowledge base of the IS (globally) and it performs in further developing and diffusing knowledge. An IS should facilitate the creation, storing and transfer of knowledge; it should create the bridges for the different organizations inside and link the scientific issues with the technical ones, leading to the exploitation of opportunities (Metcalfe, 1994).

ii. Influence in the Direction of Search

People possess and process information in different ways; therefore, it is unlikely that all of them identify the same opportunities (Shane, 2000). Opportunities arise due to several factors like technological breakthroughs in universities, advancements in firms R&D and the interaction with customers and suppliers (Malerba, 2002). This function refers the opportunities that are perceived within the system and the factors that influence the search and investment behavior of *firms and Other Organizations* within the IS. Some influencing factors can be the growth potential of the sector or technology, the changes in the environment of the firm such as regulations and public perception, and technical bottlenecks that need to be overcome (Bergek, 2007).

iii. Entrepreneurial Experimentation

One of the most important issues regarding macroeconomic policy is the nurturing of entrepreneurial activity to stimulate innovation, productivity and growth in the economy (Sarasvathy, 2001). Entrepreneurial activity is important to enhance economic growth since it has direct impact on economic factors such as employment rates and taxation incomes; but, it also has major implications from a technological development perspective. Entrepreneurs are likely to bring new knowledge and develop new capabilities that would improve the performance of an IS. Innovation Systems usually emerge in locations that provide certain conditions that imply a

comparative advantage (cheap labour, natural resources, research and industrial capabilities, etc), but these special conditions require the efforts from many entrepreneurs to take advantage of them and create capabilities that would eventually benefit the whole system. Van de Ven (1993) refers to entrepreneurs as those who "construct and change the infrastructure" of the industrial system. Entrepreneurs first visualize an individual business opportunity; establish then cooperative and competitive relationships in order to benefit from complementary specialization and alternative technological paths. The existence entrepreneurs that will be capable and eager to take the challenge to work in an uncertain innovative business is necessary. The entrepreneurs that pioneer in a new industry promote essential conditions as the formation of new entrant firms, support institutions, and develop organizational and market capabilities (Breshanan et al, 1998).

iv. Market Formation

Emerging ISs are usually engaged in markets that are inexistent or to a great extent underdeveloped. This situation can imply the absence of marketplaces, inability of potential customer to recognize and articulate their own needs, low productivity levels of the new technology and the prevalence of many uncertainties (Jacobsson and Bergek, 2006). New technologies require the creation of markets that are big enough to secure the further development and expansion of the system they are involved in. If there are not enough buyers for each stage of development, the system will lag behind and most likely cease existing. In the absence of certain buyers, companies may have to put much effort on marketing and spend too much energy and resources that the projects of new technologies might be shut down before success can occur (Moore, 2004, chapter 4).

v. Legitimization

The perception of the adequacy or "goodness" of a new technology, from industry and society as a whole, is critical to determine the level of acceptance and compliance that this technology will face. Proponents of the new technology must ensure that they are considered suitable and advantageous by other organizations that would promote *resource mobilization* and/or *influence in the direction of search*. *Legitimization* is a

process that aims to facilitate the system to become liable and accepted. It could become a lengthy process, especially when it faces aggressive competition from existing systems that feel threaten by the new IS. The formation of Advocacy Coalitions (organized groups of *actors* working toward a common goal) is important since they apply pressure over the different components of the system and influence the direction of the system by shaping its institutional regime.

vi. Resource Mobilization

Securing financing, human capital and complementary assets, and further more; making possible for all them to work together, is an important task that needs to be executed within a IS. An IS musts develop the infrastructure in terms of knowledge and physical assets necessary to undertake the innovation processes (Bergek, 2007).

vii. Development of Positive Externalities

An IS enables the creation of new agents, a variety of approaches and specialization among different *actors*. Structural changes occur due to the entrance of new firms, the emergence of pooled labor markets, the value chain development and some sort of division of labor. Informal trade of knowledge is created and this ultimately leads to spill-overs. These externalities which arise more easily because the existence of the IS, boost the creation and development of successful innovations (Bergek, 2007) (Malerba, 2002) (Metcalfe, 1994). The creation of positive externalities comes to be a function that determines the dynamics of the system; since it represents how the other functions are interacting together.

3 Methodology

This chapter describes the methodology used to analyze the ethanol industry in Honduras, and identify the main blocking and enhancing mechanisms that will be faced in order to facilitate its further development. The framework explained in the previous chapter is the foundation to the used methodology. In Figure 1, a scheme of the analytical process followed for this study is presented.

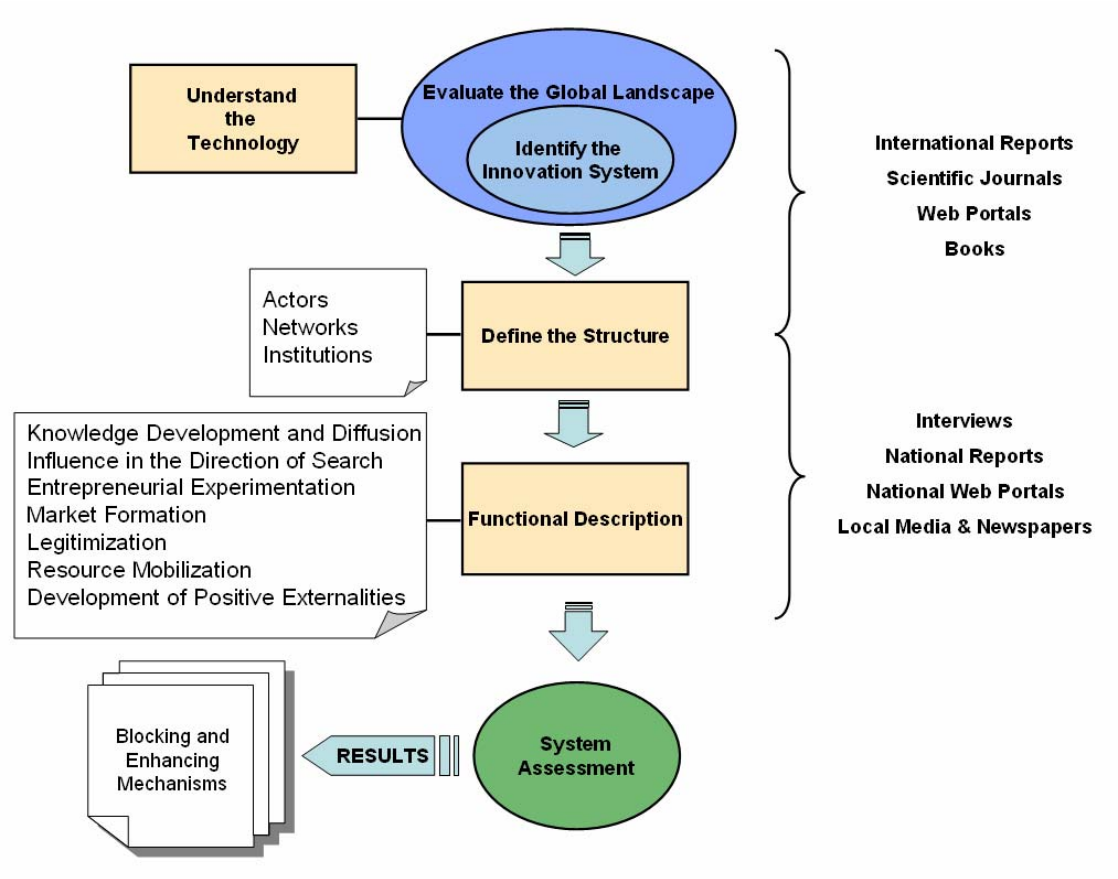


Figure 1. Methodological Scheme

Understand the Technology

Before performing a study over an industry it is important to gain some knowledge regarding the technology involved in that industry. Understanding the technological principles and their differences can also help us to define the system's borders and thus its structural components.

Identify the Innovation System and Evaluate the Global Landscape

To analyze a system it should be clearly recognized. A system is not an island and therefore, it is embedded within a global macro-system. Comprehend the global situation of an industry that is likely to be developed with exports expectations seems to be an important task. Further more, understanding and identifying some exogenous trends that could influence the studied system becomes imperative. This investigation should also provide a review of historical events and other's countries experiences in relation to the studied system.

Define the Structure

Once the system has been identified, the next step is to map its structure. The actors, networks and institutions that compose a system should now be recognized in order to create a well defined layout of the case that will be further analyzed.

Functional Description

Once the system has been mapped, it is possible to identify several actions performed by the system's components that can be related to each of the seven functions proposed by the chosen framework. These performance indicators can later be evaluated and analyzed in order to understand the system's performance.

System Assessment and Results

By evaluating the performance of the system it is possible to identify different enhancing and blocking mechanisms that are affecting the system's development process. These mechanisms can be later evaluated in order to propose possible strategies for them.

3.1 Data Collection and Management

The data collection and management is based on the method "historical event analysis" proposed by Hekkert et all (2004). In our study, the main idea was to compile events that are related to the expansion or constraining of the ethanol industry, at national and global level; and the development, diffusion and implementation of ethanol technologies.

In a global perspective, the main sources considered were: governmental reports, international organization reports –such as the International Energy Agency (IEA), the Economic Commission for Latin America and the Caribbean (ECLAC) and the Inter-american Development Bank (IADB) – newspaper articles, Chalmers e-journal database (Elsevier Science, Research Policy, etc.), PhD and Masters Theses. This data was organized by current ethanol technologies and geographical region.

In a local perspective, secondary and primary data were gathered. Due to the emergent nature of the Honduran TIS, key in the secondary data collection were the newspaper articles from Honduras and other from Latin American countries. Further data were

gathered from local governmental reports and web pages of different local organizations and companies involved in the ethanol supply chain. The primary data collection took the form of semi-structured interviews, i.e., using an interview guide (Appendix 1), based on the secondary data obtained previously and the used research approach. All the actors related to the Honduras ethanol industry were contacted, as a form of maximizing the evidence from primary data. The number of interviewees is those that finally acceded to be interviewed. Appendix 2 shows the interviewees.

The data was organized in two categories. The first one corresponds to the TIS structure: (1) all the actors identified in the ethanol industry, with its respective description and role, (2) institutions and its description and (3) networks, with its components and purpose. The actors were ordered according with the role they play in the IS, in seven domains: product, research, financing, suppliers, market, government and compliment products and services. The second category contains the events related to the emergence of ethanol industry in Honduras.

3.2 Analysis

The structural database allowed directly mapping of the Honduran TIS. The TIS structural analysis constituted the starting point to carry out the functional analysis that in turn reflects the system's performance. To perform the TIS functional analysis, each event from the second data base was associated with a function. To facilitate the allocation of events to functions, a series of indicators were defined:

- *Knowledge development and diffusion*: activities of research organizations and universities related to biofuel. Partnership or alliances toward research and/or knowledge transfer. International cooperation.
- *Influence in the direction of search*: development and interest on different Bioethanol technologies streams. Regulatory framework and governmental action toward Biofuels. Perception of bioethanol as business opportunities by private and public organizations.
- *Entrepreneurial experimentation*: diversity of business models, willingness degree to enter in the industry.

- *Market formation*: Blend strategy. Governmental programs toward consumption of Biofuel. Taxation policies. Situation of foreign markets. Standard and certification requirements, mandatory targets.
- *Legitimization*: media, government and private position toward Biofuel. Existence of lobby groups. Awareness campaign.
- *Resource Mobilization*: Investment projects related with ethanol production, distribution and sale. Capital investment grants. Financers and especial programs related to ethanol, Foreign Investment. Subsidies programs
- *Positive externalities*: Beneficial side effects as a result of the emergence of ethanol industry. Environmental, social and labour aspects. Interaction between functions.

With these indicators, it is possible to identify the performance of each function; and therefore, the dynamism of the system. Once each function has been defined in the case context, they can be analyzed in order to obtain the results that would provide the basis to fulfill the purpose of this thesis.

4 Ethanol Technologies

Before entering the ethanol development in Honduras and exploring the global landscape, it is necessary to address the competing technologies in ethanol production. Understanding the technological principles and their differences can help us to define the system's borders and thus its structural components. Secondly, it is possible to assess the effects of a particular technology on the system functions. For instance: *influence in the direction of search,* since ethanol conversion technologies differ in opportunities to be developed in different regions. The technologies are not equally mature, so the *creation of new knowledge* varies among the processes and require different *mobilization of resources* to be diffused. Specific advantages of ethanol technologies influence its *legitimization* and provide also different positive externalities.

This section reviews the existing conversion technologies to produce ethanol from two biomass categories. The first group is the "first generation", which includes sugar crops and starchy materials. The second group, "second generation", involves

materials rich in cellulose. According with this classification, this is further presented the basic steps for each process, productions costs estimations and environmental impacts of these technologies.

4.1 Feedstock and Process approaches

Currently, a variety of feedstock is used to produce ethanol. Some are rich in sugar while others contain starchy materials or cellulose. Ethanol production from any of those, involves three basic steps: the formation of a mixture of fermentable sugars, the fermentation of these sugars into ethanol, and the separation and purification of the ethanol, usually by distillation. However they differ on the approaches used to release the sugars and generation of different co-products.

4.1.1 First generation

The ethanol obtained from food crops is known as first generation ethanol. Sugar and starchy materials constitute this group.

Sugar feedstock

Sugar cane, in the form of juice or molasses is the most common feedstock used in ethanol production. Countries with tropical and sub-tropical climates present the best conditions to grow sugar cane. Other biomass feedstock rich in sugars include sugar beet, sweet sorghum and various fruits.

Sugar cane can be harvested by hand or mechanically. In the former case the dry leaves of the cane are burned few hours before harvesting, in order to control pest, and reduce harvesting and transport costs. After harvesting, the sugar cane is transported to a processing plant, either to dedicated ethanol plants or in combined ethanol-sugar factories. First the cane is washed and pressed in a mill to extract the juice, leaving a residue (bagasse). Then the juice is fermented using yeasts as catalyst, in a process that takes four to twelve hours. The results are alcohol ethanol and CO2. After fermentation, the ethanol is distilled from other by-products, resulting in a level of purity of approximately 95%. This is often referred to as hydrous ethanol because it contains 5% of water. Hydrous ethanol can be commercialized as fuel for cars running

on ethanol, but not blended with gasoline. This mixture of ethanol and water cannot be separated by simple addition of heat, as is done in the distillation process. Instead, the purification is made by physical absorption process using molecular sieves. Anhydrous ethanol is the final result, nearly 100% pure, which can be blended with gasoline. The remaining dissolved solids, called vinasse, are used as a fertilizer[2] (Grad, 2006).

Starchy materials

Starch contained in grains, as corn or wheat, is also used for ethanol production. Others examples of starchy materials are potato, sweet potato, and cassava.

Starch molecules are made up of long chains of glucose molecules. Before fermentation, starchy materials require a pre-treatment to concert starch into fermentable sugars by malting, enzymes, or acid hydrolysis. Then the mixture can be fermented and distilled. In this case the fermentation takes about 40 to 50 hours (RFA, 2007).

For corn, there are two production processes: wet milling and dry milling. In a corn dry mill, the oil, protein, and fibre in corn are recovered after fermentation as an animal feed known as distiller's dried grain with soluble (DDGS). Wet mills first break corn to divide corn oil, corn gluten meal (CGM), and corn gluten feed (CGF) to capture value for food and animal feed, before the fermentation (Wyman, 2002).

4.1.2 Second generation

Second generation ethanol is made from non-food feedstock that contain sugar in the structural portion of plants, such as waste from agriculture (e.g. straw, corn stover, bagasse), forestry, wood industry, and pulp/paper processes, giving the chance to a larger range of ethanol production. In this waste, about 40 to 50% is cellulose, about 25 to 30% of the dry plant mass is hemicelluloses and another 15 to 20% by dry weight is lignin. Together, this composite of cellulose, hemicelluloses, lignin, and other – generally lesser – ingredients is called lignocelluloses, or just cellulosic,

[2] Vinasse is used in a process called fertirrigation. This consists of using irrigation water to carry and distribute the organic fertilize in the vinasse over the soil (ISSCT, 2007)

biomass (Wyman 2002). The production process is similar to the traditional process used in the starch component of grain or corn. However, cellulosic biomass requires a more complex pre-treatment and hydrolysis steps that use acid or enzymes before the sugars can be fermented to ethanol. Today, there is little commercial production of ethanol and ethanol derivatives from cellulosic biomass, but there is ongoing RD&D in Canada, USA and also in Europe (IEA, 2004).

The conversion of sugar feedstock into ethanol is easier compared to starchy and cellulose materials since it do not require pre-treatment. Even if ethanol from sugar cane is considered a mature technology, new advances and process design could be adopted to augment the process efficiency. Theses advances refer to development of new crops, much higher level of industrial automation; new separation process, higher fermentation productivity and integrate harvesting and transport systems. Cellulosic ethanol appears as a highly promise technology. However, more research is needed to understand the performance of involved processes to meet demanding conditions of efficient pre-treatment. Implementing this technology in a commercial scale may open the door to reach significant improvement from the learning curve.

4.2 Production cost

Estimating the production cost of converting biomass in ethanol is a difficult task due to the subsidies and tax releases in different stages of the supply and value chain. Factors as type of crops, agricultural and processing technologies, land and labour cost, and governmental policies make the cost to vary in different parts of the world. The price of the feedstock in the first generation stands for the largest share of the total production cost, since the processing cost margins are relatively small. The cost of sugar and starchy materials relies on the plant location, plant size and the method for acquiring the feedstock (Cardona, 2007).

The lower input cost, efficient conversion processes, co-generation of energy and the indubitable benefit of the sugar cane as feedstock have positioned Brazil as the lowest-cost ethanol producer. The production costs have dropped around 30% from 1990 (IEA, 2004). More recent data estimate the production cost in US$0.32 per litre of gasoline equivalent (Goldenberg, 2007). Further costs reduction can be possible, by

reducing the intensity of growing cane and also by improving conversion operations, especially in the fermentation stage.

The corn-based ethanol is highly sensitive to the feedstock price, which has a great volatility. During 1980 and 1990 technological improvements on higher yield of ethanol from corn, enzymes required for conversion, and production automation led to lower production cost of corn ethanol. Energy input costs also fell over this period. However the cost has increased since 2002 due to higher price of input energy (electricity and natural gas are the main energy source in the corn to ethanol process). The production cost estimation for corn based ethanol is around US$ 0.41 per litre of gasoline equivalent (Goldenberg, 2007).

In contrast, the cost of processing lignocellulosic ethanol is fairly higher due to higher costs of conversion plants and higher operation costs while the cost of feedstock is mainly lower. Estimating the production cost of large–scale production is very difficult since this technology is currently still under development and ethanol is produced only in pilot and demonstration plants. A recent survey based on projection of commercial plants in US and Canada, estimates that the total capital cost for a large-scale production will be around US$ 156 millions with a production cost of US$ 0.36 per litre of gasoline equivalent (Solomon et all, 2007). The study also highlights the opportunities for further cost reduction as the use of cheap residues for biomass feedstock from other markets, low-cost debt financing, or integration into a bio-refinery platform to increase the product mix to include higher-value chemical co-products.

As has been presented, ethanol production costs differ widely by feedstock, technology and region. A variety of factors affect the cost structure such as feedstock costs, capital and labour costs, scale of production, process efficiency and co-product considerations. According with the estimations on data from 2005, sugar cane ethanol is the cheaper and cost-competitive biofuel compared with gasoline. This situation can remain if the crude oil price continues high, at least US$ 50 per barrel, according to the World Watch Institute (2006). Corn based ethanol can not compete with gasoline without subsidies and if the crude oil prices are below US$65 per barrel (IEA, 2006). In 2005, the price of crude oil averaged US$50.23 per barrel (US$ 0.28 per litre) and

the price has being increasing since, reaching a peek in October 2007of US$ 93 per barrel (US$0.52 per litre) (IEA, 2007). In the future, it is expected that further technological advances can reduce the production cost, especially for sugar cane and cellulosic ethanol.

4.3 Environmental impact of ethanol

The environmental impact of current methods of producing ethanol for fuel usage is usually appraised by three factors. First, the *energy balance* refers to the ratio of energy contained in a unit of final produced ethanol fuel to the energy consumed to produce this unit of ethanol. In this ratio is usually considered only fossil fuel energy inputs, such as energy farm inputs (production and use of fertilizer, seed, transportation of feedstock and the fossil fuel to operate agricultural equipment) and the energy consumed in the ethanol production process[3] (WWI 2006, EIA 2004). Second, the *reduction of CO2* and other greenhouse gas (GHG) emissions compared to gasoline in equal energy content. Third, the *land use change*, i.e., the type of land used to grow crops for ethanol production and it previous use determines the environmental impacts. Agricultural development of important habitat and sensitive ecosystems could impose significant environmental costs in the form of, for example, reduced biodiversity. In contrast, cultivation of land previously degraded by human activities could produce environmental benefits such as the mitigation of soil erosion. In addition, changed land use and farming techniques also affect the environmental impact of the land use.

Sugar cane ethanol

Ethanol from sugar cane presents a positive energy balance, because much of the energy for sugar extraction and fermentation is provided by burning the bagasse that remains after processing. Sugar cane yields are higher than other crops and since in general the more simple process of fermentation uses less fossil-fuel energy. The ratio of ethanol energy output to fossil fuel input averages 8 (Macedo, 2004). Burning bagasse can provide 100% of the thermal energy and 92% of the electricity for

[3] All the studies considered in the comparison of energy balance present data and estimations based on current large scale production plants. Same parameters are used to measure the energy consumed and the final results correspond to the average of energy inputs for several productions plants in US and Brazil, with similar technological level.

processing ethanol from sugar, and less than about 8% comes from fossil sources (Wyman, 2003). CO2 emission from ethanol is about 10% the emissions of energy equivalent litre gasoline (IEA, 2004).

In terms of land use change, the main concern is the land expansion of agricultural crops for ethanol production. This has the potential to contribute to soil depletion and erosion, habitat loss, and reduced biodiversity. The expansions of sugar cane plantations can directly or indirectly threat tropical forests. Native vegetation can be destroyed to grow sugar cane or to be transformed in pasture or agricultural land for others food-crops, after being displaced by sugar cane cultivation for ethanol production. On the other hand, the productivity of the sugar cane agricultural land has been maintained due to recycling the nutrients from the process waste, but using the bagasse as energy input can decrease the quantity of nutrient recycled (EIA, 2006)

Starchy ethanol

In the case of ethanol from corn, the energy balance differs greatly among the various studies. Some research suggest that the balance impact is negative, i.e. it is needed more energy from fossil fuel than the renewable energy the corn-ethanol provides (Pimentel et all, 2003). This result has been refuted by other studies arguing that Pimentel uses old data for estimation of plant process efficiencies and crops yield, and he does not account the co-products energy credits (Shapouri, 2002; IEA, 2004; Farrel, 2006). During the last decade, improvements on fuel conversion technologies, use of higher corn yields, and lower energy use per unit of output in the fertilizer industry have enhanced the energy efficiency of producing ethanol. According to Shapouri (2002), the energy balance including energy credits from co-products of corn ethanol in US (output/input energy ratio) is 1.67 on average (considering dry and wet milling process). In others words, one energy unit of corn ethanol requires 0.67 fossil fuel units to produce it. This result is similar to others exposed on the Biofuel for Transport (IEA, 2004) the range of fossil fuel required is 0.6 to 0.8 for one equivalent energy unit of ethanol. As the balance energy ratio is highly sensible to assumptions and estimations, Farrel (2006) developed a model that compiles energy inputs and outputs of fossil fuel from six surveys of corn-to ethanol in US. This study makes adjustment on the surveys parameters and defines a common system boundary,

in order to compare the different result on a consistent basis. The result shows that, in the best case scenario, corn ethanol reduce 13% GHG emissions per kilometre and the energy balance ratio is 1.2 (Farrel et all, 2006). The World Watch Institute (2006) presents different studies in which the energy balance is 1.5 on average. Further improvement in starch conversion technology is expected to allow the use of residues as process fuel.

Regarding the land use change, the expansion of corn can be at the expenses of other agricultural crops, raising the competition for fertile agricultural land. If large plantation of corn is expanded on land previously used for pasture, the level of GHG emission from corn ethanol would be similar to gasoline. This is due to release of GHG from changes in soil conditions, changes from root systems of different plants, etc. (IEA, 2004)

Cellulosic ethanol

The cellulosic ethanol process is estimated to be more energy-efficient than the first generation, since in the current process design almost no fossil fuel is needed to convert cellulosic biomass. The remaining lignin cannot be converted to sugars but can provide boiler fuel for process heat and electricity or be reacted into co-products. Even it no large scale production has been implemented, engineering studies show that reduction in GHG emission can be at least 70% compared with gasoline (WWI, 2006) (Wyman, 2003). However, the estimation of energy balance varies widely. Farrel et all (2006) present a level of 24 in energy balance, while World Watch Institute (2006) review studies that show a an average level of 20 in energy balance.

From ethanol made from agricultural and forestry waste, no additional land area is needed. Cellulosic ethanol offers the potential to protect lands vulnerable to erosion and restore lands degraded by overuse.

The table below shows the energy balance ratio and GHG reduction for sugar cane, corn and cellulosic ethanol, from the studies reviewed in this thesis.

	Energy Balance Ratio = renewable energy output / fossil fuel energy input	GHG Reduction
Sugar cane ethanol	8	80%
Corn ethanol	1.5	13%
Cellulosic ethanol	20	70% or more

Table 2. Energy Balance estimation and GHG reduction for sugar cane ethanol, corn ethanol and cellulosic ethanol.(Word Watch Institute, 2006)

The environmental performance of ethanol varies greatly on the production process and the feedstock used. Studies carried to measure the net fuel ethanol impact differ many times in the inputs and metrics applied, as well as estimations and assumptions. Some differences can be explained by use of older versus new data, by accountability or not of co-products and by use of different system boundaries. Ethanol from sugar cane appears as the most efficient ethanol currently under commercial production in terms of energy balance and GHG emission reductions. However, the large expansion of ethanol production can have negative impacts on environment, since more resources as land and water, and higher yield crops are needed. Measures of cellulosic ethanol show a very positive performance; even they are calculated on a pilot experience base and not on a large scale production.

5 Global Ethanol Landscape

Global ethanol landscape refers to the world current situation regarding the ethanol (1) production and consumption levels and (2) regional study of the policies to promote the development of the sector. The aim of this chapter is to present a brief overview of the global ethanol landscape in order to identify different situations that could affect the performance of the Honduran innovation system. It is not possible to execute an extensive and conscious analysis of the global system, so the attention will be focus on (1) leader regions and other that show strong initiatives, and (2) identifying some trends specifically related to three system functions: *Influence in the direction of Search, Legitimization* and *Market Formation*.

Global ethanol production for transportation has increased in the last decades. According with the F.O. Licht Report (2006), fuel ethanol has increased from around

0.5 billions liter in 1975 to 35 billions liters in 2005. In the next sections, the Biofuels situation of the different world regions is explored. The focus is on national and regional targets and policies, but also ethanol production, consumption and forecasts for the leaders: US, Brazil, EU and entry countries in South and Central America, Asia and Africa.

5.1 Ethanol in the United States of America

The US is currently the world leader in ethanol production, just ahead of Brazil (Renewable Fuel Association, 2007a). Ethanol produced in the US is primary obtained from corn crops and there are presently 125 ethanol production facilities working with a total capacity of 5.9 billions gallons per year. 76 ethanol production facilities are now under construction and ethanol is blended in about 46% of the nation's gasoline (American Coalition for Ethanol, 2007). Figure 2 shows ethanol production in the US has boosted in the last few years, achieving a remarkable sustained growth rate.

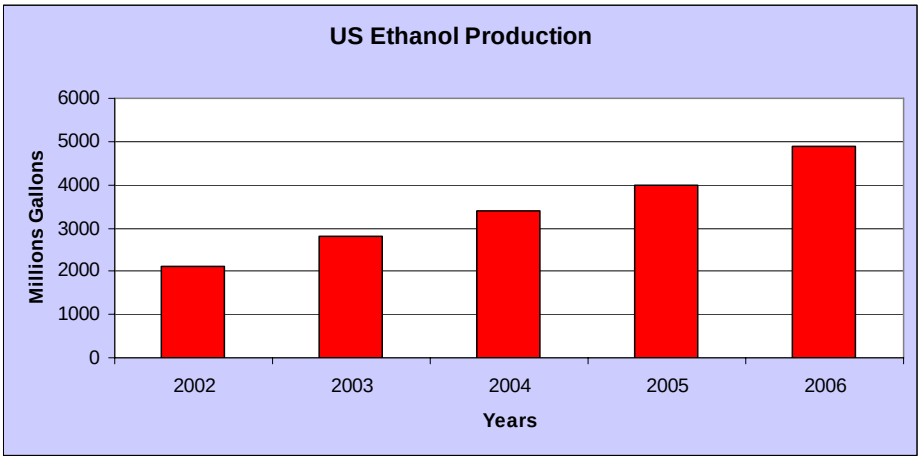


Figure 2. US Ethanol Production

Source: American Coalition for Ethanol (2007) – www.ethanol.org

The ethanol industry in the US is expected to continue growing due to the major efforts that both the federal government and state governments are doing. There are several policies that are helping to push the production and use of ethanol in the US: (1) The Energy Policy Act of 2005, which introduced the Renewable Fuels Standard (RFS) stating a requirement of steadily increasing levels of ethanol use between the years 2006 and 2012;

(2) The Volumetric Ethanol Excise Tax Credit (VEETC or the Blender's Credit), which simplified the taxation of ethanol blended gasoline while preserving the same contribution to the High Way Trust Fund (HTF) as conventional gasoline, establishing a $ 0.45 per gallon tax credit to the petroleum industry as an incentive to blend ethanol into their gasoline;
(3) The Small Ethanol Producer Credit, which provides a production income credit of $ 0.10 per gallon on up to 15 million gallons/year for small producers (less than 60 million gallons/year);
(4) The Secondary Offset Tariff on ethanol imports is a policy that establishes a $ 0.47 secondary tax per gallon on ethanol imported into the US. Central American and Caribbean countries benefit from a duty-free quote on their imports to the US. Under the Caribbean Basin Initiative (CBI), up to 7% of the US domestic ethanol production can be imported duty-free, as long as the ethanol is derived from nations covered by the CBI.

In order to encourage the consumption of ethanol in the US, there are also some incentives that are being applied by the government. Some subsidies on flex-fuel[4] cars are motivating people to acquire this type of vehicles. There are around 6 million flex-fuel vehicles running in the US and 1,120 retail stations offering E85 blends (Renewable Fuel Association, 2007b). The government fleet requirements included in the Energy Policy Act state that 75% of the light-duty vehicles acquisitions in covered fleets must be flex-fuel. There are also vehicle tax credits and fuel tax exemptions, and loan assistance programs.

The growing production and consumption levels of fuel ethanol have been driven strongly by public policy. Subsidies and incentives programs have helped to boost the production capacity and the purchasing of ethanol run cars. The production cost of ethanol in US is higher than other in the south region of the world. To protect the domestic industry, the country applies high import duties or limits the amount of duty free imported ethanol.

[4]Flexible fuel vehicles (FFVs) are designed to run on gasoline or a blend of up to 85% ethanol (E85). Except for a few engine and fuel system modifications, they are identical to gasoline-only models.

The US Biofuels consumption is projected to grow to more than three times its current level by 2030, considering the policies that are been applied at this time. If the policies that are currently under development are adopted the growing level could be over six times (IEA, 2006). It is considered that by the year 2020, the ethanol requirements in the US, considering a 10% displacement of gasoline would require a 4% use of the total cropland area exclusively for the production of ethanol (IEA, 2004). Of course, these facts are dependant on new policies and technologies.

Regardless of the major efforts that the US government is doing in promoting domestic production of ethanol, its consumption is likely to keep on surpassing production. El Salvador, Costa Rica, Jamaica, Trinidad y Tobago and Brazil are the countries that export ethanol to the US at present. In President George W. Bush's 2007 State of the Union Address, he called for increased spending on ethanol production, proposing to reduce America's gasoline use 20% in the next 10 years. For the US to fulfill its current targets for 2017, it will require an additional 36 billion gallons/year of its current imports, creating a great window for ethanol producers seeking to export (Americas Program, 2007).

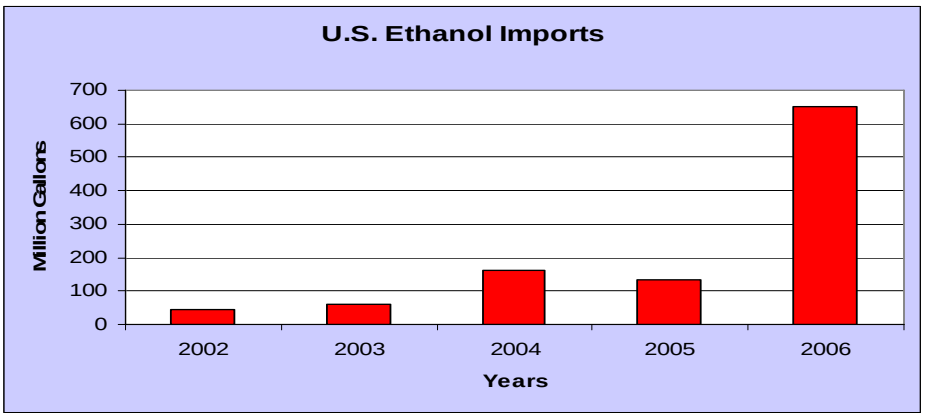


Figure 3. US Ethanol Imports

Source: American Coalition for Ethanol (2007) – www.ethanol.org

Since the US ethanol industry is still reliant on subsidies from the government and vulnerable to erratic commodity prices of the corn industry, this puts it in disadvantage to more efficient producers as Brazil. This fact, in general, affects negatively the *legitimacy* of corn ethanol, and could also *influence in the direction of search*. Since the demand of ethanol is forecasted to surpass the domestic production,

the ethanol exports would likely increase from countries with advantageous trade position, expanding the available *market*.

5.2 Ethanol in South and Central America

South and Central America are regions that are currently struggling against the volatile prices of oil. Since most of the countries in these regions are extremely dependant on oil imports their economies are very sensitive to any changes in the world oil markets. Countries such as Venezuela, Mexico, Bolivia, Argentina, Ecuador, Trinidad y Tobago and Colombia produce oil, accounting for 9.2% of global crude oil production (IEA, 2007). This amount of regional domestic oil production is not enough to stabilize the oil prices of the whole region and the energy supply based on oil is still a critical issue for many governments.

Both regions are characterized by rich natural resources, available arable land, agricultural capabilities, low population density, cheap labor and ideal climate conditions to grow current biofuels feedstock. Biofuels as ethanol represent to the regions an attractive opportunity to diminish oil dependency and improve economic development.

5.2.1 South America

Driven by the first oil crisis experienced during the 1970's, in 1975 Brazil's federal government started the National Alcohol Program (Proalcool) with the aim of encouraging alcohol production in order to replace gasoline and therefore reduce oil imports (Moreira & Goldemberg, 1999). Through the implementation of this national program, Brazil has become the world leader in ethanol usage, and just until 2007 it lost its world production leadership to the US. Brazilian ethanol is produced from sugar cane following a first generation production process and is currently the world's lowest-cost producer. Since the experience of Brazil is extremely significant in the ethanol history it seems relevant to present a brief summary of the main drivers for its sustained development.

As a legacy from the Proalcool Program, all gas stations in Brazil offer pure ethanol for sale, as well as ethanol blends with regular gasoline. There are also several

favorable tax exceptions for ethanol at the pumps – in October 2005, ethanol enjoyed an advantage of $ 0.25/Liter – This gave it a total differential of $ 0.41 in taxation rates compared to regular gasoline (GAIN Report, 2006). The guaranteed supply of ethanol at pump stations and favorable taxes for flex-fuel cars have created a fertile market for this type of vehicles, which demand is constantly increasing. Brazil has experienced, since 2003, an overwhelming success in the acquisition of flex-fuel cars among cars buyers.

Gasoline without ethanol is not longer allowed to be sold in Brazil and the current minimal ethanol blend established by the government is 20% - this was reduced from 25% due to an increase in the price of ethanol in 2005 - . Brazil has a production increase target of 40% between 2005 and 2010 and its ethanol exports are experiencing continued growth (IEA, 2006). In 2006 it exported about 19% of the total 16 billion liters it produced (Americas Program, 2007b).

Other South American countries are implementing different biofuel policies and programs. In 2005, The Colombian government established a national law mandating that all gasoline should contain a 10% of ethanol. There is also a national law that exempts from tax all the ethanol that is produced to be blended with gasoline. The government also established a $ 15 million risk fond to promote the construction of ethanol production facilities in areas with low attractiveness for investors. With these incentives that the government of Colombia has created, the ethanol industry is experiencing tremendous growth; with investments of over $ 253 millions and annual sales of $ 200 million (Federacion Nacional de Biocombustibles, 2007). Colombia is a highly efficient sugar producer and it was ranked the 7th worldwide producer in 2004 (IADB 2007).

In Argentina, the national government has set a target of using a 5% blend of ethanol or biodiesel by 2010. The Senator Falco's Law (SFL) has been approved recently and it establishes new rules to promote the biofuel industry closely following the Brazilian model. The potential of biodiesel is great in Argentina since it is the world leader producer of soybeans, a primary biodiesel feedstock (Instituto Interamericano de Cooperacion para la Agricultura, 2007; IADB, 2007). Venezuela, one of the major exporters of oil, is establishing agreements with its allied nation Cuba in order to

create ethanol production facilities that would provide ethanol to be blended with the gasoline production of Venezuela; which currently imports the ethanol from Brazil. Others countries working toward establishing biofuels programs are Paraguay and Chile (Mathews, 2007).

Brazil has been the pioneer of the region in promoting the use and production of ethanol. The 30 years ethanol program support has positioned Brazil as the lower cost producer and the larger exporter. This has *legitimatized* the ethanol from sugar cane. Following the success of Brazil, other countries in the region have developed programs toward biofuel and some have already established the industry. Not only to encourage the production but also the consumption, establishing mandatory blends to assure the local *market formation*. Brazil has *influenced the direction of search* and has been a source of *knowledge transfer*.

5.2.2 Central America and Caribbean

In Mexico, current president Felipe Calderón announced in April 2007 the Programa Nacional de la Agroindustria de la Caña de Azúcar PRONAC (National Sugar Cane Agro-industry program). This program is aimed at improving the sugar cane industry in Mexico to fulfill the growing demand of ethanol both nationally and abroad. The main target is that by 2012 Mexico will produce 6.5 millions of tons of cane for ethanol production and increase the participation of bio-energy production to achieve 7,840 barrels of ethanol per day. Mexico is also conducting research at the Mario Molina Research Center, in order to evaluate alternative sources for ethanol production, besides corn and sugar cane (GAIN Report, 2007).

The Central American region has a great potential for the production of ethanol from sugar cane. In agricultural terms, sugar cane crops can be harvested in 120 days, a period 80 days shorter than Brazil. In trade terms, Central American nations have a free trade agreement with the US (CAFTA). The CAFTA agreement allows countries covered under the CBI to export ethanol produced by foreign feedstock (i.e., sugar from another country) into the U.S. duty-free up to 7% of total U.S. ethanol production. After the 7 % of U.S. production threshold has been reached, an additional 35 million gallons can be imported into the U.S. duty-free, provided that at least 30% of the ethanol is derived from “local” (Caribbean region) feedstock.

Anything above the additional 35 million gallons is duty-free if at least 50 percent of the ethanol is derived from local feedstock. Considering the benefits that can be obtained with CAFTA, global agribusiness companies have announced plans or have finished construction of ethanol processing plants in El Salvador, Jamaica, Trinidad and Tobago, and Panama. These plants are designed to take advantage of the CAFTA ethanol provisions by importing high water content Brazilian ethanol, dehydrating the ethanol to make it fuel grade and useable in the U.S., and exporting it into the U.S. tariff-free (CAFTA's impact on US Ethanol Market, 2006). According to the Renewable Fuels Association of the US, in 2006 Costa Rica and El Salvador exported 74.4 millions of gallons of ethanol to the US (Renewable Fuel Association, 2007c). The CAFTA is seemed by many associations and agencies in the US as a threat for the domestic ethanol industry. Even though it is currently officially established, there are still some associations and agencies that keep on remarking its negative effects over the national industry and might lobby against it (CAFTA's impact on US Ethanol Market, 2006).

The Mesoamerican Biofuels Group and the Energy and Environment Partnership with Central America are two other regional programs created to support the development of renewable energy in the region (IADB, 2007). Ethanol demand in Central America is likely to attain the 120 millions of gallons by the year 2010 if the region nations follow a 10% blend policy. The production capacity of the region is far greater than the required to satisfy local demand implying that the region efforts are strongly focus on exports.

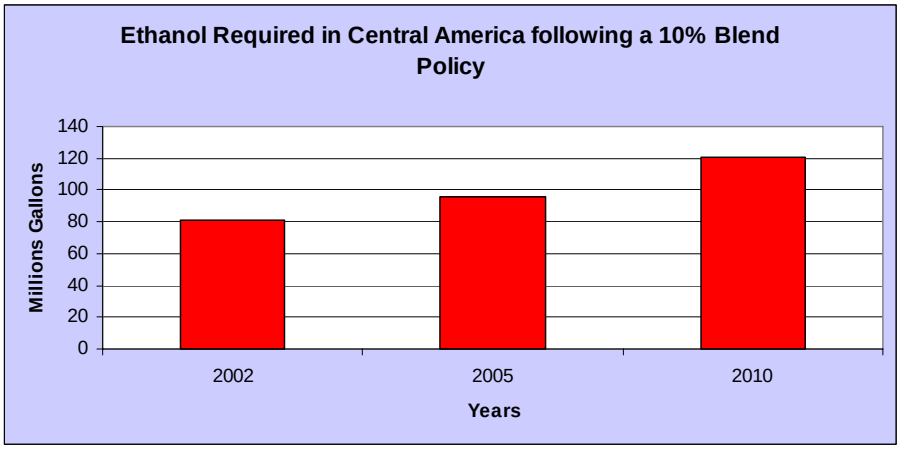


Figure 4. Ethanol Required in Central America Following a 10% Blend Policy
Source: A Blue Print for Green Energy in the Americas. Prepared for the Inter-American Development Bank by Garten Rothkpf

Contrasting with the promising positive movements that can be seen in South and Central America, there is also a strong political opposition to biofuels coming primary from Venezuela. The fact that US president Bush has shown an special interested in promoting Biofuels in Latin America has spur a wave of opposing reactions; specially from Venezuelan president Hugo Chavez – a well known opponent of the US current government – mainly arguing that the current boom in ethanol is the equivalent of starving the poor "to feed automobiles" (CBS News, 2007). It has been speculated that this situation has created some sort of division in South America, were the main allies (Bolivia, Nicaragua and Cuba) of the Venezuelan president are showing reluctance to follow strong biofuel programs. Nicaragua recently lost a $ 150 million investment for the construction of an ethanol production facility (which was moved to Honduras) due to the uncertainty of the government position towards Biofuels (El Nuevo Diario, 2007). In Bolivia, the government has not shown a serious commitment to include Biofuels in its energy policies and the ones so far established are rudimentary. Venezuela has no official government policies for Biofuels and the country is likely to remain a net importer of ethanol for several years, especially to be blended with its national oil production. The lack of a legal framework has been a powerful block for the industries development. Cuba have not yet developed a legislation for Biofuels, but its government is keen on putting investments to develop domestic Biofuels since it currently has political momentum and its sugar industry is really strong (IADB, 2007).

The Central American region has witnessed major movement toward biofuels in the last years. CAFTA allowance for ethanol exports to the US should help promote ethanol *market formation* and incentive investments in the sector (*resource mobilization).* Brazil is also seemed as an important partner in terms of investment and *knowledge transfer*.

5.3 Ethanol in Europe

European Union started the production and use of ethanol, by the middle of the 1990´s for supporting the agricultural development of the region. During the coming years due to the highly dependence of imported fossil fuel in the transport sector the EU took the first initiatives to established a biofuel framework. In the Green Paper of 2000, the EU set the target of 20% usage of alternative fuels (Biofuel, natural gas,

hydrogen) by 2020. However it was in 2003 when the European Council (EC) tried to enhance the development of Biofuels through the promulgation of three directives. The Use Directive establishes at least a usage of 2% of biofuel by 2005 and 5.75% by 2010. The Energy Taxation Directive which permits Member States to concede tax reductions and/or exemptions of Biofuel production under specific conditions. And the Fuel Quality Directive which incorporates biofuel blends to the previous environmental specification for market fuel. The aim of Biofuels Directive of 2% was not achieved, the use of biofuel accounted only 1.4%. The EC has suggested setting a new goal of 10% Biofuels usage by 2020 (EC, 2007)

Nevertheless the most ambitious targets were developed in February 2006, based on the Biomass Action Plan (2005) that pursued three aims: Promote Biofuels in the EU and developing countries with a global environmental perspective; Prepare for large-scale use of biofuel by incrementing "second generation" research, optimizing the cultivation of dedicated feedstock and supporting market penetration; and explore the opportunities for developing countries for sustainable biofuel production. On this base the EC has developed the EU Biofuel Strategy that delineate seven key policy areas: stimulate demand for Biofuels, capture environmental benefits, develop the production and distribution of Biofuels, extend supplies of feedstock, enhance trade opportunities, support developing countries, and research and development. (Communication from the Commission, A EU Strategy for Biofuels, 2006).

As it seems, the growth of biofuel industry in developing countries has an important place in this strategy, in terms of stimulating trade opportunities and support the biofuel production[5]. However, there are contrasting opinions among the Member States regarding the current conditions for imported bioethanol[6] and its future. While some want to stimulate the domestic production restricting the volume of import and establishing a specific tariff code for imported fuel ethanol, others want to eliminate market access restrictions, including zero imports duties for Biofuels and setting standards for ethanol production, in order to encourage the use of ethanol in EU. (Speech by Sten Tolgfors at the International Conference on Biofuels, 2007)

[5] Especially in developing countries affected by the Sugar Regime Reform in 2003, that among other measures, set restriction on EU sugar export.

[6] In the EU ethanol is subject to an import duty, €10.2 per hectoliter denatured alcohol and €19.2 per hectoliter undenatured alcohol. This is the case of Brazil, which is considered a MFN (most favored nations)

Concerning the measures to support developing countries, the Biofuels Strategy establishes to carry out specific studies to support ethanol production in countries part of the Cotonou Agreement[7]. In addition, it will develop a coherent Biofuels Assistance Package for developing countries and examine how best to assist national and regional biofuel platforms. (Communication from the Commission, A EU Strategy for Biofuels, 2006)

EU regulations offer two systems for encouraging the domestic cultivation of energy crops: firstly, the energy aid that was introduced with the 2003 CAP (Common Agricultural Policy) reform; and secondly, the already existing scheme for using set-aside land for the cultivation of crops for non-food uses. The energy aid of $ 62 per hectare is available to farmers who produce energy crops. It is applied on a maximum guaranteed area in the whole EU, of 1.5 million hectares. In addition some countries offer financial incentives for investment in bio-refineries (World Energy Outlook, 2006).

Ethanol represents close to 20 % of the Biofuels being used in transport in the EU. To reach the target for 2010, it is need to raise the cultivable land for ethanol crops. Some Member States have not available land to produce domestic ethanol or it will be too costly. Therefore a suitable solution to fulfill the target will to import from more competitive countries. In 2006 the EU production of ethanol reached 1,565 million of liters. The leading EU producers were Germany, Spain, France, Sweden and Poland, while the leading consumer was Sweden, with about 80% of the quantities imported, mostly from Brazil. Ethanol is mainly produced from wheat, and to a lesser extent sugar beet, in Spain, France and Sweden (EBIO 2007).

EU leading countries on Biofuel market have developed key fiscal support and strong lobbying to the introduction of biofuel. In Germany, leader of biodiesel production, the bioethanol in form of ETBE, was not used until 2004 when a new regulation allowed full tax exemption without limit of biofuel volume. At this time all bioethanol was imported from Brazil, but today Germany accounts with several plants. On the

[7] The Coutou Agreement is a treaty signed between the EU and ACP countries (group of African and Caribbean and Pacific countries) in 2000 that allow among others arrangements, reciprocal duty-free access of its respective markets (until 2008) and also access for ACP countries to funding via the Europe Investment Bank. Honduras is not ACP country.

contrary, France gives tax exemption for a limited volume of Biofuels and carefully calculates the amount of tax exemption to be given. In Spain the most important producer of bioethanol, will not built more capacity as planned, since it considers that the legal EU framework it is not adequate for further expansion. Instead the company will seek to invest abroad. In Sweden and Germany green parties' environmental motivations were important for the political support for bio-fuels, whereas in France and Spain support of the agricultural sector was considered important by the politicians (ECN, 2006).

The European policies measures seem to be smaller than those implemented in the US and Brazil. The member countries have the freedom to impose own action plans. The result is a very diverse situation in terms of national targets and variety of feedstock used to produce ethanol. Here it is not a clear *influence of search*. Biodiesel production is larger than ethanol; this also affects the *legitimacy* of ethanol.

5.4 Ethanol in Asia and Africa

Asia is a region with long agricultural tradition and favorable climate conditions for the production of sugar crops. Asian countries have started to support the development of the ethanol industry in order to confront environmental problems, the increasing oil prices and the security of energy supply. Concentrating the most populous countries with a growing demand of energy, the support and use of ethanol differs among Asian governments. China and India are leading the production of ethanol in Asia, whereas Japan does not produce it at all. Most of the countries in the Asian region will likely need ethanol imports to fulfill the projected targets. Only Thailand appears as a possible competitor in the international trade of ethanol. Mandatory blends are also at different stages of development.

Africa is a continent that enjoys similar climate and land conditions as the Latin American region. Potential land and human capital available for ethanol production activities are striking. Biofuels production seems as a source of rural development that could improve the region's extreme rural poverty and stabilize its agricultural industry, playing an important future role in the international ethanol trade. Therefore the region has been the host of foreign investments (*resource mobilization*) for the

construction of production facilities and has started relationship with Brazil for *technology transfer* and learns from its success story.

In Africa, some regions are pursuing ethanol production from corn and other with sugar cane. *The direction of search* is quite diffused. Same thing is happening in Asia, where China is the world producer of corn and perhaps would likely lean towards ethanol from corn. Other Asian countries are trying with sugar cane and cassava as well.

More in-depth information about these two regions is presented in Appendix 3. A table summarizing the global landscape is presented in Appendix 4.

5.5 Global Trends

Influence in the Direction of Search

In the global context it is possible to identify several different trends concerning ethanol. One important differential condition that can be identified is the feedstock that is used to produce the ethanol. Brazil has established sugar cane as the most efficient feedstock to be used in the production of ethanol. Contrasting with this position the US, which currently has undertake the leadership position on Biofuels production, keeps on strongly pushing corn as the primary source for ethanol. In other regions such as Europe, Asia and Africa other types of feedstock are also been used, such as cassava and beets. Besides the used feedstock there are also different processing technologies in the industry, as it is described in chapter 5. Second generation technologies are taking more relevance especially in countries that do not account with great amounts of arable land to be used for the production of ethanol, as Europe. Still, the second generation ethanol has a long way to become economically feasible and so, the first generation ethanol is the current dominant technology.

Another “competing” situation that can be identified in the Biofuel setting is between ethanol and biodiesel. Most countries are establishing general biofuel laws that do not specify conditions to either ethanol or biodiesel. Countries like Germany started betting more on biodiesel development and had created strong biodiesel industries.

Biodiesel is gaining more importance but still, it is clear that ethanol remains as the primary Biofuel currently available.

Market Formation

Regions as Europe, Brazil and the US are leading the road in establishing frameworks that would permit the creation of a worldwide Biofuel market. These regions are creating important policies and setting significant targets that are encouraging the production of Biofuels, and specifically ethanol. The main importance of these movements is that Biofuels could achieve to be treated the same way as fossil fuels are handled right now. This would mean that the commercialization and trade of ethanol and biodiesel would become smoother and more attractive since we could refer to an actual International Biofuel Market. The international laws that currently govern the trade of fossil fuels could also be applied to biofuels.

Mathews (2007) addresses this situation in a very interesting manner, where he makes reference to the term "Ergoculture", as the cultivation of energy. This new term will gain more importance since, from his perspective; the world needs to move towards the creation of an actual international Biofuel market, without trade barriers, reclassification of ethanol and biodiesel as fuels and not feedstuffs by the WTO, and the establishment of global standards. This new market will rely on a "Biopact" – which means "The creation of an unfettered global market for Biofuels" – between the "North" (mainly the OECD countries) and the "South" (a group of Developing Countries).

Legitimization

The fact that in most regions of the world governments are taking actions towards the promotion of Biofuels usage and production signifies that the acceptance of Biofuels is growing. Creating legitimacy for Biofuels is a rather complex activity since we are dealing with so sensitive subjects such as food competition and indirect pollution. Many debates have emerged around whether Biofuels represent a truly alternative or if they may become a trap. It seems interesting to refer yet again to Mathews (2007), since in his paper he addresses all of these problems in a very objective matter and

presents important arguments against the main problems that are usually appointed by Biofuels opponents. Most appointed negative sides of Biofuels and specifically ethanol are probably true, but this situation seems to be directly related to the used technology and feedstock. Ethanol from corn seems to present all the argued troubles, while ethanol from sugar cane has probed to lack all of them; when managed the right way.

The American continent, which accounts with the two main producers of ethanol in the world, is working hard on promoting ethanol fuel production and creating strong legitimacy throughout the region; just facing limited opposition from a few countries. Still, ethanol from corn has expanded really fast in the US, situation that has attracted a lot of criticism from all over the world, due to the negative implications of it. A very much critical situation regarding ethanol fuel is the way its production is managed. This is important particularly because developing countries are the ones with the capability to produce the world requirements of ethanol and yet, these countries are the ones with weaker land management and environmental control schemes. Without the adequate control, encouraging ethanol production in these regions could dramatically hurt ethanol legitimacy. Regarding this, in 2007 the United Nations has published the "Sustainable Bioenergy: A Framework for Decision Makers" report, which constitutes a detailed guide for policy makers around the world concerning the benefits but also challenges that Biofuels represent.

Global Landscape Summary

- Developed countries have established regulatory frameworks for biofuels, including blend targets and consumptions levels. They offer a number of grants and incentive programs for fostering the emerging ethanol industry.
- Even though the production of ethanol has significantly increased in the last years; it will be not enough to satisfy the more increasing demand in developed countries. Due to limited land availability in these countries that constrains the potential increase of feedstock for biofuels production. In addition, they do not account with cost effective process and the environmental impact of biofuels produced there is not good enough.
- Tropical and subtropical developing countries have favorable climate, land to grow ethanol feedstock and low cost farm labor. These raw materials used to produce

ethanol not only can be produced at a lower cost but are more energy efficient than feedstock used in developed countries.

- Several developing countries have started to engage in biofuel programs. They want to catch up the opportunities of serving this increasing demand and at the same time reduce their dependence on fossil fuel. As result, they can boost their agricultural sector, export products with a higher added-value and decrease economic crises caused by high oil prices.
- In the next 10 years no technological breakthrough is expected to occur that would radically modify the current outlook of biofuel production. This provide a window of opportunity to continue exploiting the advantages of the sugar cane to ethanol technology
- Some of these developing countries have ongoing relationship with Brazil - the main producer of ethanol from sugar cane - focused on learning about it experience and knowledge transfer.
- The EU and the U.S. have set up policies to promote and protect their national production through a variety of trade policy measures, such as tariffs and subsidies, but also by technical norms. Currently this is an issue of major debate within the EU.

6 The Emergent Honduran Ethanol Industry

Production diversification, reduction of the energetic dependence, job generation, environmental quality improvements and energetic security are among the main drivers that are creating great expectations towards the development of a strong biofuel industry in the Central American region. Practically all of the five Central American nations are currently developing Biofuels oriented laws in order to create a defined framework for this industry.

This section will focus its attention on Honduras and the case study of its emergent ethanol industry. First Honduras is introduced, focusing specifically on the development of the Honduran sugar industry. In section 6.2 the emergent ethanol innovation system is presented.

6.1 Introducing Honduras and its Sugar Industry

Honduras is the second largest country in Central America (112,090 sq km = 11.21 million hectares) and it enjoys subtropical climate conditions. 9.53% of Honduras's area is considered to be arable (around 1 million hectares) and currently it utilizes only 3.21% with permanent crops (most of the remaining arable land is considered to be in an idle state (Flores, 2007)). About 80,000 hectares of the used arable land is currently considered to be artificially irrigated (Central Intelligence Agency, 2007; Food and Agriculture Organization, 2006).

As any other Central American nation, Honduras is an agricultural country and one of its main industries is sugar production. This activity started in the 1920's, when two processing facilities were built in the north region of the country. In 1929, during the depression, the sugar industry collapsed and the two facilities were closed. At the end of the 1930's the industry experienced a renaissance and the Compañia Azucarera Hondureña (Honduran Sugar Company) was founded in San Pedro Sula, with a daily processing capacity of 150 tons of sugar cane. Ten years later, a second facility was opened with an added processing capacity of 600 tons of sugar cane per day. Another two facilities were also opened in 1948. In 1968, the Honduran sugar industry experienced a major growth and many other sugar processing facilities were built both in the northern and southern regions of the country. The "Asociacion de Productores de Azucar de Honduras" (Sugar Producers Association of Honduras, APAH) was founded in 1979. Its purpose is to defend the interests of the Honduran sugar industry.

The sugar industry currently occupies 46,000 hectares of arable land (around 5% of total arable land) from which 49% belongs to the 7 sugar mills (See figure below) and the remaining 51% belongs to independent sugar cane producers. The Honduran sugar industry produces 368,000 tons of sugar per year (around 0.2% of world production). Sugar cane production is an important agricultural product accounting for 5.6 millions tons in 2005 and with monthly growth of up to 6% in April 2007. The sugar mills are more concentrated in the northwest region of the country, as the following figure shows:

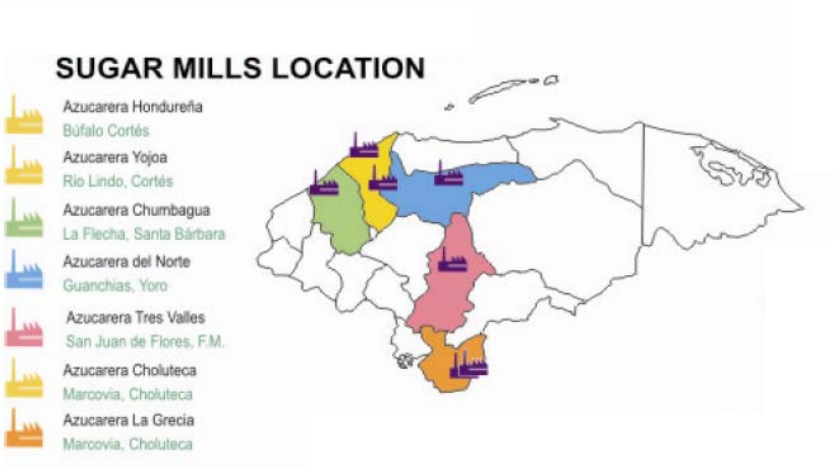


Figure 6. Sugar Mills Location

Source: Asociación de Productores de Azúcar de Honduras.

http://www.azucar.hn/aspectosgrales.htm

The 7 sugar mills in Honduras are also producing energy and have almost become self-sufficient regarding their energy needs. In a recent study conducted by the APAH (El Azúcar es Energía, 2006) it was estimated that under current conditions the sugar industry has a potential of producing 344 MW per hour of electric energy and 51 millions gallons of ethanol per year.

6.2 The Emergent Ethanol Innovation System

In this section the case of the Honduran ethanol industry is presented. First, the main drivers for the industry are described and then the current structure and functions of the system are presented.

6.2.1 Following the Leader: Spot the Opportunity

The current growth that ethanol is experiencing worldwide and the successful story of Brazil are the main drivers that are encouraging the sugar producers of Honduras to follow the opportunity to mass produce ethanol (see section 5.6 Global Trends). This interest from the private sector has been welcomed by the Honduran government since the complete dependency of the country in the imports of fossil fuels has generated many crises in the last years. The private sector envisions a great potential business opportunity both nationally and internationally; and the Honduran

government perceives a great development prospect for diversification of the agricultural sector.

The Honduran sugar industry is well developed and it has become self-sufficient when it comes to energy needs. The interest in mass producing ethanol has increased recently due to the situations that are happening worldwide and also by national and regional circumstances.

In 2004, the first initiatives related to the inclusion of ethanol into the fuel matrix of Honduras were seen. As the fossil fuel prices started to rise and Honduras began to experience several socio-economical problems derived from this situation, the government by that time started to search for different options that could represent some kind of relief from the strong fossil fuel dependency that the country has. Many times there were discussions and minor movements towards Biofuels, but at the end there were no tangible actions that could imply a real ignition point for the Biofuel industry to start a development phase.

In 2005 the prices of fossil fuels reached unprecedented highs in Honduras (2000 - $ 0.42/liter; 2005 - $ 0.70/liter; AHDIPPE, 2007). The situation generated great pressure over the new Honduran government, which based a great part of its campaign around keeping fuel prices steady (by a fuel licitation and subsidies[8]). By this time, the Honduran sugar producers started to get attracted to the production of ethanol as a potential substitute for fossil fuel. This interest resulted in the launch of some feasibility and capacity studies that were conducted by the APAH. The attention to the production of ethanol in Honduras was also occurring in a time were the sugar producers of the other Central American nations were also showing more interest in the ethanol business. The fact that Costa Rica and El Salvador were already exporting ethanol was a major incentive for the Honduran sugar producers to evaluate this business opportunity.

The Honduran executive government is currently facing an oil crisis (Honduran Government Portal, 2007) by giving heavy subsidies to the fossil fuel industry in

[8] These subsidies are grants of money made by the government to fuel distributors thereby altering the price or cost in a way which affects the output.

order to maintain the prices steady. They are also working in creating a favorable environment to encourage the production and commercialization of Biofuels. This is considered as a promising solution that would not only reduce the country's dependency on fossil fuel imports, but also improve the development of rural regions. It is important to mention that while the executive government is showing a strong commitment towards ethanol and Biofuels in general, the legislative government has not demonstrated a similar behavior as the Biofuels Law have been in their hands for almost a year and has not yet showed any indicatives of becoming approved any time soon.

6.2.2 On the road to Systematization: Structural Development

As the Honduran ethanol innovation system is in an emergent state, it is understandable that its structure is not expected to be fully developed. The system is currently under development and the existing actors are beginning to interact through some networks demonstrating the first steps of systematization. In this section, the structural development of the system is described, divided in three segments: Actors, Networks and Institutions.

ACTORS

The map of actors illustrates the different key actors that are involved in the ethanol innovation system. The actors are divided into seven different domains depending on the actions that they perform inside the system: Product, Research, Financing, Suppliers, Market, Government and Complementary Products & Services (See Table 3).

DOMAIN	ACTORS
Product	**Commercial Producers** Azucarera Hondureña Azucarera Yojoa Azucarera Chumbagua Azucarera La Grecia Azucarera del Norte Azucarera Tres Valles Azucarera Choluteca **Maybes** Pellas Group (Nicaragua) Agile Solutions (Brazil) MAN Ferrostaal AG (Germany) **Associations** Association of Sugar Producers of Honduras (APAH) Association of Sugar Producers of Central America (AICA)
Research	Honduran Agricultural Research Foundation (FHIA) Pan-American Agricultural School (EAP) Honduran National Autonomous University (UNAH) University of San Pedro Sula (USPS)
Financing	Central American Bank for Economic Integration (BCIE) Inter-American Development Bank (IADB) National Bank of Agriculture Development (BANADESA) Private Banks
Suppliers	Independent Sugar Cane Producers – Represented by the Association of Independent Sugar Cane Producers
Market	**Fuel Distributors** Represented by the Honduran Association of Petroleum Products Distributors (Ahdippe) **Media** Honduran Newspapers **User Groups** National Transport Council **Users** Private Retail
Government	Presidential Special Projects Office Secretariat of Industry and Commerce (SIC) Secretariat of Agriculture and Livestock (SAG) Secretariat of Natural Resources and Environment (SERNA) Secretariat Public Infrastructure and Transport (SOPTRAVI)
Complimentary Products & Services	Honduras National Harbor Enterprise Car Distributors represented by the Honduras Association of Cars Distributors (AHDIVA)

Table 3. Ethanol Innovation System Actor Map

The table represents the different identified actors that are currently present in the Honduran IS. These actors were divided in different domains depending on the role they perform inside the system.

Product Domain

The sugar producers of Honduras, which consist of seven sugar mills and are represented by the APAH, are the main local entrepreneurs that want to start ethanol production in the country. They have taken a very active role and have relied little on governmental aid. Even though neither of the seven sugar mills produces commercial ethanol at the moment, all of them have been involved in the studies conducted by the APAH. As result they have quantified their ethanol production capabilities and the investment required for it (APAH, 2007).

Recently the Pellas Group of Nicaragua, one of the major sugar and liquor producers in that country, began research activities in Honduras with the aim of evaluating the possibility of starting ethanol production in the Olancho region. The Pellas Group has expressed their keenness on making great investments in order to build an ethanol production facility in Honduras and become a big player aside with the national producers (Starkman, 2007). There has also been interest by companies from Brazil and Europe in investing in ethanol production facilities in Honduras. Recently, a delegation from the company Agile Solutions from Brazil came to Honduras to explore the opportunities offered by the country (Flores, 2007). The German company MAN Ferrostaal AG has also expressed its interest in starting ethanol production activities in Honduras. It is likely that many international companies would become important actors within the ethanol system (Summa Magazine, 2007).

Market Domain

As the ethanol industry in Honduras is currently in an emergent stage and no commercial ethanol is produced neither imported, there is still no tangible market. There are seven fuel distributors in the country: TEXACO Caribbean, COPENA, UNO, EXXON MOBIL, PUMA, DIPPSA and SHELL (AHDIPPE, 2007). The fuel distributors are represented by the Association of Petroleum Products Distributors (Ahdippe). These companies would become the national customers of the ethanol producers, which would distribute gasoline containing different blends of ethanol to the general public through the already existing private fuel stations.

The National Transport Council is a private organization representing the interests of the public transport companies. The aim of this organization is to create a standardized and more efficient public transport system in the main cities of the country. They are currently involved in a major national project related to biodiesel (Aleman, 2007).

Biofuels in general have been appearing in the Honduran media for the last couple of years. Most of the publicized articles have presented Biofuels as a positive alternative to be followed by the country. Both ethanol and biodiesel have been exposed by the media as feasible options for the country to reduce its fossil fuel dependency and generate other positive externalities. Some minor debates have been showed in the media regarding Biofuels but nothing too negative to create some kind of unconstructive or pessimistic scenario that could discourage potential producers or users (see Appendix 3).

Besides the national market, the sugar producers are more interested in exporting ethanol. There is still no particular international customers identified by the sugar producers but the experience of El Salvador and Costa Rica gives then the certainty of an attractive international market for them.

Government Domain

The Presidential Special Projects Office is the leading entity in Biofuels matters. This office has been working since 2005 in many biofuel projects, especially with biodiesel. The Presidential Advisor head of the office is aware of the magnitude that ethanol production would have compared to biodiesel. Due to this the office will soon began to work towards ethanol fuel, especially because in august 2007 the Honduran government will meet with president of Brazil and a Brazilian energy commission. In this gathering, local authorities will discuss several ways in which Brazil could aid Honduras in creating a healthy ethanol industry (Starkman, 2007).

Several other governmental entities are involved with ethanol fuel production and commercialization. The Secretariat of State in Agriculture and Livestock (SAG) is the governmental entity in charge of developing and executing actions to increase the

country's competitiveness in the agriculture and food sectors (SAG, 2007). They are responsible of the agriculture and food policies and controls over the country. The Secretariat of State in Industry and Commerce (SIC) is in charge of promoting and facilitating the industrial development, commercial trade, exports and investments in the country (SIC, 2007). The Secretary of Natural Resources and Environment (SERNA) is responsible of the development of policies and control related to environmental issues and the management of the natural resources (SERNA, 2007). The Secretariat of Public Infrastructure and Transport is responsible of the development of the national public infrastructure and transport (SOPTRAVI, 2007).

Research Domain

The Honduran Agricultural Research Foundation (FHIA) created as a private, apolitical non-profit business with the aim to perform research activities related to agricultural development and diversification. Presently the Foundation has its installations in La Lima, and six Demonstrative and Experimental Centers located in different climates and agricultural regions of the country (FHIA, 2007).

The Pan-American Agriculture School (EAP) is a private international university focused on the sustainable management of natural resources, environmental conservation, global competitiveness, and rural transformation to reduce poverty. The EAP institutional research is focused on the rural communities, forests and watersheds, small and large agricultural and agro-industrial businesses and the regional and global markets. The University is one of the leading organizations in Latin America oriented in the agricultural field, with a strong technological and business orientation (EAP, 2007).

Other academic institutions are also engaged in ethanol related subjects, mainly by the elaboration of some theses related to the subject. The National Autonomous University of Honduras (UNAH) is the main higher education organization in the country. It is a public entity that regulates the national higher education system and it has a division of Agricultural Studies in charge of the agriculture professional careers and research activities within the subject (UNAH, 2007). The University of San Pedro

Sula (USPS) is a private higher education organization located in the industrial region of the country.

Suppliers Domain

The Sugar Producers of Honduras own 49% of the national sugar cane production. The remaining 51% of the national sugar cane production is owned by independent farmers (10,000) represented by the Association of Independent Sugar Cane Producers (APAH, 2007).

Financers Domain

The Association of Sugar Producers of Honduras (APAH) has expressed the capability of the industry to obtain private financial resources for its ethanol production projects (Fasquelle, 2007). However, it is likely they will require funds from other organizations in order to make the industry grow and it is also possible that other interested entrepreneurs might be in need of special funds to start their own ethanol production programs and therefore, the role of development banks and other financial organizations become important within the system.

The Central American Bank for Economic Integration (CABEI) and the Inter-American Development Bank (IADB) are the most important financers when it comes to development projects. The CABEI is the leading source of multilateral financing for the integration and development of Central America. It is constituted by five Central American nations (Guatemala, Honduras, El Salvador, Nicaragua and Costa Rica). It has been a pioneer in the backing of social programs, developing economic, social, education, and health related institutions, in these countries. Currently the organization is evaluating financing support for renewable energy projects in the region, including biodiesel and ethanol production. It has also been a promoter of regional integration and has brought support to the private sector, including the micro, small and medium sized enterprises (BCIE, 2007).

The IADB is an international development organization that provides loans and grants to help finance sustainable economic and social development projects and support

strategies to reduce poverty, expand growth, increase trade, investment and regional integration, and promote private sector development and modernization of the State (IADB, 2007).

The private banks and the National Bank of Agriculture Development (BANADESA) are institutions that provide financial aid to the agriculture and industrial sector.

Complementary Products and Services Domain

It has been mentioned several times before that the main incentive to invest in the ethanol industry in Honduras is the export of the Biofuel and not so much the domestic market. Honduras counts with four port facilities (three in the Caribbean and one in the Pacific Ocean) all of them managed by the Honduras National Harbor Enterprise. These port facilities represent important export routes to the US, Europe and Asia; being the most important the Port of Puerto Cortez, which is considered to be one of the most important ports in Latin America and now has the category of Megaport[9]. Regarding the ethanol industry the National Port Enterprise will require investing in expanding their facilities to make them suitable for handling fuel exports. Currently, the imported fuel is received in the facilities of Puerto Cortez and Puerto Castilla. Since the country does not produce any type of fuel by the moment, there is not a developed infrastructure specific for managing fuel exports (Honduras National Harbor Enterprise, 2007). We can not determine the magnitude of the required investments for this matter but we can assume that these investments are unlikely to be so great to represent a bump in the road for ethanol exports (The ports already handle fuels; it would only require some adjustments for the new export function). It is also important to consider the possibility of using the fuel storage facilities that the government is planning to build as ethanol exporting channels as well.

National Cars distributors do not offer flexi-fuel cars presently. They are not involved in any activities related to biofuels.

[9] The Megaport Initiative began in 2003 as a cooperative effort between the U.S. and the host country to add radiation detection capabilities to key ports. This will make it possible to screen cargo for nuclear and radiological weapons of mass destruction. The U.S. supports the installation of the equipment, training and maintenance, while equipment is operated by host country personnel.

INSTITUTIONS

Currently the institutional framework is based on a national bill established in 1988. Decree 79-88 of 12 July 1988, signed by the President of the Republic on July 15th, 1988, contains the Law on Carburized Alcohol ("Ley del Alcohol Carburante"), which objective is to rule the activities related to the production, storage, use, handling, transportation, and merchandising of carburized alcohol and its compounds. It covers definitions, abbreviations and general provisions; authorization to produce carburized alcohol and specific special conditions; and complementary and final provisions (Global Legal Information Network, 2007). In September 2006 the executive government of Honduras presented a Law project to the national congress consisting on the new “Law for the Production and Consumption of Biofuels”.

The new Biofuels law proposal establishes general guidelines that govern the system and provide actors with general principles that would help them to determine their own course of action. The law will promulgate several measures. First, benefits for biofuel producers, such as: Exoneration of tax payments for a period of 15 years non extendable. Beginning from the sixteenth year, the producer would pay just a 25% of the total amount of payable taxes. Second, the creation of the Biofuels Technical Unit (Unidad Técnica de Biocombustibles, UTB), which would be a governmental entity, dependent of the Secretariat of Industry and Commerce, in charge of controlling, monitoring, production administration, promotion, commercialization, distribution and storage of the Biofuels in the country. The UTB would be the responsible entity of establishing the Biofuels blends to be used in the country. Third, national biofuel production should always account with at least 51% of domestically produced feedstock.

The Secretary of Agriculture and Livestock and The Secretariat of State in Industry and Commerce will be directly involved in the ethanol industry when the Biofuel Law is passed by the National Congress. The former will be responsible of research activities regarding the sustainable production of required raw materials for the generation of Biofuels and its derivatives, through incentive programs, promotion and credits to the agriculture production of the country. The latter through the Normalization and Metrology Office is already working in a normative regulating

ethanol fuel and they have already developed the same normative for biodiesel (Mejia, 2007). All the governmental regulations related to Biofuels are developed jointly with the other Central American governmental agencies. This initiative has been followed in order to create a regional biofuel market with equal standards; situation that have been discussed by the region's authorities in previous gatherings.

In a matter of international regulation, critical when pursuing to develop an export oriented industry; the Honduran government is currently evaluating the different international standards that are been developed (e.g. the ASTM D4806 in the US). It was expressed by the Presidential Special Projects Office that they are considering the ethanol fuel standard that is being developed by the European Union (CEN/TC 19 Ethanol Task Force), because it includes higher quality conditions (Starkman, 2007).

NETWORKS

Since there is not commercial ethanol production in Honduras yet, there is not any association or organization specialized in representing the interest of ethanol producers per se. The APAH is the leading private organization that is working towards the development of the ethanol industry, representing and bringing together the seven sugar mills that will produce ethanol and conducting lobbying activities with different governmental agencies. It represents the main private network in the system.

The APAH has developed strong relationships with the other sugar associations and research organizations – as the Guatemalan Sugar Cane Research and Capacitating Center (CENGICAÑA) and the Association of Sugar Producers of Central America (AICA) – in Central America in order to keep updated in matters related to sugar production and furthermore, the production of ethanol.

The Presidential Special Projects Office represents another important network in the system. Its role is to establish linkages with others governments and private sector, working towards the development of the biofuel industry. It is expected to create relationship focused on Foreign Direct Investment and knowledge and technology transfer, related to the production and commercialization of ethanol and biodiesel. An

example of this initial network is the recent visit of Brazil´ president (Starkman, 2007).

6.2.3 Learning to Walk: Early System Performance

In this section we will address the performance of the system. Here we will describe situations related to the different functions that are being performed currently in the system, according to the obtained information from different interviews and the previous sections.

Knowledge Development and Diffusion

First generation Ethanol production technology is mature and countries with tropical climate conditions are ideal for ethanol production specially using sugar cane as the primary feedstock. Brazil has created the most efficient production processes for ethanol derived form sugar cane and also has become main exporter. These circumstances incite Honduras to establish Brazil as a strategic partner in the development of the ethanol industry.

Research activities related to the production process of ethanol fuel are limited in the country. On the other hand, those concerning various aspects of feedstock production (increasing agricultural output and productivity) for biofuels are gaining more attention among agricultural oriented research organizations. One of those is the FHIA that will likely conduct comparative studies of different varieties of sugar cane and other feedstocks for the production of ethanol (Alfonso, 2007; FHIA, 2007). Currently the FHIA is conducting a research project related to the production of biodiesel from Jatropha. The EAP is another local organization that is getting involved with ethanol fuel research studies. The academic entity has created the "Center for Renewable Energy" with the aim of conducting projects related to the development of clean renewable energy in Latin America. Recently, the EAP has expressed a commitment in expanding its research activities concerning ethanol fuel; due to the growing importance of this biofuel and the benefits it could bring to the region (EAP, 2007).

The UNAH has no official projects focused on ethanol fuel. However, there are a few licentiate theses that have addressed this issue, e.g.: Evaluating the Use of Ethanol in Internal Combustion Engines; Evaluating Alternative Ethanol Production Methods from Cassava, Potato, sorghum, Cabbage Residues and Corn; and Evaluating the Agriculture Performance of Sugar Cane. The University of San Pedro Sula (USPS) has also a thesis on the potential of ethanol production from sugar cane (IICA, 2007b).

It is important to mention that the diffusion of the imported knowledge and technologies can be considered to be very efficient. The Sugar Producers Associations (APAH) is in charge of the knowledge and technology diffusion activities among the sugar mills. The APAH is the epicenter of any knowledge transfer actions, making sure that all the seven sugar mills are updated. Activities regarding ethanol production could also be handled by this association.

Influence in the Direction of Search

Virtually all interviewees perceive sugar cane as the optimal feedstock to be used for the production of ethanol in Honduras. Some other feedstock have been evaluated with that purpose. In April 2007, it was announced by the Honduran media that some Chinese companies were considering the possibility to invest in the production of ethanol from cassava in a facility located in the northeast region of Honduras (Azucar-Etico, 2007a). Besides this, there have been limited activities with Sorghum and beets.

As the potential that Honduras has is the availability of land, sugar production capabilities and cheap labor, the main focus of potential investors is towards first generation ethanol. At the moment, there are no shown interests related to second generation ethanol production (Starkman, 2007).

In the last couple of years there has been a great commitment from the government towards the biodiesel industry. Currently, there are several projects related to biodiesel production and there is a major national project related to the use of biodiesel as the primary fuel for the public transport (Aleman, 2007). This situation may create the perception that biodiesel is the Biofuel that is going to be mainly

exploited in the country and that ethanol would not attain the same benefits from the whole system; at some point, discouraging investors and researchers. The fact that ethanol has not been fully considered yet does not mean that it will not be supported by the government. The executive government is keen on developing the ethanol industry but has not started more aggressive initiatives since it requires the approval of the "Biofuels Law" by the legislative government (Starkman, 2007). As it was expressed by the Presidential Special Projects Office, "Without an established framework for ethanol production and commercialization, it is not possible to start any project since ethanol production investments are too high to risk it without an approved positive investment environment". There is a commitment to exploit the ethanol industry derived from the already established sugar industry.

Entrepreneurial Experimentation

This function presents a significant dependence on the other functions of the systems. Entrepreneurial experimentation evaluates the entrepreneurial activities that are going on inside the system. This entrepreneurial activity depends mostly on the incentives that the system offers. Other functions as *Market Formation* and *Legitimization* play an important role in encouraging *Entrepreneurial Experimentation.*

At the moment the potential producers have not established the model to produce ethanol, i.e. in dedicated plants or combined with sugar production. The latter alternative allows shifting production of ethanol for sugar and vice versa, depending on the market conditions. The high price of the sugar is a factor that can discourage ethanol production, as it has been experienced in the last year. This situation is worthy to take in account at the moment to design the business model for ethanol production and commercialization.

Some entrepreneurs, as The Pellas Group, are experimenting with new sugar cane species in the Olancho region. The aim is to increase the sugar cane yield and it resistance against pests. Expanding foreign market for ethanol is seen by the domestic and international entrepreneurs as the main drivers for exploiting ethanol production in Honduras. This opportunity becomes more attractive considering the Free Trade Agreement with different nations.

Market Formation

At present, there is no market for ethanol in Honduras. Since ethanol production has not started for its commercialization as a fuel, there is not an existent market, but there is definitely a latent one. As it has been discussed before, the expectations for ethanol from both the production and the consumer sides are high. The national and even regional market for ethanol is still waiting for a positive legal framework to begin.

In Honduras, and most likely in all the five Central American nations, it is almost certain that a 10% ethanol blend will be established as mandatory, which would create a rather attractive initial market for national producers; 47.5 millions of liters a year for Honduras (Unidad Técnica del Petróleo, 2007) – See box 1 below. A mandatory blend would require all gasoline distributors to provide customers with ethanol blended gasoline or gasohol. It has been in discussion the possibility of establishing an initial optional blend, meaning that each gasoline retailer would not be mandated to offer gasohol and this would be optional (Starkman, 2007). This situation would involve a great campaign informing the final consumers of the benefits of using ethanol since the demand would depend entirely in the will of the consumers to push gasoline retailers to offer the gasohol to them.

The national market is important for national producers to be encouraged by entering on a known environment, but the international market is also very important, specially to attract foreign investments that would make the industry stronger (see section 6.6 Global Trends). The export focus of the industry is justifiable since Honduras could serve the domestic demand producing ethanol only from molasses[10] (Cepal, 2004) or cultivating additional sugar cane, corresponding to less than 1% of the arable land (see box 1). The US is currently the most attractive foreign market for ethanol producers in Honduras. Due to, the market is already well developed and there are positive expectations portraying a healthy growing industry with some minor opposition. CAFTA gives Honduras a strategic position for exporting ethanol to the US and the fact that Honduras counts with state of the art port facilities with easy access to the US market is another important advantage offered by the country. Europe and Asia are the other two interesting markets for Honduras. Europe in

[10] Rest of the sugar production, that can also be used to produce ethanol

particular, could become a great customer for the Central American Region since a free trade agreement is in process since 2006, where both ethanol and biodiesel will be considered in the negotiations.

Legitimization

Considering that Honduras did not have a modern positive legal framework for ethanol fuel the APAH decided to take an active role and to prepare a draft of a "Biofuel Law" that was sent to the national congress for approval. The APAH has also been involved in several meetings with governmental agencies in order to inform key officials of the benefits that the ethanol industry could bring to the country (Fasquelle, 2007). Disregarding the efforts that the APAH has done in the last few years the "Biofuel Law" has not been approved yet. In general, it can be considered that the government has a positive attitude towards ethanol and that considers it to be a viable industry that could help in the development of the country.

National media has played a rather important role for ethanol. Most newspapers and News programs have addressed ethanol as an important alternative for the country to bring some kind of relief to the strong dependency on oil imports. Ethanol has also been portrayed by the media as an important industry that could help to develop rural areas and generate jobs. There have been little negative expressions about ethanol, being the most important one the competition that food crops could have if the ethanol production got out of control. This situation occurred in 2006 since the country started to experience a shortage of corn, something that was immediately related to an increase in the exports of corn due to the corn shortage that the US suffered linked to ethanol production (La Prensa, 2007). Negative exposure has also come from Venezuela and Nicaragua, where both presidents have shown their opposition to the development of the Biofuel industry in Latin America and have focused the attention on the cons that are generally appointed to Biofuels. All in all, ethanol still maintains a very positive portrayal in the media, situation that has been recently spur due to the visit that Brazil's president and a group of investor did to the country (see Appendix 3).

Fuel distributors have shown a rather skeptical, yet not negative, position towards ethanol. This situation might be related to the slow approval process that the Biofuel Law has experienced, which can send a "no commitment" signal to the general public (Silva, 2007). There are also some concerns the undefined process for handling the biofuel (who, how and where the blend is going to happen). Still, the fuel distributors are not against alternative fuels. Some of then, as is the case of DIPPSA, are already involved in important projects with biodiesel producers, and some biodiesel pumps have already been positioned in some gas stations (Starkman, 2007).

It was mentioned before that the government has been working very close with biodiesel producers for the last few years, leaving ethanol aside at a certain point. But this situation was clarified by the Presidential Special Project Office and ethanol will enjoy a stronger more active support in the governmental agenda. In fact, the successful story that biodiesel is experiencing and the exposure it is getting from media is creating an awareness of the potential that the country has regarding Biofuels and the general public has become more attentive to the subject; situation that can be beneficial for ethanol as the positive experience with biodiesel is likely to create a smoother path for ethanol to enter in the market (Starkman, 2007).

Finally, it can be said that the main driver that is building legitimacy towards ethanol fuel is the high petrol price. This situation has created several crises in the country and at the moment it is suffering from a petrol shortage that is causing many socio-economical problems. Oil prices have created a general position that welcomes any type of alternatives that could relieve consumers of higher costs. Ethanol is definitely seen as a positive alternative and it lacks of significant opposition.

Resource Mobilization

The sugar producers of Honduras have stated that their group is capable of undertaking the first investments required to start ethanol production facilities in three of their seven sugar mills located across the country. This financial capability has been referred to be as high as $ 70 million coming from private funds from credit organizations (Azucar-Etico, 2007b). Since the beginning, the sugar industry has

shown a secure disposition of financial resources ready to be used in the investments required to start the ethanol industry.

Other important sources of resources are the foreign investments. In the recent visit to Honduras, the president of Brazil brought with him a group of Brazilian investors that got together with Honduran investors to discuss business opportunities regarding the production of ethanol and biodiesel. This is not the first time that Brazilian companies have shown interest in starting activities in Honduras. There is also interest from Colombian companies to invest in the ethanol industry with the aim of exporting to the US. In august 2007 Honduras, Guatemala and El Salvador signed a Free Trade Agreement with Colombia, where it was expressed by Colombian investors to build two biodiesel production facilities – and depending on the improvements of the region, ethanol production facilities will be considered as well – in the region, one in Guatemala and the other in Honduras. There has been interest from some Asian companies to invest in the ethanol industry in Honduras in order to later export the ethanol to their own countries. Particularly, companies from China, Taiwan and Japan are the ones exploring the possibilities to invest in the ethanol industry in Honduras (Azucar-Etico, 2007; Starkman, 2007).

The CABEI is currently involved in several biodiesel projects jointly with the Secretariat of Agriculture and Livestock. This entity had not started to provide financial support to any ethanol oriented project but they do not rule out this possibility and in fact are most interested in any clean energy related initiative through their energy department. Investing in projects related to alternative clean energies is the aim of this organization, situation that is confirmed by the great commitment that is currently showing with biodiesel investing over $ 90 millions (Montoya, 2007). The organization is aware of the potential that ethanol has and they are keen on starting similar projects related to ethanol production as it was expressed recently by the bank's president who said the bank is willing to create ethanol projects with funds of over $178 millions. The organization is currently financing ethanol projects in Guatemala of over $ 70 millions (El Heraldo, 2007).

The IADB has not any particular ethanol related project at the moment but the institution is also interested in clean energy projects. In fact, the IADB has recently

created the "Interamerican Ethanol Commission" with the mission to promote the usage of ethanol in the gasoline pools of the Western Hemisphere (Interamerican Ethanol Commission, 2007). It is likely that through the creation of this new ethanol commission, there would be plenty financial resources to aid new ethanol projects.

Governmental resource mobilization can be spotted in the development of infrastructure that would positively affect the ethanol industry. The National Port Enterprise is the autonomous governmental agency in charge of the administration of the four ports in the country. These ports could become the main access that ethanol producers will have for their ethanol fuel imports to the US, Europe and Asia. It is important to consider that these port facilities will require investments if they are going to be used for ethanol exports since currently they do not count with specific infrastructure related to fuel exports (they already handle fuel imports) (National Harbor Enterprise, 2007).

Another important activity that the government is pursuing right now is the building of two fuel storage facilities, one on the north and the other on the south region of the country. These facilities will store most of the fuel that will be imported into the country and the ethanol blend will probably be done there. One of the purposes of building these containers is to reduce the bargaining power that transnational fuel importers have in the fuel industry right now.

There are also many projects regarding the expansion and updating of the road system of the country. The main project is the so called "Dry Channel". This project consists in the building of a freeway that would connect the south and the north region of the country. The implications of this project are substantial considering it will improve the transport system used by the ethanol production facilities to mobilize their production either to be blended in the storage facilities or to be exported. There are also projects related to improving the roads that connect rural areas across the country, with expectations of developing around three thousand kilometers of roads in the next few years. As ethanol production is likely to be developed in rural areas, it will be important to consider the necessity that would arise from ethanol producers to account with adequate roads to transport the ethanol fuel to distribution sites. This can be already observed when the Pellas Group demanded to the Honduran government

that in order to start their investments in the Olancho region they should develop a road that would connect its facilities with a distribution site.

Land is an important resource for the ethanol industry and Honduras counts with sufficient arable land (see section 6.1) – see Box 1. Although this is an important advantage there is also a drawback in it. Most of the available arable land belongs to several independent owners who can be reluctant to sell their properties. This situation has slow down the Pellas group investments since they have a hard time negotiating the acquisition of the amount of land that they required (Starkman, 2007).

Required Land to Fulfill National Ethanol Demand

Honduran Sugar Cane efficiency rate: 96.48 tons/hectare*

Ethanol efficiency rate: 72 liters/ton of sugar cane **

Honduran Ethanol Demand estimate (10% Blend): 47.5 million liters

$$\text{Required Land} = \frac{47.5 \text{ millions liters}}{72 \text{ liters/ton}} \div 96.48 \text{ tons/hectare}$$

Required Land = 659,722.22 tons ÷ 96.48 tons/hectare

Required Land = 6,838 hectares

To fulfill the national demand of ethanol, the producers would require 6, 838 hectares of land to cultivate sugar cane. This represents only 0.68% of the total amount of arable land available in Honduras (1 million hectares), and around 1% of the arable land which is not occupied by permanent crops (632,000 hectares).

**Source: Asociación de Productores de Azúcar de Honduras (APAH)*

*** Source: Grad (2006)*

Box 1. Required Land to Fulfill National Ethanol Demand

Development of Positive Externalities

The creation of positive externalities comes to be a function that determines the dynamics of the system; since it represents how the other functions are interacting together. In general, *Entrepreneurial Experimentation* is a function that has strong interaction with *Market Formation*, *Legitimization* and *Resource Mobilization* since intrinsically; the later ones represent incentives for entrepreneurs to enter in a specific industry. Since the system is currently at a very early development stage it is not possible to determine significant positive externalities at the moment, we can conclude that at this point the most important positive externality is the positive environment that has been created in the system regarding ethanol. It is expected that once the system is in a more developed stage it would generate some other significant externalities such as rural development, reduction of the dependency on fuel imports, environmental improvements and exports diversification.

7 Assessing the System's Performance

In the previous section, identified situations were related with each function. In this section, these situations are discussed in order to provide a system assessment that would serve as a basis to identify the different blocking and enhancing mechanisms.

The Honduran innovation system is at an emergent state. Currently, there are no tangible projects related to ethanol fuel production. The system lacks of a defined institutional framework that would provide more concrete guidelines to understand it. These conditions represent a big challenge to this type of analysis since the studied situations are often based on expectations, opinions and conjectures from people involved in the subject. Key factors in the emergence of this IS are the intangible and not formal events that occur. In this context the informal networks as lobby groups and other kind of meetings, are difficult to identify for several reasons. Normally this kind of networks are not documented and consequently it is difficult to get some antecedents of its existence; and maybe, the limited period of time for the research did not allow to discover some others important informal networks. Some of the institutional components are also very complex to recognize, since they are not concrete and belong to a behavioral dimension. Desire, perception and expectation shape this category. To create a more feasible analysis for the Institutions, in a large

extent, it was given priority to tangible rules. Additionally, many conditions are in fact "projects", not concreted yet, which intensify the dynamics of the system, due to uncertainty and mutual dependence. This is the case of the Honduran Biofuel Law, which affects in large extent several functions and it is still in a project state.

Several signals of structural development and dynamism can be spotted. First of all, there are several different actors within the system that are interacting, between each others. This has created a number of networks, both learning and political, that have started to mobilize knowledge and influence across the system. In general, it can be considered that some groups of actors enjoy strong relationship amongst them, initiating healthy networks that provide them with enough bargain power inside the whole system. The main weaknesses can be spotted between different groups or different domains. For example, the relationship between the government and the fuel industry (including importers and distributors) has recently become quite broken due to several conflicts that have not been completely resolved yet (Silva, 2007). The same thing can be perceived between the potential ethanol producers and the fuel industry, were we could not identify a liaison between both important groups.

There are also some initiatives regarding the establishment of an institutional framework that would dramatically help the system to further develop. However, the "Honduran Biofuels Law" has not been approved yet. It can be conjectured that the approval have not been achieved since the legislative government was waiting for the cooperation with Brazil's government to be officially established. The well experienced Brazilian officials could bring their knowledge and help the Honduran government to create a framework based on their experience. It is also important to mention that since the five Central American Nations (Guatemala, El Salvador, Honduras, Nicaragua and Costa Rica) are willing to create a regional Biofuel framework (Mejia, 2007) – meaning that all the five countries approve Biofuel laws that maintain regional standards – then the process becomes even slower. The government has also shown awareness of the importance of the international institutional framework and is considering following the standards developed by the European Union; though this is not official yet. The expectations of an attractive institutional framework are a positive condition of the system, however; its lethargic process may create the perception of a "lack of commitment".

As the system is going through a systematization phase, the interactions between the components of the system are already taking the first steps of functional development. For each of the functions, proposed by the selected analytical framework, numerous indicators of performance were identified.

Knowledge Development and Diffusion has been performed fairly well. Dutrénit & Katz (2005) have appointed knowledge and technology development as one of the major weaknesses that Latin America has when it comes to exploiting innovation activities and creating well developed innovation systems. As they insightfully expose, in Latin American countries the innovation process (or what they call "Learning trajectories") has typically occurred by default, as an accidental consequence of 'learning by doing' during the expansion of local production activities, or of 'adaptive engineering efforts' carried out on the basis of imported know-how. This situation is perceived in the case of the ethanol industry in Honduras, regarding the ethanol production process. Local actors are relying almost entirely on imported know-how related to the ethanol production process and its commercialization, due to the lack of capabilities that are experienced by both public and private entities regarding the generation of knowledge in this matter. This situation might be at a certain point acceptable since they are dealing with a mature type of technology and of course, they are taking a "follower" position consisting on taking advantage of an already proven business.

On the positive side, an important generation of knowledge related to the production of feedstocks for biofuels is happening and is likely to become more active. The system is taking advantage of the core capability of the country, which is agricultural expertise. Research activities are also encouraged since there is a regional interest in ethanol. Most Central American nations are performing research activities encouraging others to do so. At this point, this duality seems to work well since both types of knowledge complement each other. Anyhow, actors should make more efforts to create conditions that could enhance the *Knowledge Development and Diffusion* function in the system. Major knowledge creation initiatives should be carried out in the future in order to develop an innovation system capable of creating sustainable conditions without strong dependency on imported knowledge and technology. To quote Dutrénit & Katz (2005): "The real challenge therefore seems to

be how to create a 'pro-active' technological strategy that would put major innovation efforts and technological generation activities in the driver's seat of the development process".

The *Influence in the Direction of Search* is quite focused. Following the global trends that currently have positioned first generation ethanol from sugar cane as the most efficient biofuel, the system's actors have targeted this type of technology and are likely to pursue it. Even though, there have been some limited activities regarding other type of feedstocks and technologies, in general, the system is likely to strongly lean forward to sugar cane. This is a logical position; the country is taking advantage of an already developed capability, the well established sugar industry. Regarding competition with biodiesel, it is obvious that the biodiesel industry is far more developed than ethanol. The Government, Financiers, Researchers and Producers have worked together in order to develop several biodiesel production facilities from different feedstocks (Jatropha and even fish). Biodiesel has also enjoyed of very positive media exposure and it even has its own governmental website (Honduran Presidential office, 2007). Beyond representing an actual competing industry that would steal resources and attention, biodiesel might represent an incentive to develop an ethanol industry as well. Biodiesel has portrayed biofuels as a true alternative to fossil fuels, and it is helping to build a strong legitimacy, developing a national market and encourage investments for biofuels in general. Due to the current biodiesel national project involving public buses, it would be possible to envisage a similar project with ethanol fuel with taxis cars. If the biodiesel success is smartly exploited, we might dare to state that, at a certain point, the ethanol industry would emerge as a positive externality of the biodiesel industry.

Market Formation in the international landscape looks very promising. It can be perceived that the world is moving towards the formation of an international market where biofuels could be traded as fossil fuels are nowadays. Even though there is a rather significant opposition that is slowing down the process, this global movement is already creating an attractive market for exports. In the national context, the formation of an initial nurturing market is almost entirely dependant on the establishment of a mandatory blend through the approval of the so expected "Biofuels Law". There is also being in discussion the establishment of an initial non mandatory blend.

Consumers in Honduras are well aware of all the problems that are being generated due to the dependency on petrol imports, but we can speculate that a great majority is unaware of the role that ethanol could play in the fuel industry of the country. It is important to mention that even though the non mandatory blend strategy is followed, but due to tax exemptions and maybe some subsidies the gasohol blend is offered at a lower price than regular gasoline; there would be definitely a push from customers to gasoline retailers to offer the gasohol blend. The consumer will be drawn to use ethanol blends because of their competitive price than of its environmental benefits. Both strategies are been evaluated by governmental agencies and even though both of them are on discussion it is expected that a mandatory blend will be the track that the government will like to pursue. Anyhow, the Biofuels Law still remains as a proposal and no signs of a prompt approval are at sight.

Currently, the general idea is that the national customers for ethanol will be the fuel distributors. Disregarding this situation, the government is currently pursuing the goal of building two main fuel storage facilities in Honduras, one in the north region and the other one in the south region. The objective of this project is that the government will be able to have almost absolute control over the imports of fuel into the country, following the recent strategy where the government buys the country's required fuel directly. It is possible, but not certain, that these storage facilities could also take charge of performing the blends with Biofuels and therefore the gasohol will be provided to the fuel distributors, eliminating their investment needs and making the government the main customer of ethanol. If this strategy is followed by the government it would provide an important complementary service for the ethanol industry that would help to reduce any reluctance that the fossil fuel industry could present towards developing the domestic ethanol industry.

Although non tangible ethanol production projects have actually started, *Entrepreneurial Experimentation* can be considered to be somewhat positive. The number of investment projects, both from national and international sides, gives the system some important initial dynamism. However, any entrepreneurial initiative is considerably discouraged by the absence of a positive national institutional framework and at the end; none of them have evolved to tangible investments. Besides the efforts from the Pellas Group from Nicaragua - which is still dealing with

land acquisition problems -, there are no signals from international investors to begin concrete investment projects in the region. The fact that the APAH, after being the main national enthusiast, has recently expressed a temporary discouragement due to a drop in the international price for ethanol fuel and the sustained growing behavior of sugar price. It is a significant drawback for the development of the system. This situation can also become very harmful for the legitimization process, since it could damage the perception of ethanol fuel as a more attractive export oriented industry and an important source for expanding the foreign exchange reserves.

National media has portrayed ethanol fuel as a positive alternative to fossil fuels and an important opportunity for Honduras to diversify its agricultural sector and mitigate the heavy burden of petrol imports. The recent oil crises faced by the country have also dramatically contributed to biofuels initiatives. The growing national biodiesel industry is also providing positive insights about the potential of biofuels and its success can be exploited as a presentation card for ethanol. The expectations of an encouraging institutional framework that would provide important incentives for investors gives also an important quote in the legitimization process; however, due to the lethargic aptitude of the government, this could also become a double-edged sword.

The legislative authority (National Congress) seems to have forgotten about the biofuels law project that has been on their hands for over a year now. On the other hand, the executive side has not exercised significant pressure to speed up the process, even thought they are aware that without an attractive framework, ethanol production is unlikely to start due to its major investment requirements. This uncertainty created by the government can be harmful for the legitimization process. However, this can not only be thrown over the government. The private sector has its quote of responsibility. Disregarding their initial enthusiastic efforts and leadership, the sugar producers failed to associate with other important actors that would create a strong advocacy coalition that would be able to efficiently push the national congress to take the biofuels law more seriously. Different from biodiesel producers, whom cleverly established relationships with several important actors from different sectors, and include them in their projects - the national fuel distributor DIPPSA, National Transport Council, the CABEI, German Technical Cooperation and the government -

in their projects; the sugar producers maintained a more independent approach and most of their initiatives to associate with other actors remained weak and inefficient.

Resource Mobilization has been lead by the private sector. The sugar producers took since the beginning, a very active role by announcing their capability of secure by their own means the required financial resources to start ethanol production in three of their sugar mills. Development Banks play an important role in creating special funds for projects related to renewable energies. The CABEI is the main financer of biodiesel projects in the country and has already established financing projects related to ethanol in Guatemala. Although in Honduras, neither the CABEI nor the IADB has special ethanol projects for the country. They are certainly interested in developing the industry, especially considering the active role that the private sector has shown. The Government has not shown initiatives about the provision of resources directly related to ethanol; although, they are pursuing some projects that are focused on agricultural and rural development, and could benefit the ethanol industry indirectly – such as the improvements on roads that connect rural areas (which could be used for sugar cane cultivation) with the main roads. Trade conditions are also a major advantage that is attracting foreign investors aiming to export to both the US and Europe. *Resource Mobilization* appears to be very dynamic; however, most initiatives remain just as initiatives.

7.1 Identified Blocking and Enhancing Mechanisms

As a result from the previous evaluation, it is possible to identify seven enhancing and four blocking mechanisms that are influencing the system's performance. These mechanisms are portrayed in the figure below; and concurrently, their relationship with each function is also presented.

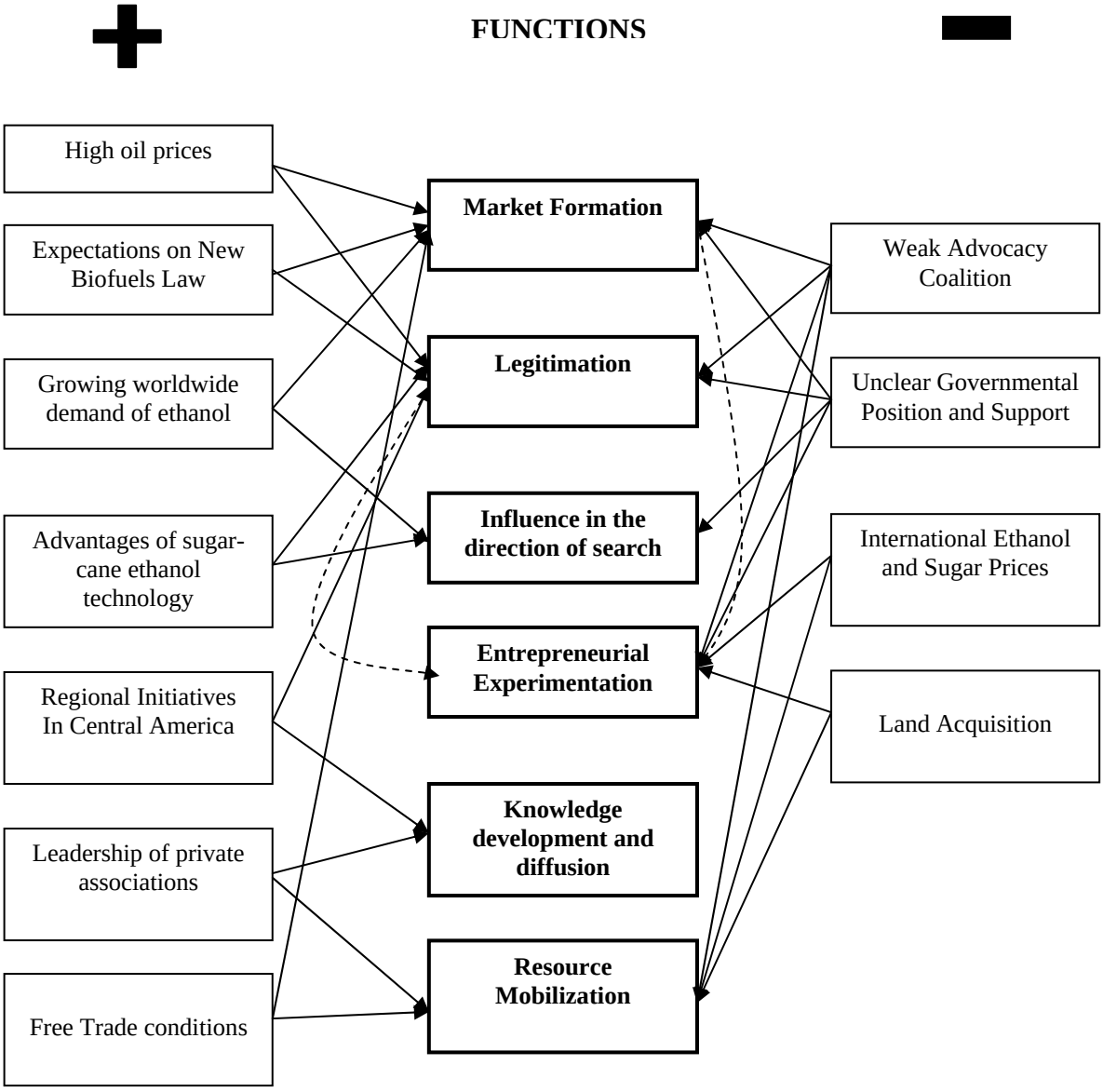


Figure 6. Ethanol Blocking and Enhancing Mechanisms

In the figure, we can identify that there are many enhancing mechanisms that provide positive dynamism to the system. Nevertheless, the functions Entrepreneurial Experimentation, Resource Mobilization and Market Formation are blocked by two significant mechanisms. A "Weak Advocacy Coalition" and an "Unclear Governmental Position and Support" are two critical issues present in the system that are negatively affecting it. The lack of strong connections between key actors and the ambiguous position that the government is portraying are two main challenges that need to be overcome in order to develop the industry.

A "Weak advocacy Coalition" seems to be an important blocking mechanism. Sugar producers have maintained a rather independent position, that has probe to be positive since it has provide them with a leadership image and they actively ignited the whole biofuels movement in the country. However, the sugar producers have failed to create strong liaisons with other important actors, situation that has deteriorated their bargaining power over time. The main challenge for the private sector is to work together with other actors, such as fuel distributors, financers and the government, in order to create a strong coalition that would allow them to exercise pressure over the governmental institutions involved in the creation of the institutional framework. This institutional framework starts with the "Law for the Production and Consumption of Biofuels" but then, several different policies need to be developed in conjunction by the involved public entities. These entities have the challenge of creating an attractive framework that would provide entrepreneurs with enough incentives to invest but at the same time; carefully address issues related to land management and agricultural development, so the exploitation of resources can be handled in a responsible manner, avoiding future legitimization problems that could result in strong opposition and further more, a possible system failure.

The "Unclear Governmental Position and Support" is another identified critical blocking mechanism. The private sector showed valuable leadership by conducting initial studies and elaborating a proposition for a biofuels law that was sent to the National Congress. The government expressed their interest and commitment to the subject but no results have been achieved. While the executive government, through the Presidential Special Projects Office, shows a strong commitment to biofuels; the legislative government seems to have forgotten about the subject. This situation

brings important instability to the system creating an uncertainty that investors are afraid of and, spurs other actors' reluctance. The Challenge for the government is to define a joint strategy where the involved governmental entities define their roles and commit to the subject. In this way, a more stable situation can be perceived by entrepreneurs and investors that would encourage them to move resources in a certain field.

"International Ethanol and Sugar prices" is an exogenous situation that directly affects the Honduran IS. The combination of an increasing international sugar price and a decreasing ethanol price is critical especially in the national context. An increasing sugar price may encourage sugar producers to lock-in in their core business and oversee the potentiality of ethanol fuel diversification. Sugar producers have already considered flexible ethanol production/sugar processing facilities. This would allow then to shift sugar or ethanol production according to the international prices of these commodities. Anyhow, sugar producers have recently hesitated about embarking in the ethanol fuel industry. Public help might become vital to reignite the national ethanol fuel private initiatives. The government has stated that subsidies will not be considered for encouraging biofuels in the country. The basis for this argument is that the biofuel industry is enough attractive to require subsidies. It is necessary to revaluate this position since the current picture may not be as they think. A well design subsidies program could represent an important incentive for sugar producers to find again, ethanol production as an attractive business.

"Land Acquisition" problems have been experienced by a foreign investor. This situation could represent a disincentive for others looking to establish ethanol feedstock production activities in the country. The government should take an initiative similar to the one used with biodiesel; where a land study was conducted in order to determine the regions with better conditions for this industry to develop. Currently, the government is also performing an ambitious national land regulation program that would help to organize land usability and ownership. This issue is quite sensitive, since it is necessary to provide potential investors with attractive land quantities without creating conflict with the current agriculture laws. These laws establish land ownership limits in order to avoid large estate owners. However, sugar cane fields enjoy several advantages that, under the proper permits, allow sugar cane

producers to expand their land acquisitions above the established limits. Land acquisition is a matter that directly concerns to the Secretariat of Agriculture and Livestock and the cadastral entity, and is necessary for these public organizations to consider this subject with the adequate diligence.

8 Concluding Remarks

The purpose of this master's thesis was to analyze the ethanol industry in Honduras and identify the main blocking and enhancing mechanisms that will be faced in order to facilitate its further development. To do so, we employed an innovation system approach, which consisted in the study of seven functions performed by the different components of the system. Before this, we engaged in a brief study of the involved technology and the global landscape related to ethanol fuel. As a result from the analysis, seven enhancing and four blocking mechanisms were identified.

The Honduran innovation system is at an emergent state. Currently, there are no tangible projects related to ethanol fuel production. This situation presented several restrictions to the study. In spite of these methodological limitations we managed to perform a conscious analysis that allowed us to identify several different enhancing and blocking mechanisms that are affecting the system and presenting important challenges for its actors. Currently, there are seven enhancing mechanisms – (i) High oil prices, (ii) Expectations on new Biofuels law, (iii) Growing worldwide demand, (iv) Advantages of sugar cane ethanol technology, (v) Regional initiatives in Central America, (vi) Leadership of private associations, (vii) Free trade conditions – that provide the system with significant positive effects, implying the possibility of prosperous development.

Nonetheless, the four identified blocking mechanisms – (i) Weak advocacy coalition, (ii) Unclear governmental position and support, (iii) International ethanol and sugar prices, (iv) Land acquisition – are critical issues that could create significant drawbacks if not tackle in a proper manner. We provided some recommendations that should be taken in consideration as initial points to design strategies to overcome these conditions.

At this early stage the four identified blocking mechanisms are the main challenges in the system. However, as the system will evolve over time and many other implications will arise, creating more challenges. It is important to mention that at the moment, we do not consider that the *Knowledge Development and Diffusion* function has critical issues to deal with. But, as ethanol technology is very dynamic and there is much R&D going on worldwide, it is important that the actors remain attentive and become more active in this subject. Especially due to the significant implications that the sudden development of a more efficient process or technology would have over the system. Due to its technological and research capabilities, the Pan-American Agriculture School (EAP) should take leadership over this challenge and become an important knowledge developer and learning network in this matter. The private sector and the government should become more active in this subject as well, by creating special projects in conjunction with academic organizations.

APPENDICES

APPENDIX 1

Here is an example of the guiding questions used during the interviews. Some of the questions varied according to the interviewee.

1. Which has been your involvement in the development of the new "Biofuels Bill"?
    a. Which factors were considered when developing the bill
    b. It has been stated that no fiscal incentives will be included, why?
    c. Do you believe that the bill will create enough attractive conditions for entrepreneurs?
2. Are you currently developing any plans regarding:
    a. Land management
        i. Forest and Jungle predation
        ii. Bad Agriculture Practices
        iii. % on land use for food
        iv. Quality of land been used – Land more suitable for food production
    b. Individual Farmers Support and Protection
        i. Especial Loans
        ii. Land Ownership
        iii. Encourage Cooperatives
    c. Investments in Supporting Infrastructure
        i. Roads
        ii. Water Supply
        iii. Distilleries
    d. Informing Future Users
    e. Job creation targets – possible trade-off with efficiency
    f. Establishments of Standards for ethanol – Tests on cars to avoid further problems that could hurt legitimacy

3. It has been announced that Honduras has established an agreement with Brazil about Knowledge and Technology transfer regarding Biofuels Production and Use.
    a. Are there any developed programs already with this purpose
    b. How this relationship is been managed
    c. Which are the governments expectations about this relationship
4. What are your expectations on Foreign Direct Investments? Do you think the industry heavily relays on it? Are local producers protected?
5. What are the implications regarding CAFTA?
6. How are the trade relations regarding ethanol with Europe and Asia?
7. What about Flex-fuel cars? Have you considered the promotion of this type of cars (with tax exemptions, etc)?
8. Are there any incentives for Gasoline Distributors (Shell, Texaco, etc...)? What reaction do you expect from them?
9. Are you considering promoting ethanol through ad programs? To educate people?

APPENDIX 2

Interviewees List

ORGANIZATION	INTERVIEWEE	POSITION	LOCATION
Secretariat of Industry and Commerce	Reinaldo Mejia	Normalization Office	Tegucigalpa
Secretariat of Industry and Commerce	Fredy Cerrato	Secretary of State	Tegucigalpa
Presidential Special Projects Office	Moises Starkman	Head of the Office	Tegucigalpa
Association of Sugar Producers of Honduras	Carlos Melara	Executive Director	Tegucigalpa
Association of Sugar Producers of Honduras	Maritza Fasquelle	Executive Assistant	Tegucigalpa
Secretariat of Natural Resources and Environment	Marco Flores	Energy Director	Tegucigalpa
Secretariat of Natural Resources and Environment	Olga Aleman	Energy Specialist	Tegucigalpa
Central American Bank for Economic Integration	Carlos Montoya	Executive Director	Tegucigalpa
Honduran Association of Petroleum Distributors	Sarahi Silva	General Manager	Tegucigalpa
Honduran Agricultural Research Foundation	Jose Alfonso	Project Coordinator	San Pedro Sula

APPENDIX 3

Ethanol in Asia

Japan has no mandatory blends, but promotes the 3% blend. With limitation on feedstock to produce ethanol, Japan arises as a likely export market. The government has also designed a national budget to encourage the domestic production of ethanol into the coming years. Brazil has take steps forward in this potential market with the creation of a Brazilian- Japanese joint venture and an agreement between Petrobras and Mitsui in order to study ethanol logistic in Brazil. However, the potential of this initiative may become jeopardized due to the present concerns of government, automakers and oil companies about the feasibility to introduce mandatory blends; these different groups only agree in the potential of replacing MTBE for ETBE, which represents anyway a good possible export market for ethanol (USDA 2006).

During the last two decades China has encouraged the use and production of ethanol, developing a three phase program which included large support on R&D, legislation and different economic mechanisms to introduce Biofuels. The last phase consisted of a small-scale production, using grain and cassava as raw materials, and finalized with the promulgation of the ethanol Extensive Use Law. This established a financial and administrative system to support the development of ethanol. Some provinces use 10% blend (E10) and have subsides on ethanol production. The next government's goal is to achieve large-scale production of biofuels before 2015 and increase of biofuel on transport to 15% before 2020. The growing transportation sector may demand in 2020 22.8 million tons of both biodiesel and ethanol. Considering the different alternatives feedstock and planning production capacity, China would produce around 8 million tons, creating a supply deficit of 12.8 million tons of ethanol (IADB, 2006).

India's experience in the development of the ethanol sector has been a bumpy road. In 2003 the country started with a mandatory blend of 5%, but a deficit in the availability of molasses – a by-product of sugar cane - , the exclusive ethanol feedstock; resulted in higher ethanol prices and the impossibility for oil companies to fulfill the mandate. The government had to halt the mandatory blending, until the recovery of the molasses industry. The first phase of the ethanol program set the 5% blend becomes

mandatory again, in 2006. This demand is expected to be served with domestic production, but the country presents some drawbacks for ethanol production; limitation of water resources, scare land for sugar cane cultivation and current utilization of molasses that is low-sugar concentrate resulting in a less efficient rate production than direct sugar cane.

Motivated by the upcoming increasing demand of ethanol, Thailand and the Philippines want to develop the ethanol industry for overseas export and also have implemented mandatory blends of 5%. The former is the largest producer of cassava and unlike the other countries in Asia the future production is likely to increase more than the internal demand. However, the Philippines are not expected to fulfill the domestic demand and will remain importing ethanol for the upcoming years.

In the case of Australia, the country became engaged with the environmental issues and consequently the support of biofuel in 2005; with the establishment of the Action Plan of Biofuels, which repeated a previous target of 350 million liters by 2010. The government supports the ethanol industry with grants to blending, production plants and creating market trough government E10 contracts. The production subsidies are valid until 2011, so the producers have the pressure to improve the cost-effectiveness to avoid the take over by cheaper ethanol imports. No blend is mandatory and the confidence on ethanol remains low in the consumer's side, with almost no support of the domestic auto-makers. In addition, Australia lacks cultivable land for ethanol feedstocks and an eventual expansion of the ethanol production raises concerns about the balanced export agriculture regime (Nielsen, 2006).

Pakistan enjoyed duty-free ethanol exports to the EU until 2005, resulting in the lost of the position as second-largest ethanol exporter just ahead of Brazil. To absorb the surplus of ethanol production, the government is planning to impose a 10% blend, restrict the molasses export, the main ethanol feedstock; and establish a mandatory quote of domestic fabrication of flexi-fuels cars. (Jordbruksverket, 2006).

Ethanol in Africa

Currently the only significant importer of ethanol in Africa is Nigeria, which imported 180 million liters in 2005. Nigeria's main crops with the potential of being used for

ethanol production are sugar cane and cassava. China is the leading investor in Nigeria's ethanol industry and both governments have established a joint project expected to cost around $ 76 million. And the government has already released around $ 197,000 to cassava farmers for improvement on mass production. (Inter-American Development Bank, 2006)

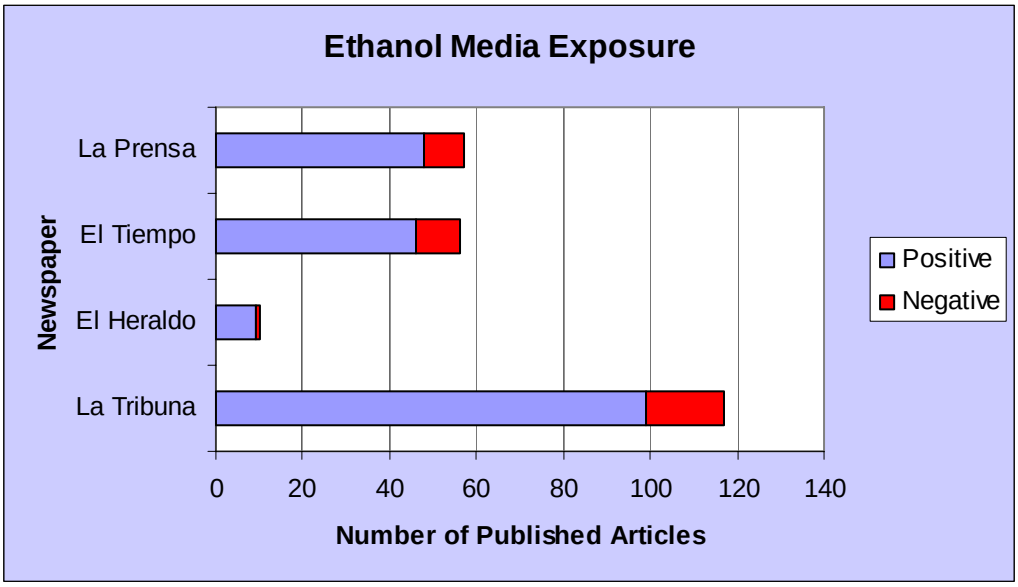
In South Africa, corn farmers, investors and specialists in the clean technology market have formed a private cooperation company called "Ethanol Africa"; which is a company that is strongly supporting ethanol production development in the country (Ethanol Africa, 2007). The South Africa's Energy Development Corporation bought 25.1% stake of Ethanol Africa in order to add impetus to viable initiatives of ethanol production in the region. Ethanol Africa is planning to invest around $ 87 million in the construction of 8 ethanol production facilities based on corn crops. Ethanol production from sugar cane has great potential and viability studies are being carried out right now (IADB, 2006). Mozambique is one of the most promising African nations in the production of ethanol. Stable political conditions, climate, large uncultivated arable lands (only 9% of the available 36 million hectares is being used), and low wage labor make. Mozambique aims to produce ethanol mainly from cassava and sugar cane, and the government has embarked on an ambitious land concession program managed by the Mozambique Bio-Fuels Industries Lda (MBFI). The Empresa Nacional de Hidrocarbonetos (ENH) and Mozambican State Oil Company (Petromac) have several biofuel programs aiming to produce 280 millions liters of ethanol and biodiesel per year. Petromac and the Committee for the facilitation of Agriculture between Mozambique and South Africa (COFASOMA) have agreed to invest € 80 millions in an ethanol production facility based on sugar cane, with an annual capacity of 220 millions of liters (Inter-American Development Bank, 2006). Other ethanol productions plants have also been announced; a Mozambican sugar producer is planning to invest in ethanol production plant with a capacity of 17.6 million liters per year, the Sweden ethanol producer Sekab plans to open an ethanol factory in Mozambique and Tanzania in 2010 and one factory every year until 2015 (Gröna bilister 2007) and a Pro-Cana, a private company with British interests, is set to invest $430 million for the construction of a new plant for the production ethanol, sugar and fertilizers (allAfrica, 2007).

APPENDIX 4

Country	Official Targets	Policies	Potential impact on Honduras ethanol industry
Brazil	40% rise in production 2005-2010	-20% minimum mandatory blend -Tax exception for ethanol at the pumps (Around € 0.30/liter) -Tax exceptions for Flex-fuel cars	Brazil's exports to the US and the EU are currently suffering from taxations. Brazil is seeking to invest in ethanol dehydrating plants in Central America to export ethanol from there to the US, blended with domestically produced ethanol. These investments are also accompanied by agreements related to commercial and technical knowledge transfer.
Colombia	10% mandatory Blend 2010	-Tax exception to all ethanol produced to be used in gasoline blends -€ 19 million risk fond to promote the construction of ethanol plants	The ethanol industry in Colombia is experiencing tremendous growth and it is possible that they could follow a similar path as Brazil in establishing investments in Central America.
Venezuela	No Official Targets yet	Alliances with Cuba in order to build ethanol production facilities	If it would efficiently high-scale produce ethanol domestically to be blended with their oil production this could result in lower prices for their gasoline exports.
Central America And Caribbean Region	No Official Targets yet	-The five Central American nations are currently working on developing National Biofuel Laws. -Central American Free Trade Agreement (CAFTA) - Plan Puebla Panama (PPP) - Mesoamerican Biofuels Group - Energy and Environment Partnership	The Duty-free access to the US and EU markets creates a great potential market for ethanol exports in Honduras. The development of national Biofuels laws that would establish local mandatory blends will provide an initial nurturing market for the industry.
Mexico	Produce 7,840 barrels of ethanol per day 2012	National Sugar Cane Agro-industry Program encouraging the development of Biofuels.	Is possible that Mexican Corporations would be interested in investing in the Honduran Ethanol industry.
US		-Energy Policy Act of 2005 – Renewable Fuels Standard (RFS) -Volumetric Ethanol Excise Tax Credit	The US represents the most attractive market for the Honduran ethanol industry. With the current policies that are already applied or in the developing phase is clear that the US is going to required great amounts of

		(VEETC)	ethanol from other countries. Honduras enjoys a favorable commercial relationship with the US and CAFTA gives Honduras open doors to the US market.
	Reduce Gasoline use in 20% 2017	-Secondary Offset Tariff on ethanol imports to protect domestic industry. -Caribbean Basin Initiative (CBI) with limited import quotas to member countries.	On the other hand, NAFTA gives similar opportunities to Mexico, a country that has not yet a strong ethanol industry but could develop one; which could aggressively compete with Honduras.
	€ 0.18 per liter of ethanol produced 2012	-Central American Free Trade Agreement (CAFTA) -North American Free Trade Agreement (NAFTA) -Promotion of the MTBE substitution by ethanol.	
			-Honduras enjoy of unlimited duty-free imports of ethanol in EU until 2008. This status will likely continue. -Honduras can benefit from the EU Biofuel Assistance Package for developing countries. -Wiliness to fulfill the targets requirements with half ethanol imports, since the domestic production is not cost competitive with sugar cane- to-ethanol. **Germany** Larger target than EU impossible to meet with domestic production due to lack of arable land. It is expected a rising in the price of domestic ethanol production, due to government study to cut the subsidies on ethanol crops and change the tax system on biofuel. Strong business relationship with Brazil **France** uses a tender system to supply internal ethanol. Abroad producer can benefit of the exemption duty offer by the tender system, if they meet the condition to supply the French market. **Spain** Even the largest producer will not expand the capacity production; the domestic actors remain still grown as a way to develop the agricultural sector. **Sweden** Expect to raise the mandatory blend to 10% Promoting the reduction on exporting ethanol. Despite the expectation on second generation ethanol Sweden will remain as a large exporter of ethanol fro direct blending. Swedish companies announced to build production facilities in Africa.
		- EU CAP provision: energy aid of €45 per hectare is available to farmers who produce energy crops.	
		-Current Biofuel Strategy, establish seven key policies:	
EU	5.75% by 2010 Suggest target 8% by 2015 And 25% by 2030	1. Stimulating demand for Biofuels. 2. Capturing environmental benefits. 3. Developing the production and distribution of Biofuels. 4. Extending supplies of feedstock. 5. Enhancing trade opportunities. 6. Supporting developing countries. 7. Research and development.	

APPENDIX 5



Number of Published Articles related to ethanol in 2007.

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