Assessing the biomass potential for supplying an increased blending mandate in Argentina with a focus on food security

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Abstract

The impacts caused by the use of traditional fossil fuels on climate change have created a need to substitute these with sustainable forms of energy. In the transport industry, specifically, the use of biofuels has been employed in recent decades to reduce the reliance on fossil fuels. Blending mandates are a viable policy tool which can be used to reduce GHG emissions of the transport sector by mixing fossil fuels with a set percentage of biofuels. However, the use of food crops to generate biofuels can create competition over resources and requires a detailed assessment to safeguard food security. FAO have developed the BEFS analysis tool to assess the bioenergy potential of a country's biomass whilst ensuring that food security is not compromised. Using Argentina as a case study, this thesis applies the BEFS RA tool to analyse Argentina's existing biomass potential with an increase in blending mandate as the main consideration. The energy crops selected for analysis are sugarcane and maize for ethanol, and soybean for biodiesel. The agro-economic data for each crop were collected from a range of sources including governmental databases and agricultural reports. Assessment of potential biomass feedstock available, profit margin analysis of crop production, and financial assessment of the feasibility of construction of biofuel plants was carried out. The results provide an initial assessment of the viability of increasing the blending mandate. Although an increase in the blending mandate from energy crops is supported by this research, the economic instability of Argentina is an obstacle for the industry and governmental support for the policy must exist to ensure its viability.

Key words: Bioenergy, blending mandates, food security, BEFS, Argentina.

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Abbreviations and Acronyms

BEFS – Bioenergy and Food Security

(BEFS) AF – Analytical Framework

(BEFS) RA – Rapid Appraisal

FAO – Food and Agriculture Organisation

GAEZ – Global Agro-Ecological Zoning

GDP – Gross Domestic Product

GHG – Green House Gas

IRR – Internal Rate of Return

LCA – Life Cycle Assessment

MMT – Million Metric Tonnes

Mtoe – Million tonnes of oil equivalent

NPV – Net Present Value

SAyDS – Secretaria de Ambiente y Desarrollo Sustentable

SVO – Straight Vegetable Oil

VAT – Value Added Tax

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Chapter 1: Introduction

1.1 Background

The improvement of energy systems is an on-going process in human development. In recent history, the aim of the energy sector is to develop renewable forms of energy which help to mitigate climate change (Moomaw et al., 2011). Examples of these include solar, wind and bioenergy, amongst others (Boyle, 2004). Biofuels have long been viewed as a sustainable substitute to traditional fossil fuels, especially in the transport sector (IEA, 2018). However, bioenergy is one of the most controversial forms of renewable energy and has divided opinion of researchers (Singh et al., 2016). This is due to first-generation biofuels being produced from food crops and therefore potentially affecting food security (Fischer, 2009). The competing nature of first-generation biofuels and food prices is not unique. Similar competitive relationships exist with both water and land use and therefore these should be mitigated to ensure that the developed supply chains are sustainable (Rulli et al., 2016). Adequate assessment of the potential networks and minimising the change in land use are two of the main mitigating factors which can be undertaken (Lago et al., 2019). Furthermore, ensuring the feedstock production can be maintained year on year is also key to ensuring long-term sustainability (Bauen et al., 2009).

Argentina is an interesting case study due to the important role the bioenergy industry plays within the country, compounded by the economic volatility the country is experiencing (World Bank, 2020; Mathews et al., 2008). Recent inflation has caused manifold problems for the industry due to price freezes which have made production insolvent (Biodiesel Argentina, 2020). The current instability offers opportunities to strengthen the industry and to enact changes which will support further growth. However, any changes in the industry should be accompanied by a detailed assessment of the potential impacts on food prices, employment opportunities and the cost of fuel (Wesseler & Drabik, 2016). Given that the majority of biofuel in Argentina is produced from food crops, ensuring that sustainable practices are followed is paramount to guaranteeing that these new developments offer improvements to sustainability and lead to a reduction in GHG emissions.

1.2 Problem Statement

The importance in safeguarding food security when developing first-generation bioenergy networks is paramount (Mohr & Raman, 2013). The use of food crops to produce energy can give rise to competing interests relating to food prices, land and, water use and therefore needs to be properly considered to ensure environmental and social benefits from these developments (Janssen, 2011).

Crop management practices and complete assessments of the potential networks should be performed to guarantee that these are net positive (Lago et al., 2019).

The agriculture sector plays a key role in the Argentinian economy and the feedstock potential of the country has led Argentina to become a leader in biofuel production (Timilsina et al., 2013). A blending mandate was subsequently introduced as a policy tool to provide a national market for biofuels. This refers to the blending of biofuels with traditional fossil fuels at ratios mandated by the government. However, the current economic recession experienced in Argentina since 2018 has had detrimental impacts on the bioenergy industry. Costs have continued to increase, driven by over 50% inflation on the previous year, and the December 2019 price freeze on biofuels has led to production costs that are higher than the market price of biofuels (Joseph , 2020; World Bank, 2019). The reduced feedstock prices due to the coronavirus pandemic have alleviated the costs slightly, however, biofuel plants have been operating at a loss and the stability of the industry is at risk (Agrovoz, 2020; Biodiesel Argentina, 2019/2020). Furthermore, the law supporting the biofuel mandate is set to expire in 2021 and offers opportunities to support the struggling industry and increase the market for biofuels.

The economic uncertainty and political pressures experienced by Argentina created statistical uncertainty in the country as data were not effectively collected which can hinder the assessment and implementation of effective policy (Antón et al., 2019). However, to ensure that sustainable bioenergy networks are developed, a detailed assessment of the techno-, socio- and economic impacts of these new developments must be performed. This will help to guarantee sustainability and safeguard volatile food prices. Furthermore, this supports the objectives of the Argentinian government to strengthen the agricultural industry and improve the development of bioenergy (Gobierno de Argentina, 2016).

1.3 Research Objectives

The objective of this research is to assess the potential impacts that increasing the blending mandates for biofuels in Argentina can have on the economic, environmental, and social contexts, by using the BEFS tool to analyse the potential feedstock available and the end uses.

1.4 Research Questions

Main Research Question:

- Can an increase in the blending mandate of Argentina be supported by the available biomass feedstock whilst safeguarding food security?

Research Sub-Questions:

1. What are the main bioenergy and food security considerations in the country context?
2. Does effective crop management provide the necessary feedstock for increased biofuel capacity?
3. What is the current state regarding the production of biofuels in Argentina? Is increasing the production of biofuels for the transport sector a viable option? What impact has the current price freeze had on the profitability of biofuel production?

1.5 Thesis Outline

This thesis is comprised of three sections. The introduction and the literature review are presented in Chapters 1 and 2 and the research design in Chapter 3. The results obtained from the BEFS tool are presented in Chapters 4, 5 and 6 and correspond to the modules that make up the framework. Finally, the main discussion and the conclusion sections are presented in Chapters 7 and 8. The full results for the three modules are presented in the Appendices.

Chapter 2: Background Research

This aim of this chapter is to identify and review the main concepts relating to bioenergy and food security to provide the background context for the tool selection.

2.1 Bioenergy Overview

Bioenergy refers to the renewable energy which can be extracted from biomass sources. Biomass sources include oil crops and starch crops, lignocellulosic materials (residues) and wet biomass such as organic waste and manure, amongst others (FAO, 2014). This energy is derived from the sequestration of carbon in organic matter through photosynthesis. Therefore, this energy type is considered renewable as crops can be regrown to offset the carbon emitted through combustion (Dahiya, 2014). Bioenergy exists in various forms depending on the feedstock material supplied and the conversion technique used. Conversion techniques include combusting solid biomass to produce heat and/or power, generating electricity from biomass to supply rural communities with electricity, combined heat and power (CHP) and industrial biogas processes to generate power for large-scale activities, or producing liquid biofuels for the transportation sector (FAO, 2014).

2.2 Food Security Overview

The concept of food security has had a variety of definitions throughout the last 50 years. The commonly accepted definition used today was agreed at the 1996 FAO Food Summit (Upton et al., 2016). Food security exists when "all people at all times have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2003: 313).

Upton et al., (2016: 137) designed a set of axioms through which this definition can be visualised hierarchically using four parameters: availability, access, utilisation, and stability. The link between these four parameters and the FAO definition are detailed below:

1. Scale Axiom – The scale required encompasses "all people".
2. Time Axiom – The time concept relates to stability as variation exists over time and should be understood "at all times".
3. Access Axiom – This axiom relates to both availability as well as accessibility and depends on "physical, social and economic access".
4. Outcomes Axiom – This axiom refers to the concept of utilisation and is related to ensuring the available food resources for an "active lifestyle".

2.3 Bioenergy and Food Security

The production of first-generation biomass and food crops are closely related due to both industries utilising the same resources. The competing nature of these two industries creates an important nexus between energy and food which must be adequately considered to ensure novel bioenergy networks do not affect the local food supply.

2.3.1 Impacts of Bioenergy Development

The development of new bioenergy sources offers exciting possibilities for both social development as well as environmental improvements (Wu et al., 2018). The replacement of fossil fuels and the increased energy security offered by these networks are counterbalanced by issues relating to water scarcity, soil degradation and impacts on food security (Benites-Lazaro et al., 2020). The role of bioenergy can be categorised into Northern and Southern requirements. Northern economies view bioenergy as a means of reducing carbon emission, to meet decarbonisation targets, and to improve energy security and mitigate higher global oil prices. Southern economies focus on the use of bioenergy to improve rural poverty and electrification (Clancy, 2013). Although there is some overlap in uses, the contrast in the application of bioenergy between developed and developing countries demonstrates the adaptability of bioenergy networks depending on the requirements and available resources (Clancy, 2013).

Synergies of Bioenergy Production

Examples of synergies developed through bioenergy supply chains include combining the production of bioenergy with waste management techniques to improve process sustainability and to help introduce concepts of circularity (de Boer & van Ittersum, 2018). Assessing agricultural crop residues can provide the basis for the creation of new bioenergy networks (Scarlat, 2010) which can have a positive role in reducing waste and carbon emissions (Rajmohan et al., 2019). Furthermore, these new networks can produce energy sources for off-grid communities and can help to modernise energy sources in rural areas. This can greatly impact the quality of life of the local population as it offers improvements to energy consumption, food production, living conditions and job prospects (Pollock et al., 2019).

Drawbacks of Bioenergy Production

The production of bioenergy can create important drawbacks within the water-land-food nexus. To ensure sustainable development of bioenergy networks, it is of paramount importance that a detailed analysis of potential conflicts regarding resource allocation is performed to ensure the creation of sustainable energy networks (Rulli et al, 2016). Developments in bioenergy can lead to loss of biodiversity and can greatly impact the local environment by polluting the water supply and degrading the topsoil (Wu et al., 2018). Furthermore, the increased use of food as bioenergy feedstock may impact food prices which creates important social problems. Finally, public opinion surrounding bioenergy is far from positive due to the negative media portrayal which can hinder the creation of bioenergy sources (Kline et al., 2017).

2.3.2 Sustainable Bioenergy Development

The production of bioenergy is not intrinsically positive, nor negative. The effect that developing bioenergy networks have are dependent on their implementation (Roos et al., 1999). If correctly implemented, bioenergy sources can provide positive impacts to both social and economic development and environmental improvements. However, if implemented incorrectly, these can cause permanent damage to local & global ecosystems (Wu et al., 2018). Therefore, an approach which considers the sustainability of bioenergy should be adopted to ensure first-generation biofuels are a net positive to potential bioenergy developments.

FAO (2014) has developed a systematic approach for the creation of sustainable bioenergy networks. This approach is visualised in figure 1 below and consists of various analysis tools:

- Context Analysis, Objectives and Mobilisation: this section focusses on analysing the specific country and provides a comprehensive framework to assess bioenergy development. The BEFS RA tool helps to provide a base knowledge which can be expanded upon.
- Guidelines, integrated national assessment and strategy development: this section provides further detailed analysis into risk prevention and environmental safeguarding. It can also help identify knowledge gaps which hinder the development of sustainable bioenergy.
- Assessment, evaluation, and response: this section evaluates the sustainability of the bioenergy networks and helps to finalise the creation and implementation of sustainable networks.

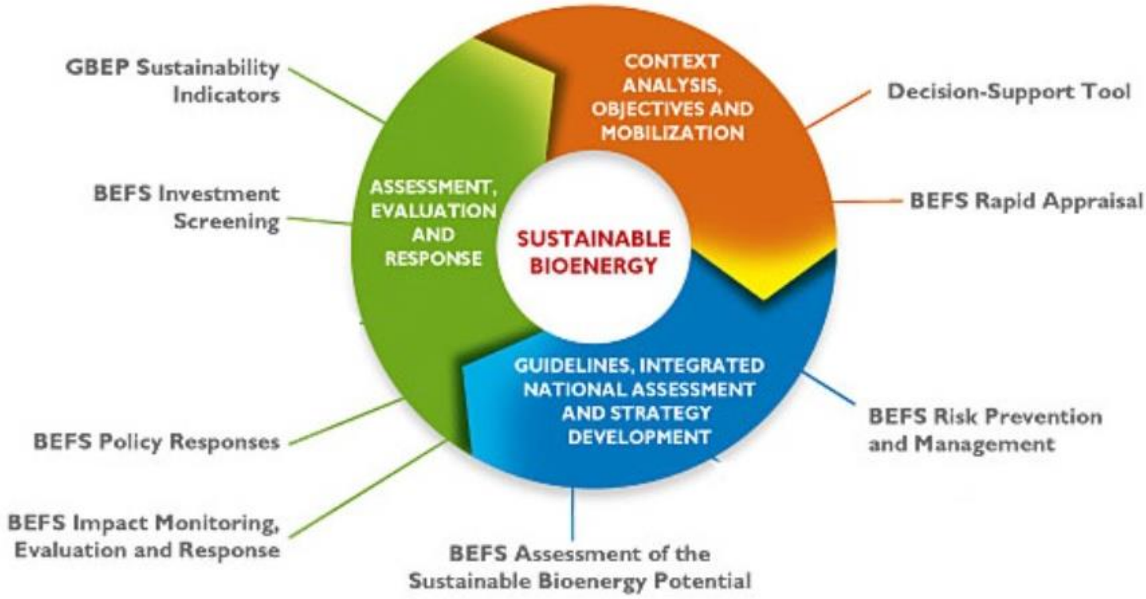

Figure 1: FAO Support Package to Decision-Making for Sustainable Bioenergy (FAO, 2014).

2.4 Bioenergy and Blending Mandates

2.4.1 Overview

Biofuels have been added to fuels to combat climate change since the early 2000s and were thought to initially provide energy security and a reduction in pollution. This was achieved through introducing blending mandates, tax breaks and investment support (FAO, 2016). Biofuel blending mandates are the major policy incentives which governments use to encourage the mix of biofuels into traditional fossil fuels for use in the transport sector (de Gorter and Just, 2009). Blending mandates are used to reduce the consumption of fossil fuels and therefore increase the sustainability of the transport sector (Bonaldo, 2020). Furthermore, the set blending mandates have provided a relatively constant demand in a constantly evolving industry (Rouhany and Montgomery, 2018). This has helped to drive investment into biofuel plants which in turn has made the production of biofuels more competitive when compared to their fossil fuel equivalent (Bonaldo, 2020). The concurrent use of both blending mandates and tax credits as bioenergy policies create limitations and reverses the potential impacts of the tax credit. This is because subsidising biofuels through tax credits ends up subsidising the consumption of fossil fuels, especially at lower blends. Blending mandates offer various advantages over tax credits and should be used as an independent policy to achieve the best results (de Gorter and Just, 2009). Interestingly, most of the biofuel production is used in the domestic market and the international trade market has remained relatively stagnant over the past decade (FAO, 2016; Rouhany and Montgomery, 2018). The reliance on food crops to supply the biofuel demand required has led countries to scrutinise the use of first-generation biofuels and has driven the creation of second- and third-generation options. This is especially true in Europe where the use of food crops to generate biofuels has been limited to encourage new generation methods and to reduce the reliance on imported biofuels (Drabik and Venus, 2019). However, first-generation biofuels are still used worldwide, and can have positive impacts if food security and food prices are safeguarded.

2.5 Biofuel Impacts on GHG

Although first-generation biofuels are considered a sustainable energy source, there is an ongoing debate to assess the impact on climate change. This is due to the competing nature of biofuels with food security, water use and changes in land use (Barnabè et al., 2012). The use of biofuels is still considered a sustainable alternative to fossil fuels, particularly in the transport sector, and the potential negative impacts on the environment should be mitigated to ensure that the maximum sustainability potential is met (Barnabè et al., 2012). The main consideration regarding the impact of biofuels on sustainability relates to changes in land use and the related GHG emissions. The production of energy crops to be used as feedstock is dependent on the land used and therefore increases in biofuels can pose serious risks to the environment (Rouhany and Montgomery, 2018). The use of existing farmland and idle cropland in the production of biomass should be selected and deforestation should be avoided due to the unsustainable nature of production. Furthermore, indirect changes in land use should also be avoided. When complete LCAs are performed on biofuels networks, the real impact of these can be properly assessed (Barnabè et al., 2012). Taking into consideration the current blending mandates of over 40 countries, Timilsina and Mevel (2013) found that the land used to produce biomass is critical to the sustainable impact of biofuels. Their study found that if the current bioenergy targets are met through first-generation biofuels, the use of forests is the critical factor in determining the sustainability of global biofuel use. If the targets are implemented by 2020, the use of forests would create a net increase in GHG until 2043. However, if only farm and croplands are used to produce the required biomass, the net increase in GHG would exist only until 2021, after which a decrease in GHG occurs (Timilsina and Mevel, 2013). Although the use of first-generation biofuels has come under scrutiny recently, the mitigation of GHG emissions in the transport sector is still a viable option to reduce emissions due to biofuels producing less pollutants than traditional fossil fuels (Rouhany and Montgomery, 2018).

Chapter 3 – Research Design & Methods

This chapter presents the overarching research design used within this report to provide answers to the formulated questions. The main objective of this section is to provide a clear outline of the data required in the research and to provide an operational framework which provides clear structure. The systematic formulation of the analytical framework provides a detailed structure to guide the progression of this project whilst adhering to the needs of the objective (Verschuren & Doorewaard, 2010). Furthermore, the analysis tool used to achieve the research objectives is presented in this section.

3.1 Research Framework

As described by Verschuren & Doorewaard (2010, p.65), "A research framework is a schematic representation of the research objective" which contains the required "steps that need to be taken in order to achieve [the research objective]". This ensures that the required knowledge to perform a successful project is systematically presented and available to the researcher. Figure 5 provides the initial research framework used in this project.

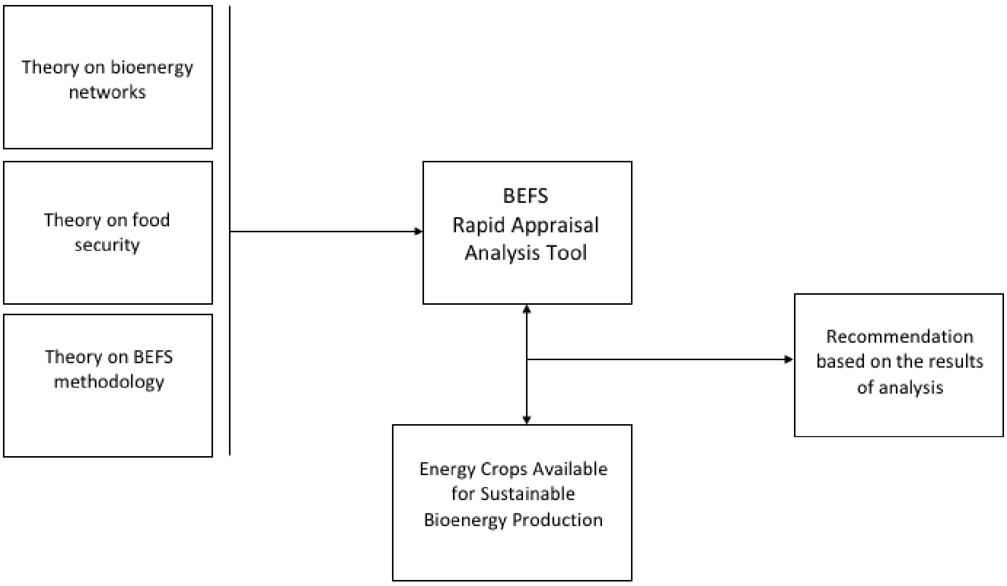

Figure 2: Research Framework.

3.2 Research Strategy

The research strategy of a project aims to provide an overall plan to follow in order to achieve the research objectives. The research strategy is combined with a research method which directs the collection and analysis of data (Johannesson & Perjons, 2014). A series of conditions exists to select the appropriate research strategy. These are: how the research question is framed, the level of control the investigator has over the events, and whether the focus is contemporary or historic (Yin, 2014). In relation to case studies, explanatory questions should be asked and the focus should be on contemporary events where the investigator has no control over the events (Yin, 2014). As defined by Yin (2015: 194), a case study is "an empirical inquiry that closely examines a contemporary phenomenon within its real-world context".

This project is focussed on a contemporary phenomenon (blending mandate policy) considered within the real-world context of Argentina, with an emphasis on food security. The research method employed is the BEFS tool created by the FAO. This tool is a valid method to achieve the research objectives as it clearly directs the collection and analysis of data with the objective of ensuring that food security is guaranteed. Due to the nature of the research objective and the question formulated, and considering the research method selected for the analysis, the use of a case study has been selected as the most appropriate research strategy. The selection of a single-case study as opposed to a multiple-case study is dictated by the research method and the scope of the research.

3.2.1 Case study credibility

The credibility of a case study can be strengthened by addressing validity and reliability. Validity refers to "identifying correct operational measure for the concepts being studied and defining the domain to which the study's findings can be generalised" (Yin, 2014: 40). In this case, as the aim of the study is framed towards ensuring food security, the selection of the analysis tool helps to support the research validity. Furthermore, the BEFS tool helps to build a chain of evidence by directing the data collection.

Reliability is defined as "demonstrating that the operations of the study can be repeated with the same results" (Yin, 2014: 40). As the BEFS tool clearly and systematically guides the user in the data collection, it can be expected, that the same results will be achieved if followed correctly. Furthermore, the previous application of the analysis tool in past research also helps to support the reliability of the tool selection and therefore the research project. Finally, the use of trusted data sources and cross-referencing data wherever possible ensure that the data collected is both valid and reliable.

Due to the specific context of this case study, the findings have limited scope to be generalized. As discussed, Argentina's complex and unique economic and geo-social situation renders it an outlier and therefore worthy of study. Valid outlying case studies may stress economic models, and so provide a beneficial feedback loop to improve their resilience. Hence, the findings from this study may, in part, be generalised by the improvement of the models used.

3.3 Methods

3.3.1 BEFS Overview

The importance of adequately assessing the relationship between bioenergy networks and the impact on food security can be explained by the competing nature of these two factors. The FAO's mandate includes eliminating world hunger and achieving food security in developing countries (FAO, 2020). As discussed in section 2.1, bioenergy networks can have a positive impact on rural poverty and electrification, and therefore should be considered in supporting the transition to ending poverty in developing countries. To support the use of bioenergy networks and ensure that they are sustainable and coordinated with food security, FAO has developed the BEFS Approach. This approach aims to provide reliable bioenergy network assessments which consider social, environmental, and economic parameters and is especially focussed on improving rural conditions and utilising agricultural residues (FAO, 2014).

3.3.2 BEFS Analytical Framework

The overall BEFS approach consists of providing a framework which can be used by countries to analyse the development of sustainable bioenergy and can assist with rural development and policy formulation. Food security in developing countries is paramount to the development of new bioenergy networks as they may compete for the same resources. BEFS offers the user a flexible framework which can be adapted to suit the requirements or resources of the target crop or industry to be analysed. Depending on how developed bioenergy networks are or on the desired end use of the products, the framework can be tailored to individual users and provide very specific results. The analytical framework developed for this assessment tool is presented in figure 2 below.

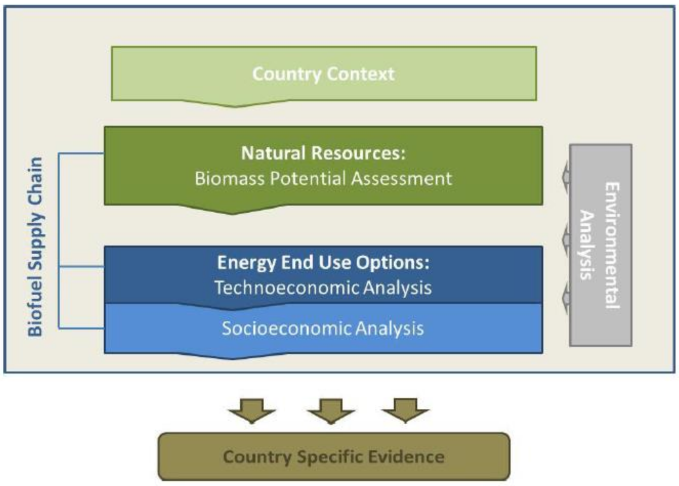

Figure 3: BEFS Analytical Framework (FAO, 2014)

The framework provided considers the unique characteristics of the country analysed and assesses the potential biomass available from the various biomass options. These are considered alongside the main food crops to ensure food security is integrated within the framework. Furthermore, environmental, economic, and social sustainability are also integrated within the framework and help ensure that a complete analysis is conducted. The analytical framework for this approach can be applied using a more simplified tool (BEFS Rapid Appraisal) or a more in-depth tool (BEFS Detailed Analysis). The BEFS Rapid Appraisal tool used in this research project will be detailed below (FAO, 2014).

3.3.3 Rapid Appraisal Analysis Tool

The Rapid Appraisal (RA) tool is the simplified version included in the BEFS AF which is used to provide an initial understanding of the potential bioenergy networks available within a country, region, or industry. Although the RA tool provides a preliminary assessment, it still supplies a complete analysis of bioenergy networks from production to use. The analysis can be performed quickly and with minimum data, is applicable to any country or region and provides an overview of the potential markets available. The tool is comprised of three modules, namely Country Status, Natural Resources, Energy End-Use, which combine to distinguish the selected bioenergy route and provide the results for it. Figure 3 below presents the BEFS AF for the RA method and the three modules relevant to this framework are described below.

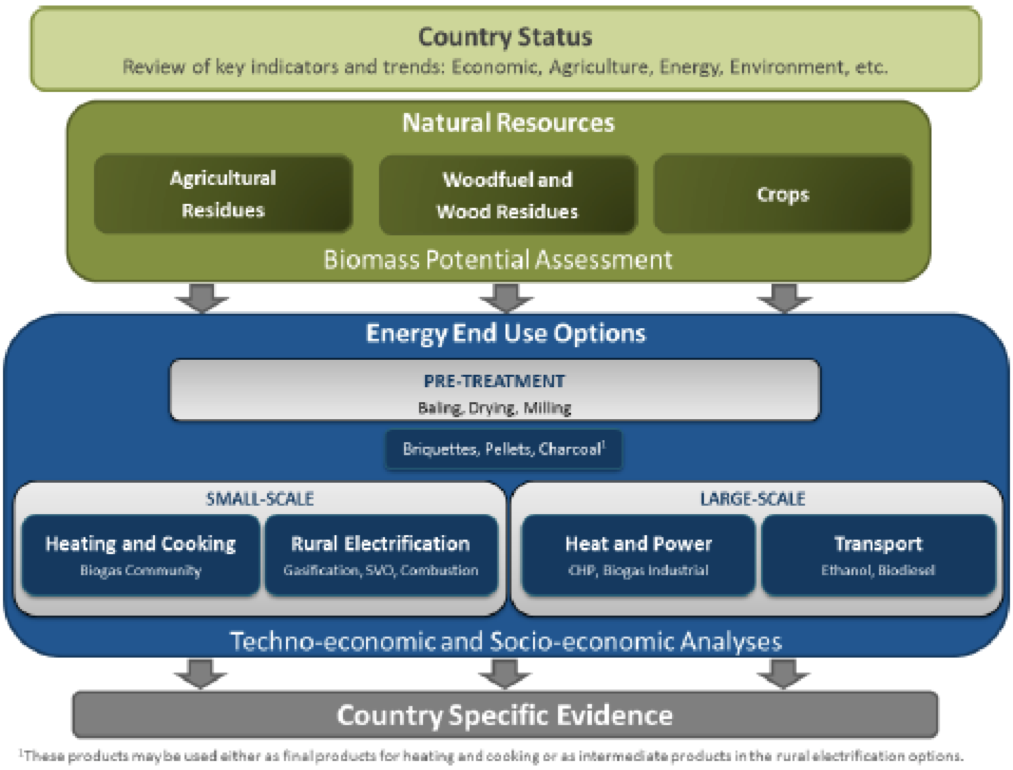

Figure 4: Analytical Framework for BEFS RA Tool (FAO, 2014).

Country Status Module

This module provides the key information concerning the food, agricultural and energy sectors and is the basis of the subsequent modules. The key information required includes the country context, key food commodities, the trade position regarding the key food crops and the overall energy consumption by sectors, in households as well as fuel consumption in the transport sector.

The required data ensures that food security is the major consideration to the results of the analysis. The energy data in this module ensures that the use of bioenergy within the country is understood and helps to identify areas which hold potential for bioenergy use.

Natural Resources Module

The second module allows the available feedstock to be quantified. This module is comprised of three components which analyse the three biomass feedstocks available. These are: Crops, Agricultural Residues and Wood Residues. This module allows the user to analyse all three components or to select the most appropriate depending on country needs.

The Crops component consists of the following tools:

- The Crop Production tool which analyses the potential production of biofuels from the various biomass feedstocks selected in the country status module.
- The Crop Budget tool which provides preliminary techno-economic information including profitability and production costs and revenues.

The Agricultural Residues component consists of the following tools:

- The Crop Residues tool which analyses the potential feedstock available from crop waste to produce solid biomass.
- The Livestock Residues tool which analyses the potential feedstock available from animal manure to produce biogas.

The Woodfuel and Wood Residues component consists of the following tools:

- The Forest Harvesting tool analyses the bioenergy potential of forest harvesting and forest residues.
- The Wood Processing Residues tool analyses the potential wood processing residues available.
- The Forest Plantations tool analyses the potential biomass resources available from bioenergy plantations and provides a cost-benefit analysis of these.

Energy End-Use Module

The final module assesses the potential bioenergy uses. The various applications are considered within the five submodules and are dependent on the previous tools. These submodules are: Intermediate or Final Products, Heating and Cooking, Rural Electrification, Heat and Power and Transport. As with the natural resources module, the submodules, can be analysed as a whole or the most relevant pathway can be selected and analysed individually.

The Intermediate or Final Products submodule analyses the potential production of solid biomass, namely, Briquettes/Pellets and Charcoal which can be used for heating or cooking.

The Heating and Cooking submodule analyses the potential biogas available at a community level. The component analyses the instalment and production of biogas using various technologies and provides techno-economic and socio-economic analysis of this installation.

The Rural Electrification submodule analyses the potential supply of electricity to off-grid rural areas. This consists of three separate components which are Gasification, SVO and Combustion.

The Heat and Power submodule analyses the potential production of heat and electricity from local biomass resources. The two components relevant to the submodule are CHP (cogeneration) and Biogas Industrial.

The Transport submodule analyses the potential for liquid biofuel production from the feedstock availability estimated in the Natural Resources module at a small, medium, or large-scale of production.

The Pre-Treatment submodule analyses the cost of preparing the biomass feedstock for the final production stage and provides added detail to the overall bioenergy network. It can be performed before the Energy End-Use submodule is selected. Both the Biogas Community and Transport components contain a pre-treatment analysis in their specific tool.

Interlinkage between Modules

The relationships and links between the three modules are displayed in figure 4 below. As stated previously, the Country Status module helps to build the required data for the subsequent modules. Furthermore, the Natural Resources module collects important feedstock data which is utilised in the Energy End-Use module. These data are also linked to the food security analysis performed in the Country Status module and therefore ensure that the final energy module is dependent on the food security analysis performed initially.

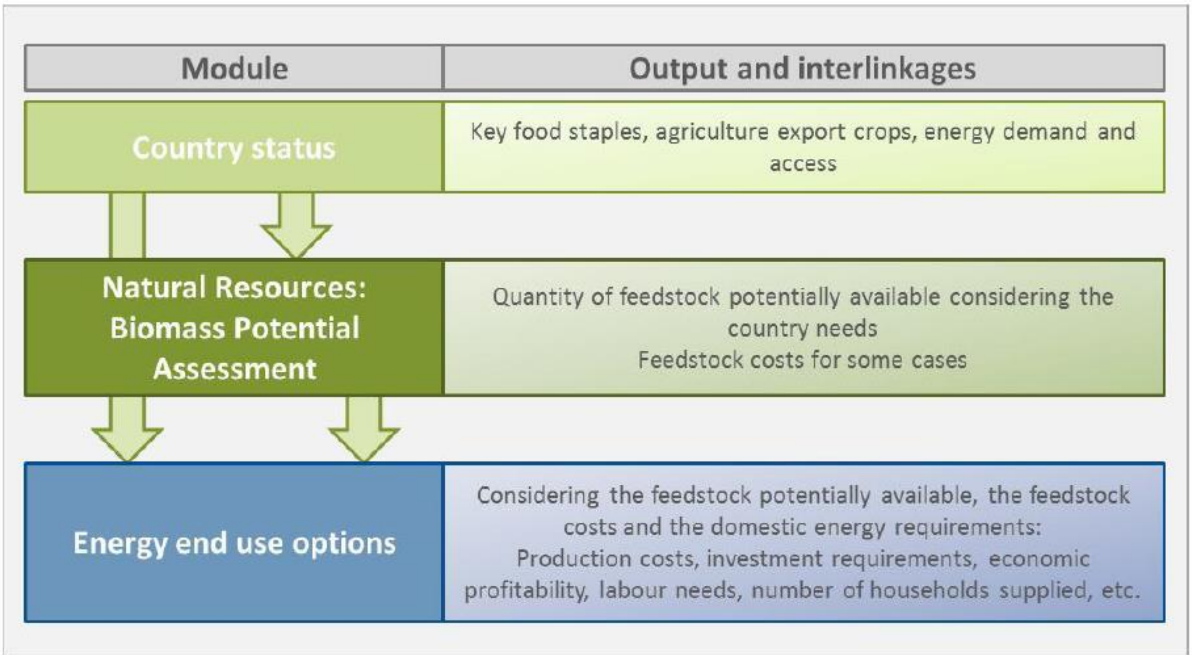

Figure 5: Interlinkage between the Rapid Appraisal modules (FAO, 2014).

Table 1 below helps to summarise the various modules, submodules, components, and tools which form the overall framework of the BEFS RA tool.

Table 1: BEFS RA module structure (FAO, 2014).

Module	Submodule	Component	Tool
Country Status		Country Status	Country Status
Natural Resources		Crops	Crop Production
			Crop Budget
		Agricultural Residues	Crop Residues
			Livestock Residues
		Woodfuel and Wood Residues	Forest Harvesting
			Wood Processing Residues
			Woodfuel Plantations
Energy End-Use	Pre-Treatment	Pre-Treatment	Pre-Treatment
	Intermediate or Final Products	Briquettes	Briquettes
		Pellets	Pellets
		Charcoal	Charcoal
	Heating & Cooking	Biogas Community	Biogas Community
	Rural Electrification	Gasification	Gasification
		SVO	SVO
		Combustion	Combustion
	Heat & Power	CHP (Cogeneration)	CHP (Cogeneration)
		Biogas Industrial	Biogas Industrial
	Transport	Transport	Transport

3.4 Data Collection

The data required to answer the research questions and the source of data and accessing methods are presented in the table 2 below.

Table 2: Data Collection for each research question.

Research Question	Data Required	Sources
What are the main bioenergy and food security considerations in the country context? (SRQ1)	Country Overview: Agricultural & Energy	FAO STATS, The World Bank, Argentine Census
	Agricultural Trade	FAO STATS
	Energy Demand and Supply	IEA, Governmental Datasets
Does effective crop management provide the necessary feedstock for increased biofuel capacity? (SRQ2)	Crop Production: Yields and Land Use	FAO STATS, Governmental Datasets, USDA Data, OECD-FAO dataset, GAEZ, Scientific Literature
	Crop Budget: Prices and Costs	
What is the current state regarding the production of biofuels in Argentina? Is increasing the production of biofuels for the transport sector a viable option? What impact has the current price freeze had on the profitability of biofuel production? (SRQ3)	Industrial Production Costs and Financial Information	Governmental Datasets, BEFS RA Tool, Quiminet
Can effective energy crop management simultaneously support an increase to blending mandates and safeguard food security in Argentina? (MRQ)	Results obtained from the analysis tool	BEFS RA Modules: Country Status, Natural Resources, Energy End-Use

3.5 Data Analysis

This research project utilises quantitative methods for the data analysis.

3.5.2 Validation of Data Analysis

A variety of techniques exist to perform data validation on a research project. This project utilises existing data to perform an analysis of the bioenergy potential in Argentina. The Four Design tests can be used to validate the data; the test which is most relevant to the project is construct validity. This consists of using multiple sources and establishing a chain of evidence at the data collection phase of the project (Kidder & Judd, 1986). The selection of reliable sources of data, such as the UN or governmental datasets, is key to ensuring that the data selected are adequate for the research project.

3.5.3 Analytical Framework

The analytical framework developed in this chapter is presented in figure 6 below.

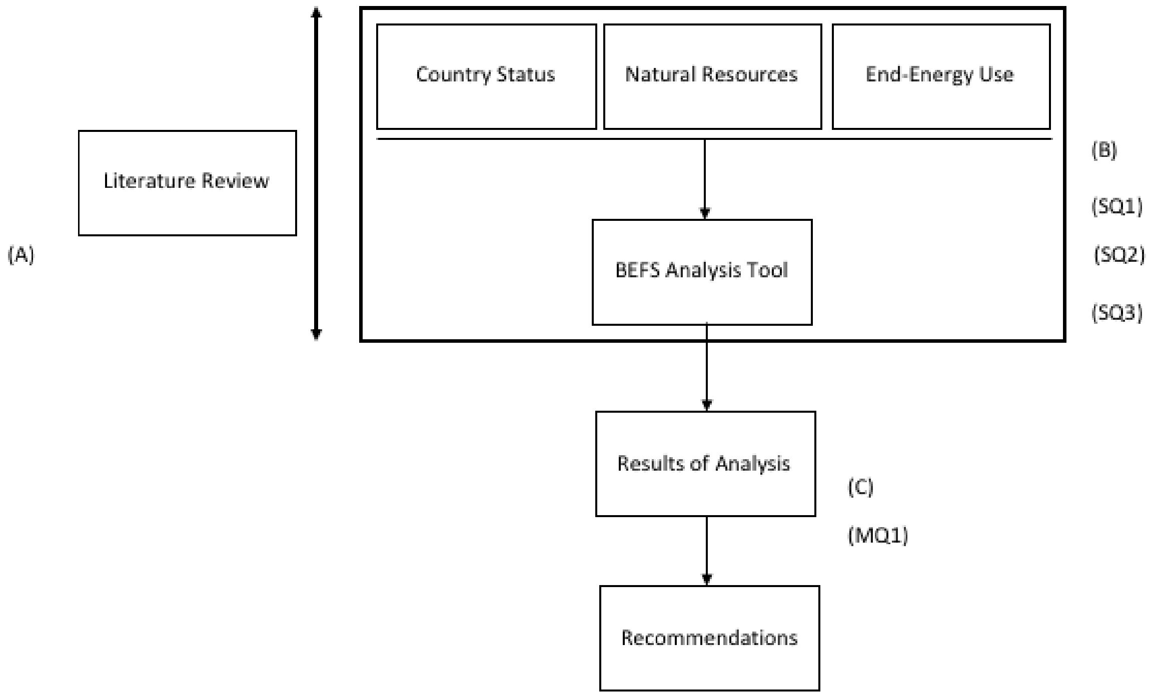

Figure 6: Analytical Research Framework.

This framework consists of four phases which are described below:

(A) Relevant literature review to provide background to the research.

(B) Collection of data required for BEFS analysis tool.

(C) Assessing results from the tool.

(D) Providing recommendations based on the result section.

3.6 Research Limitations

One of the key limitations on the study was the time available to perform the analysis. A more in-depth analysis could have been undertaken with more time to assess other aspects of the bioenergy industry such as forest and crop residues or the use of sugar molasses as the feedstock for biofuels as well as other potential end use options.

Another important limitation was the data availability. Due to the country's economic volatility and high rates of inflation, there were several datasets that either were not available or were not complete. Hence, some datasets needed to be extrapolated from previous years. Although the costings of sugarcane production were adjusted for inflation, the accuracy of extrapolating the costings using only inflation raised some precision issues. Furthermore, the crop budget section of the tool created some significant limitations in the results of the research due to the required data parameters. The level of detail required was too precise when considering the scope of the project and therefore a different method had to be employed. I discuss the new method in section 5.5 of the report.

Finally, the exact blending mandates which should be adopted and the implementation of such cannot be answered by this analysis. A further survey analysis of various stakeholders, including biomass and biofuel producers, could be performed to gain further insight into the needs of the industry and the best available improvements.

Chapter 4: Country Status

The full results for this module and all the data discussed within it are presented in Appendix 1 and are summarised in this chapter.

4.1 Introduction

Bioenergy supply chains involve a variety of different sectors and requires an understanding of each one at the country level to perform a detailed analysis. The main sectors relevant to bioenergy networks are food and agriculture, energy and trade and economic indicators. The country status module helps to develop the key understandings in each area and creates a framework which ensures the focus of the analysis is based around food security. The structure of this module is depicted in figure 7, below, and shows the breakdown of the various sections.

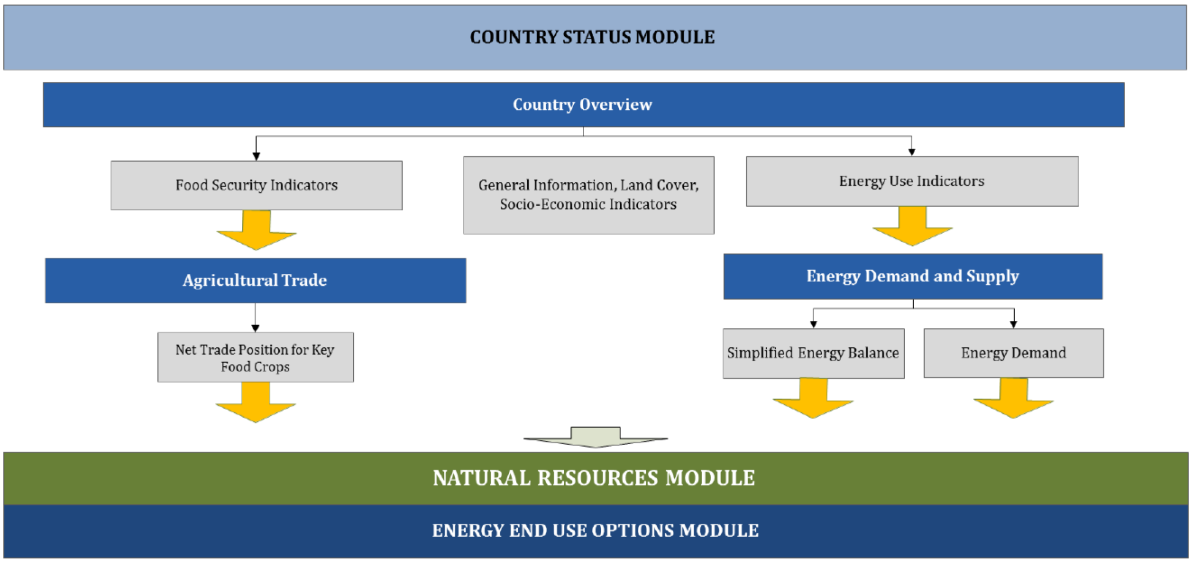

Figure 7: Structure of Country Status Module (FAO, 2014).

4.2 Scope and Objectives

The objective of this module is to provide an overview of the key sectors related to bioenergy by selecting key indicators relating to food security, agricultural trade, energy use, demand and supply and more general information regarding the country analysed.

4.3 Country Overview

4.3.1 Population

Argentina has a total population of 43,417,000 with an urban population of 92% and a rural population of 8%. The rural-urban divide in all countries is an important indicator of a country' development and industrialisation. This divide can affect the access to basic amenities such as electricity and running water and impact access to health and education (PRB, 2015). Argentina historically has had major displacement from rural to urban zones which has led to increased centralisation around the capital, Buenos Aires, and a disparity in public funding along this divide. This has led to lower levels of access to health and education (Zapata et al., 2019) and much lower GDP in rural areas and worse infrastructure in rural areas (Verner, 2006).

4.3.2 Economic, Agricultural & Energy Indicators

The data relating to the main economic indicators are collected in this section. The main parameter which is worth considering is the inflation of consumer prices which for 2019 stood at 54% with respect to 2018. This level of rapid inflation creates major economic uncertainty and can have a significant effect on agriculture as future markets cannot be guaranteed. This creates issues for producers regarding access to capital and sale price of products which can cause a complete loss of profits (Lema et al., 2018). Furthermore, inflation can greatly affect food prices which has a critical impact on food security and affects the poorest people in the country (Antón et al., 2019). Agriculture accounts for around 7% of GDP and 54% of total land area and agricultural exports account for up to 54% of total exports. This exemplifies the important role that agriculture plays in Argentina, most significantly in rural areas which also account for the poorer regions. Other relevant indicators in this section include access to electricity as a percentage of population which is just under 100% and poverty headcount as percentage of population which is around 32%. The poverty rate indicates that the average person will be vulnerable to food price volatility.

4.3.3 Food Supply & Agricultural Trade and Production

As explained previously, this module ensures that food security is the key consideration in assessing the development of new bioenergy networks. The data collected in this section allow for a good understanding regarding the key foodstuff and the main exported agricultural goods. Table 3, below, shows the most important agricultural commodities regarding food supply to the local population. The data collated in this section ensure adequate selection of food crops to develop bioenergy networks. The most important crops relating to food supply should be avoided from selection to protect the food source of the local population and ensure food security. Regarding exports of trade commodities, soybeans, in cake, oil and raw forms, as well as maize, account for 58.2% of agricultural trade in Argentina.

Table 3: Food Supply and Key Foodstuff in Argentina ranked by kcal/capital/day.

FOOD SUPPLY AND KEY FOODSTUFFS

Rank	Food commodity	Food supply (kcal/capita/day)	Share in total food supply
1	Wheat and Products	896	27.7%
2	Sugar (Raw Equivalent)	396	12.2%
3	Bovine Meat	337	10.4%
4	Sunflowerseed Oil	269	8.3%
5	Milk - Excluding Butter	205	6.3%
6	Poultry Meat	182	5.6%
7	Maize and Products	95	2.9%
8	Rice and products	85	2.6%
9	Pig meat	82	2.5%
10	Potatoes and products	69	2.1%
	Subtotal	**2,616**	**80.8%**
	Total food supply	**3,239**	100%

4.4 Net Trade Position of Key Food

The five key foodstuffs presented in table 3 are analysed further with respect to their net trading position in this section. Assessing the export value of these crops is an important indicator to select food crops for bioenergy. This is because it provides an understanding of the excess production which is not utilised in the country as a food source. This helps to ensure that there is no overlap between food crops and energy crops and safeguards food security.

Net Trade Position for key food crops in the past 10 years

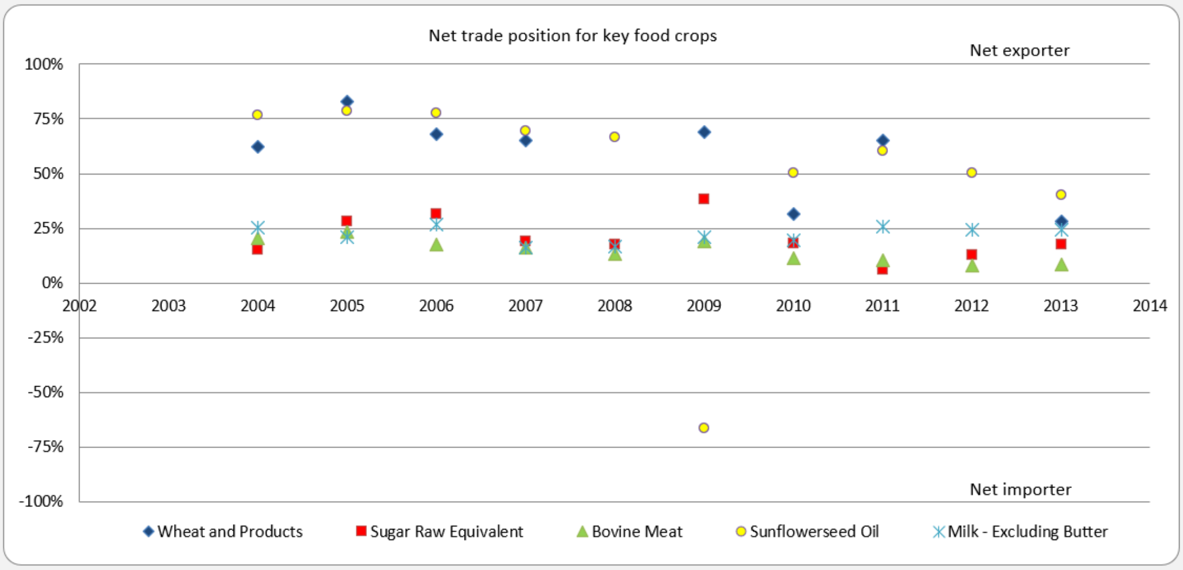

Figure 8: Net trading position of key food crops over a ten-year period.

As can be observed in figure 8 and has been previously detailed, Argentina is overall a net exporter of agricultural goods, including the main food crops produced in the country. The only instance of importing a key crop occurred in 2009 when 66.6% of sunflower seed oil had to be imported. The strength of the export percentage for these key crops suggests there is a surplus of agricultural goods and therefore there is adequate potential for bioenergy production from energy crops.

4.5 Energy Balance

This section provides an overview of the energy considerations in Argentina regarding production, consumption, and trade position for the main types. Argentina has reserves of both crude oil and natural gas and therefore produces most of its own supply with close to 100% and 80%, respectively. Overall, the main energy import for the country is natural gas which accounts for 52.9% of imports followed by oil products (petrol and diesel) which account for 29.4%. Overall final consumption is dominated by oil products and natural gas with 42.6% and 33.9% respectively. Biofuels and waste account for 4.9% of the final energy consumption in Argentina. Figure 9, below, demonstrates the dominance of natural gas in the industrial and residential sectors, whereas oil products are dominant in both the transport and agricultural sectors. Biofuels are mainly utilised in the transport and industry sectors although to a much lesser extent than traditional fossil fuels.

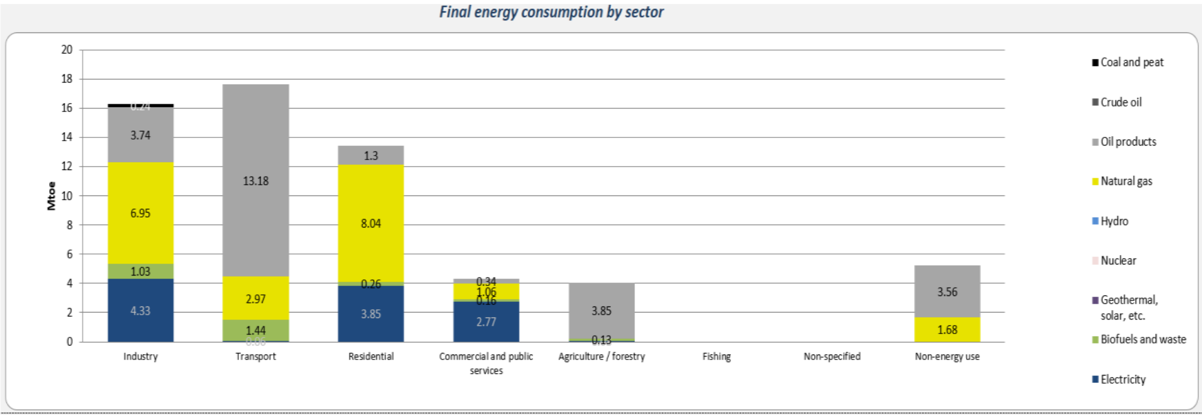

Figure 9: Final Energy Consumption by Sector in 2017.

4.6 Energy Demand

This section collects the data relevant to the fuel consumption in the transport sector. The production of both traditional fossil fuels and of liquid biofuels are assessed and compared to evaluate the overall position regarding consumption. Regarding fossil fuels used in transportation, Argentina produces 8,171 ML/year of diesel and 5,104 ML/year of petrol and imports 1,784 ML/year and 406 ML/year, respectively. Regarding liquid biofuels, Argentina produces all the biofuel it requires with 1,890 ML/year of biodiesel and 870 ML/year of ethanol. It is also one of the major exporters of biodiesel, exporting 893 ML/year. The blending mandate for both biodiesel and ethanol is also included and stands at 10% and 12% respectively. This blending data allows an analysis of the target production of biofuels which is depicted in figure 10. As can be observed, the current targets of production to ensure blending mandates are met is currently being supplied by the biofuel production.

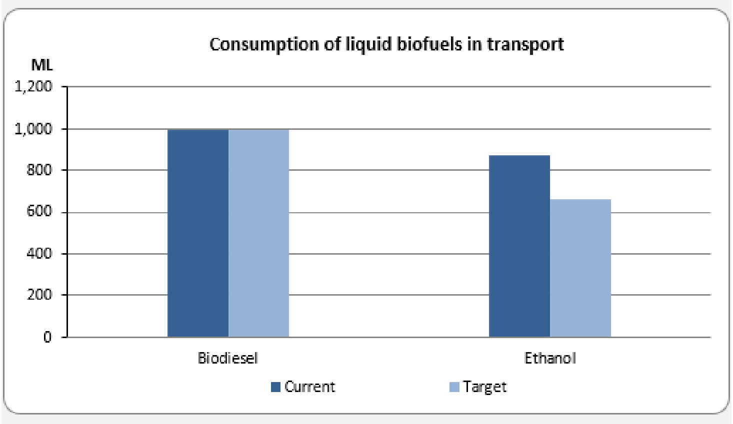

Figure 10: Biodiesel and Ethanol consumption relative to blending mandates in 2019.

4.7 Argentina Blending Mandate Policy

Historically Argentina has an important agro-industrial sector and has been a major producer of crops. The uncertainty in the aftermath of the 2001 financial crisis in Argentina and the imposition of VAT withholding on the agricultural sector created a resilient industry which combined historical expertise and the incorporation of new technologies to remain competitive in international markets (Buraschi, 2014). The adaptation to the limitation experienced by the sector form the basis for the large bioenergy potential which exists in Argentina due to significant increases in yields (Buraschi, 2014). Although the domestic market for bioenergy began in the 1970s and 1980s with the development of anhydrous ethyl alcohol, real interest in the industry began in the late 1990s with various countrywide projects. The 2001 financial crash and the subsequent rise in the price of vegetable oils (the basis of biodiesel production) led to much higher production costs and the industry became economically unsustainable (di Paola, 2013).

The SAyDS was created through the resolution 1076/2001 to orientate the production of biofuels with respect to climate change and the Kyoto Protocol. Subsequently, the resolution 1156/2004 created a new biofuel program within the Department of Agriculture which aimed to "promote the sustainable elaboration and use of biofuels" (di Paola, 2013, p. 8). In 2006, the National Law 26.093 concerning the Regulatory Regime and Promotion for the Production and Sustainable Use of Biofuels was sanctioned and was passed with the Decree 109/2007 and replaced SAyDS. This law mandated a 5% blend of both ethanol and biodiesel by 2010 (Rozemberg et al., 2009) and later, further decrees increased the blending mandate to 10% and 12% for biodiesel and ethanol, respectively. The law

26.093 was ratified for 15 years and ends in 2021 (Rozemberg et al., 2009). In 2018, Argentina entered a new economic recession and inflation more than doubled in a year leading to huge economic uncertainty. The government has tried to slow the rate of inflation via various economic policies. Regarding the biofuel industry, the government has imposed a price freeze on the consumer price of biofuels which has stood in place since December 2019 (Ámbito, 2019). This artificial manipulation of the market has led to a lack of investor confidence and has ensured that biofuel producers operate at a loss due to the rise in inflation (Campos do Prado et al., 2019).

4.8 Discussion Country Status Module

The Country Status module provides a country-wide understanding of the main industries related to bioenergy development and the key indicators relating to each one. The main findings from the module are summarised in this section and correspond to the answer to RSQ1.

What are the main bioenergy and food security considerations in the country context?

The agricultural sector plays an important role in the economy of Argentina. The industry represents 54% of the total land area of Argentina and accounts for 7% of GDP. Argentina is a major global agricultural producer and has enough produce to be a net exporter on all its key food crops. Agricultural products account for over 50% of total exports which indicates there is potential feedstock available for bioenergy processing. Although Argentina is a major food producer and food security is a secondary issue, it should still be highly regarded as 5% of the population suffer from undernourishment and changes in food crop use could lead to worsened rates. Economic uncertainty, exemplified by 54% inflation rates on consumer prices, and high levels of poverty (32% of population), are the main factors currently threatening food security in Argentina. Thus, bioenergy developments should assess the impact on food security, especially considering the high volatility of consumer prices. Furthermore, the high reliance on exports in the agricultural industry is subject to impact from export tariffs and anti-dumping regulations and changes in global food prices can also impact the agricultural industry. Although Argentina is a relatively industrialised country, a large percentage of its agricultural exports are simple raw materials and not processed products. Raw materials as an export commodity receive a lower rate of return than refined products. Furthermore, small-farm holders tend to have limited industrialisation and improvements in equipment and agricultural products such as fertiliser could improve country-wide yields in agriculture and help protect food security.

The energy sector offers areas which can support increased bioenergy development. Although Argentina is a producer of fossil fuels, a high percentage of both oil and natural gas are currently imported. The reliance on imported fuels offers an opportunity for the substitution of traditional fossil fuels with first- and second-generation biofuels. Furthermore, due to the increased cost of imports caused by inflation, substituting imported fossil fuels with local alternatives could safeguard energy costs and improve industrialisation. A breakdown by sector demonstrates that the transport and agricultural sectors have the highest reliance on oil whereas the industrial and residential sectors are highly reliant on natural gas. Currently, biofuels and waste account for 4.9% of the final energy consumption and the importance of biofuels in the energy mix offers room for improvements. A blending mandate for both biodiesel (10%) and ethanol (12%) exists and the production levels of biofuels meet the current requirements. This indicates that bioenergy developments in the transport sector are only viable if blending targets are increased or if biofuel exports are increased. Argentina is already a leading exporter of biodiesel globally and thus expansion of existing industry is viable as the knowledge and expertise required already exists. A focus on rural electrification is unnecessary as access to electricity is reported at 100%.

Chapter 5: Natural Resources Module

The full results for this module and all the data discussed within it are presented in Appendix 2 and are summarised in this chapter.

5.1 Introduction

As explained in Chapter 2, first-generation biofuels can be produced from multiple feedstock options including energy crops, agricultural residues and Woodfuel or residues amongst others. This module allows an overall assessment of the natural resources available for bioenergy production within the country and builds on the knowledge gained in the Country Status chapter. The three components of this module are Crops, Agricultural Residues and Woodfuel & Wood Residues and the overall structure of the module is presented in figure 5.1.

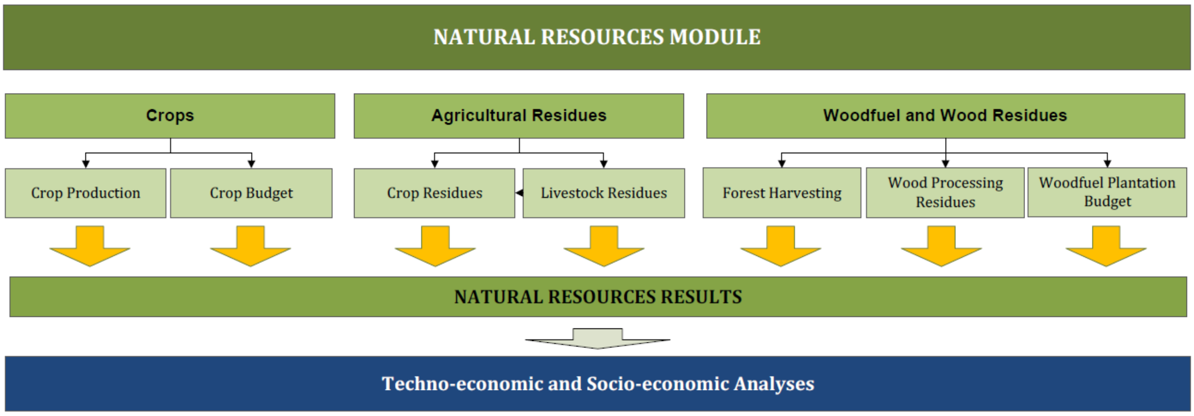

Figure 11: Structure of Natural Resources module.

The Crops component was selected for this analysis as it focusses on energy crop production and on liquid biofuel production. This component includes two tools:

- The Crop Production tool, which can be used to assess the current energy crop production and the potential for added production.
- The Crop Budget tool, which helps to assess the gross margin, production costs and profitability of crop production.

5.2 Scope and Objectives

The objective of this module is to provide an overview of the potential for energy crop feedstock production. Sustainability and food security are the main parameters considered when analysing the potential production. The potential for additional production is assessed using intensification, extensification[1] and substitution of crop options.

5.3 Selection of Crops

The selection of bioenergy crops to be used as potential feedstock must be undertaken. This ensures that the tools in this module prioritise food security and should be considered alongside the results of the Country Status module. Key food crops considered in sub-chapter 4.3.3 should be omitted from comparison to guarantee that the potential bioenergy feedstocks are not competing with the main food resources. Furthermore, the net trade position of potential feedstocks analysed in sub-chapter 4.4 should be considered. Agricultural foods which are imported should be avoided to minimise the amount of excess imports as this ensures increased self-sufficiency. The crops selected for analysis are the following:

1. Sugarcane – this crop was selected as it is a key crop to generate first generation biofuels. Although the crop is the second key food supply of the country (table 3), it has also been a net export crop with approximately 20% of production being exported over a 10-year average (figure 8). Furthermore, sugar and sugar molasses are already used to produce ethanol and overall consumption of sugar in Argentina is decreasing.
2. Sunflower – sunflower seed oil represents the fourth key food supply (table 3) with an 8.3% share, however, it is also a major exported crop with over 50% of production exported over a 10-year average (figure 8). The excess inputs could be used to produce SVO and biodiesel.
3. Maize – maize is the second most exported agricultural commodity representing 11.6% of agricultural trade and only accounts for 2.9% of the share of total food supply. It is currently being used to produce ethanol and therefore offers existing potential as an energy crop.
4. Soybeans – soybean and related products account for 46.6% of the total share of agricultural exports in Argentina and its use as an energy crop does not compete with food resources. It is currently used to produce biodiesel and therefore is a suitable crop to analyse.

Further criteria for assessment include overall energy balance and industrial capabilities. As discussed in sub-chapter 4.5, Argentina is a significant producer of energy and mainly imports natural gas and the main priorities for energy production surround the increased development of existing technologies. Regarding industry, the crops selected are currently used to produce biofuels and therefore an expansion in this production would not create major logistical and technological issues for the country.

[1] Extensification refers to increasing production by improving yield whilst keeping the agricultural area unchanged.

5.4 Crop Production Tool

5.4.1 Net Trade Position of Selected Crops

The four selected crops to be analysed for potential feedstock production are examined in this section with respect to production, domestic consumption, and trade position over a 10-year period. This analysis allows for a detailed understanding of each crop with respect to current excess feedstock and should be understood to be used later in the analysis. The graphical results of the trade position for the four crops can be visualised in figures 12 and 13 below.

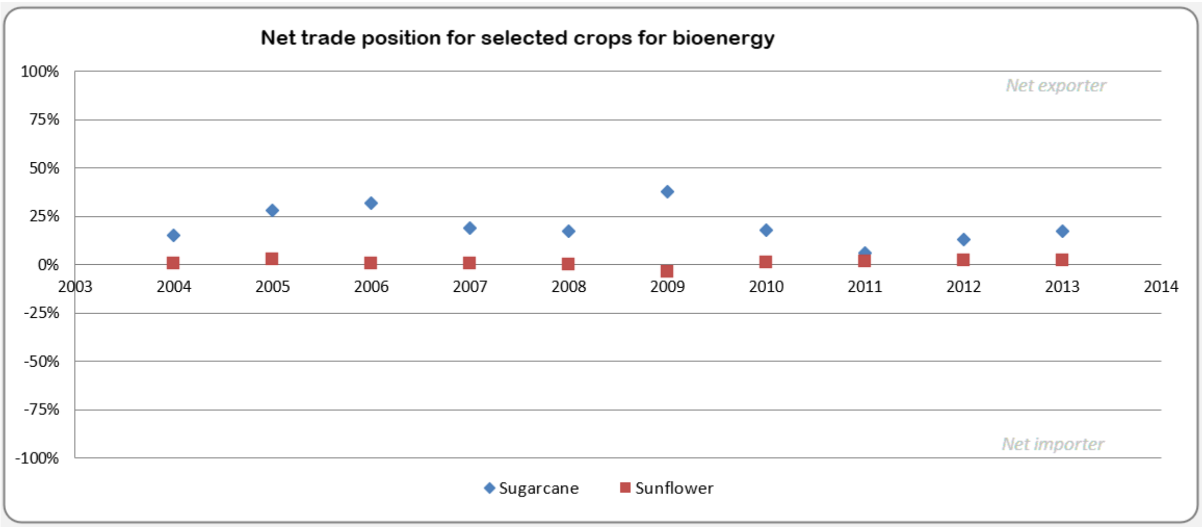

Figure 12: Trade position for Sugarcane and Sunflower over the 10-year period.

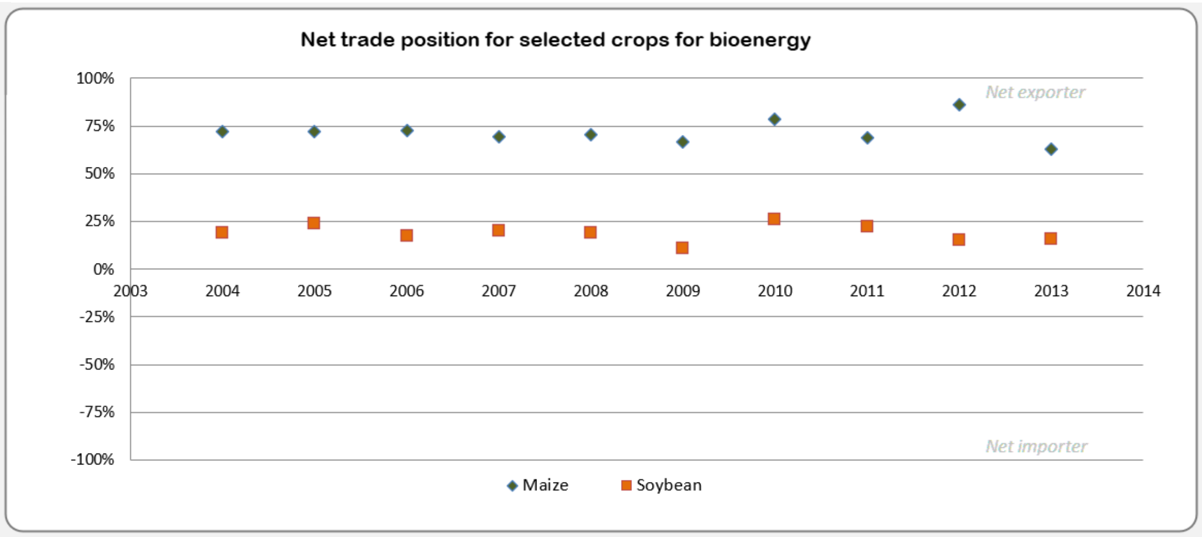

Figure 13: Net trade position for Maize and Soybeans over the 10-year period.

- Sugarcane[2] – Over the 10-year period examined, Argentina has always been a net exporter of sugar. The exporting rate has ranged from 6.1% to 38.0% where the highest exporting rates are due to a positive stock variation from the previous year. Furthermore, the domestic consumption of sugar has increased at a relatively steady percentage from 1.5 to 1.7 MMT over the 10-year period analysed and roughly corresponds with the population growth experience over that period.
- Sunflower – This crop is the only one where there is no significant net trading and most of the production is consumed domestically which indicates they are self-sufficient in sunflower production. The exporting rate ranges from 0.4% to 2.6% with 2010 being the only year where Argentina was a net importer with 3.7% (figure 12).
- Maize – Maize shows the highest export rate over the 10-year period examined. This ranges from a minimum of 63.0% to a maximum of 78.7%. The production amount has more than doubled over the 10-year period showing a major drive towards maize production and domestic consumption has almost doubled from 4.39 to 7.88 MMT over the same period.
- Soybean – The net trading position over the years analysed is relatively high ranging from 11.2% to 24.1% of the total production. The total production of soybeans has the largest variation year-on-year which may respond to international demand and prices or to crop rotations. It is also the most produced crop with maximum production of 52.67 MMT in 2010.

5.4.2 Intensification Option

The intensification option identifies potential increased production by increasing the overall yield of the crops. This can be achieved through the improvement of farming techniques and/or through the increased use of agricultural supplies including fertiliser or farming equipment. There are three levels of input which can be used to assess the overall yield of the selected crops. Low input level refers to rainfed production with minimum use of agricultural supplies and manual labour force. Intermediate level input refers to either rainfed production with increased use of supplies and/or mechanical labour or irrigated production with a low level of agricultural supply use. High level input refers to the irrigated production with high levels of agricultural supplies and machinery used.

The data collected on the selected crops are presented in table 4 and are used as the basis for the intensification analysis performed. The current yield and annual production are used to calculate the current production area in hectares and this figure is then used as the land area for the intensification. Appropriate potential yields should be selected considering the different inputs and land suitability.

[2] The trade position of raw sugar is used instead of sugarcane. This is because sugarcane is processed immediately after harvesting and raw sugar is traded as an international commodity.

Potential yields based on GAEZ data are referenced at the various input levels to guide the selection of intensified yield. The results are presented in table 4, below, and summarised for each crop. As Argentina is a semi-developed country with a strong agricultural sector and therefore a mechanised high-level input was selected for intensification of each crop. The potential production for bioenergy is presented in table 5.

Table 5: Current production for each selected crop.

		Crop 1	Crop 2	Crop 3	Crop 4
		Sugarcane	Sunflower	Maize	Soybean
Parameter	Unit	Current production			
Current yield	t/ha	60.00	2.00	6.30	3.20
No. of harvests/year		1	1	1	1
Annual production	t/year	22,500,000	3,300,000	32,000,000	51,000,000
Total production area	ha	375,000	1,650,000	5,079,365	15,937,500
Intensified production (Potential production on the same area with increased yields)					
Water supply	Select	Irrigation	Irrigation	Irrigation	Irrigation
Input level	Select	High	High	High	High
Intensified yield	t/ha	77	2.10	8.50	4.00
No. of harvests/year		1	1	1	1
Potential production	t/year	28,875,000	3,465,000	43,174,603	63,750,000
Total production area	ha	375,000	1,650,000	5,079,365	15,937,500

Table 4: Potential feedstock production for bioenergy

Potential production for bioenergy					
		Sugarcane	Sunflower	Maize	Soybean
Potential production	t/year	875,000	65,000	1,974,603	3,550,000
Area of production	ha	11,364	30,952	232,306	887,500

Sugarcane – the yield for sugarcane was found to be 60.00 t/ha in 2019 by using an OECD-FAO dataset and USDA statistics. The total production for that year was 22,500,000 tonnes. This is much lower than the FAOSTAT 10-year average and suggests a bad crop year. As previously stated, the input level selected was high and the intensified yield chosen is 77 t/ha. Although a considerable improvement on current yields, it is still well below the potential yields suggested by GAEZ for a high input level. Based on this assumed yield, the potential production was estimated at 28,875,000 tonnes using the same area of production. This allows for the potential production of 875,000 t/year to be used as bioenergy feedstock.

Sunflower – the yield for sunflower was found to be 2.00 t/ha in 2018 by using USDA and national statistics and the total production for that year was 3,300,000 tonnes. This yield is comparable to the FAOSTAT 10-year average which stood at 1.73 t/ha for the period 2005-2014. As previously stated, the input level selected was high and the intensified yield chosen is 2.10 t/ha. Although a small improvement on current yields, it is in the range of moderately suitable potential yield suggested by GAEZ for a high input level. Based on this assumed yield, the potential production was estimated at 3,465,000 tonnes using the same area of production. This allows for the potential production of 65,000 t/year to be used as bioenergy feedstock.

Maize – the yield for maize was found to be 6.30 t/ha in 2018 by using national statistics and the total production for that year was 32,000,000 tonnes. This yield is comparable to the FAOSTAT 10-year average which stood at 6.61 t/ha for the period 2005-2014. As previously stated, the input level selected was high and the intensified yield chosen is 8.5 t/ha. This is a considerable improvement on current yields; however, it is within the range of moderately suitable potential yield suggested by GAEZ for a high input level. Based on this assumed yield, the potential production was estimated at 43,174,603 tonnes using the same area of production. This allows for the potential production of 1,974,603 t/year to be used as bioenergy feedstock.

Soybeans – the yield for soybeans was found to be 3.2 t/ha in 2019 by using USDA statistics and an OECD-FAO dataset and the total production for that year was 51,000,000 tonnes. This yield is higher than the FAOSTAT 10-year average but comparable to actual yields. As previously stated, the input level selected was high and the intensified yield chosen is 4.00 t/ha. Although a considerable improvement on current yields, it is much lower than the 4.90 country average yield suggested by GAEZ for a high input level. Based on this assumed yield, the potential production was estimated at 63,750,000 tonnes using the same area of production. This allows for the potential production of 3,550,000 t/year to be used as bioenergy feedstock.

5.4.3 Change of Crops

The following option to increase the amount of biomass feedstock consists of a change of crops assessment. This allows for the reallocation of existing cropland to be used to grow other bioenergy crops. The complete analysis required to accurately assess the impact of switching crops is very extensive and therefore this tool is used to provide an indication of the potential offered by the change. As this research project aims to maximise the production of sugarcane, the crops which will be compared are sugarcane as the bioenergy crop and maize as the current crop. Maize has been selected due to its high export rates which allows for a reduction in production without affecting the local production of ethanol or the food security of Argentina.

As can be observed in table 6, below, the current production of maize has been reduced from 32 MMT to 31 MMT. Considering the average export rates of over 70%, reducing production by 1MMT is a reasonable amount which will have a minimal impact on exports. This change in crops could produce 158,730.16 ha which if used for sugarcane could support additional production of up to 9.52 MMT. Although maize and sugarcane are mostly grown in different regions, there is some overlap in the provinces of Santa Fe, Tucuman, and Salta. By increasing the production in these northern regions, the aim is to drive investment in these poorer rural areas which have suffered from centralisation and investment focussed on Buenos Aires and the surrounding provinces. This could potentially help increase local GDP levels to similar levels seen in southern provinces.

Table 6: Hypothetical change of crops from maize to sugarcane.

Current crop		
Current production		
Parameter	**Unit**	***Maize***
Yield	t/ha	6.30
No. of crop cycles		1.0
Annual production	t/year	32,000,000
Production area	ha	**5,079,365.08**
Planned production		
Annual production	t/year	31,000,000
Area required	ha	**4,920,634.92**

Crop for bioenergy		
Planned production		
Parameter	**Unit**	***Sugarcane***
Yield	t/ha	60.00
No. of harvests/year		1.0
Potential production for bioenergy		
Annual productic	t/year	**9,523,809.52**
Area required	ha	**158,730.16**

5.4.4 Extensification Option

The extensification option relies on increasing the overall production area of crops to increase the production of bioenergy crops. This is achieved by assessing trends in land use over time and ensures that extensification is a sustainable option considering the country-specific requirements. The historical trends in land use are presented below from the period 2004-2016 (figure 14 and table 7).

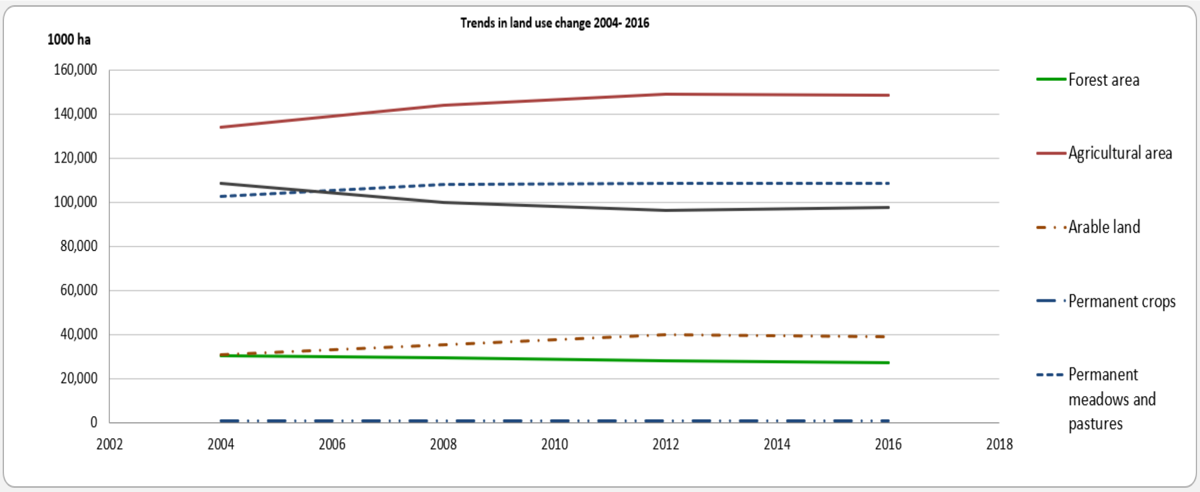

Figure 14: Trends in Land-Use by type in Argentina between 2004-2016.

Table 7: Trends in Land Use Changes in Argentina over the period 2004-2016.

Forest Area	In the period 2004-2016, a decrease of forest area was recorded. This could be an indication of deforestation at country level. Total forest area decreased by 3,408,800 ha, i.e. by 11.17%.
Agricultural Land	In the same period, the total agricultural area increased by 14,355,000 ha, i.e. by 10.69%.
Arable Land	The arable land (area under annual crops) increased by 8,425,000 ha, i.e. 27.38%
Grassland	Grassland area (permanent meadows and pastures) increased by 5,930,000 ha, i.e. by 5.78%
Conclusion and Recommendations	Data on land use change during the period 2000-2010 indicate that the expansion of the agricultural area may be one of the key drivers for deforestation. Therefore, policy measures and actions aiming at the increase of agricultural yields without further expansion of agricultural area is strongly recommended.

Table 7 is generated by the BEFS tool in the Natural Resources module and helps to understand the changes in land use over time and the impact these have on the potential expansion of production area. The main consideration for this section is the impact that agriculture and farming expansion can have on available forest area. The data in Argentina show that there has been a decrease in forest area of 11.17% between 2004-2016 and indicate that one of the key drivers for deforestation is expansion of agriculture land. Therefore, the tool recommends that increases in agricultural yields be achieved through either intensification or through change of crops and not through the expansion of agricultural land. Furthermore, the displacement of crop land by beef production should be minimised as this increases the use of forest areas for beef production.

As the extensification option has been ruled out as a viable option for Argentina, the following section of the analysis is not required.

5.4.5 Crop Production Results

The results from the additional potential production of bioenergy crops are presented below (figure 15). They include the intensification and extensification options as well as the change of crops option. As discussed in section 5.4.4, the current land use in Argentina does not support the increase of crops through extensification of production and therefore the focus is limited to intensification and change of crops.

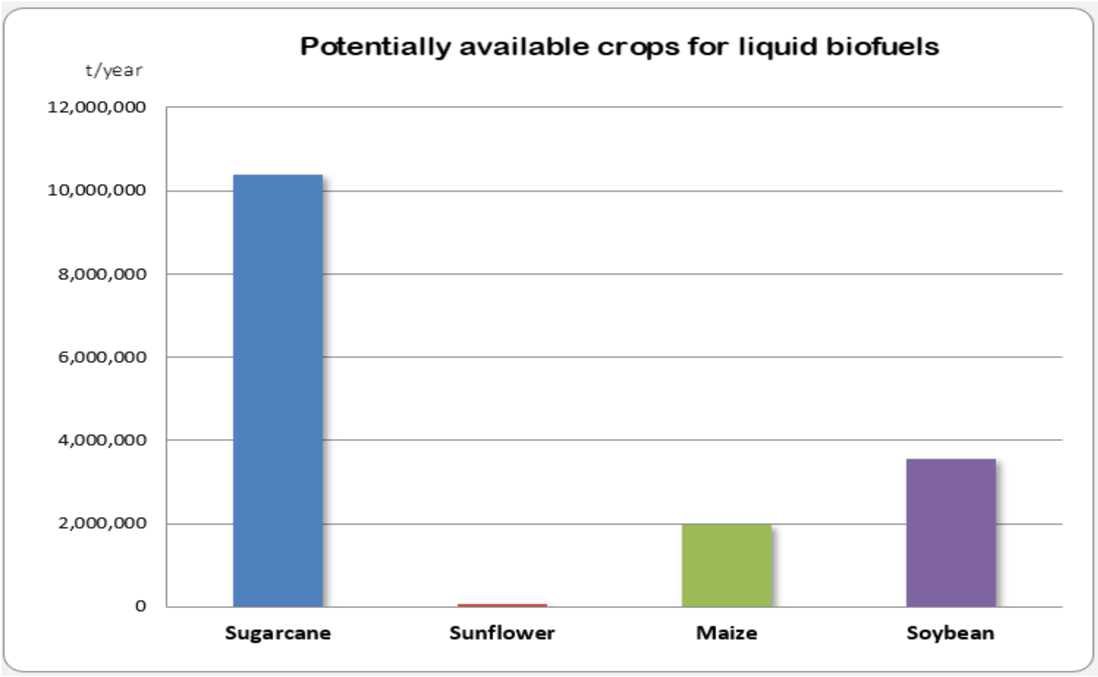

Figure 15: Potential Increase of Selected Bioenergy Crops in t/year.

As can be observed in the results in Appendix 2, the crop with the most potential for intensification is soybean. This is due to the low yields which are currently achieved from the crop relative to the potential yield, and the high proportion of cropland already allocated to soybean production. The land area used for maize production is also high and therefore intensification of yields provides a high energy crop potential. The potential crop availability of sugarcane is directly dependent on an increase in production area by changing crop production. Currently sugarcane plantations account for a small agricultural area and substituting 3.1% of maize land area with sugarcane could provide a significant increase in sugarcane feedstock available for liquid biofuel production. Overall, figure 15 shows the combined results of both the intensification and the change of crops options and it can be clearly seen that sugarcane, maize and soybean offer the most potential. However, it is worth noting that the export amounts of all crops are excluded from this analysis and therefore both maize and soybean have a much higher potential if exports are diverted to bioenergy production.

5.5 Crop Budget Tool

Results are presented in Appendix 3.

5.5.1 Crop Budget Introduction

Due to issues existing in the crop budget section of the tool relating to the data provided, the tool could not be used for the agro-economic analysis of the production options. To obtain the data required for the Energy End-Use module, a new simplified crop budget tool was created. The new tool provides an economic assessment by comparing the gross profit margin of the selected crops and extracts the required hours and costs of production for the subsequent tool. The costs are split into fixed and variable costs and are assess against the profits achieved from the crop yield to provide an indication of the production costs.

Several assumptions have been used within this tool to provide the required data for the subsequent module. These are:

- The fixed costs were assumed constant between crops when data not available.
- Linear extrapolation was assumed when gross margin yield differed from the required yield.
- UTA conversion was assumed comparable to Australian hours.
- Establishment of sugarcane plantation costs are spread equally over the lifetime of the plantation which is assumed to be 4 years.
- Intensified yields taken from available data and not as suggested by crop production tool.
- Intensified yield for soy assumed as rainfed.

5.5.2 Crop Budget Results

To make this simplified crop budget relatively comparable to the BEFS crop budget tool, an assessment of profitability on the selected crops has been performed. Although the analysis is more limited than the BEFS tool, these numbers provide an indication of the profitability of crops. It should be noted that the profitability of crops is dependent on a myriad of factors which can greatly vary between years and crop production is subsidies by government which is not included in this analysis. Furthermore, the data presented in figure 16 represents the results for the intensified yields. [3]

As can be seen in figure 16, maize is the most profitable crop per hectare followed by sugarcane and soybean. The fixed costs of sugarcane are much higher compared to the annual crops due to the costs of establishing a plantation. Soybean has the lowest profitability due to the much lower yields achieved per hectare compared to maize and sugarcane. Both sugarcane and maize use irrigation which accounts for a large proportion of the variable costs and environmental impacts.

[3] The units for figures 16 are USD/ha.

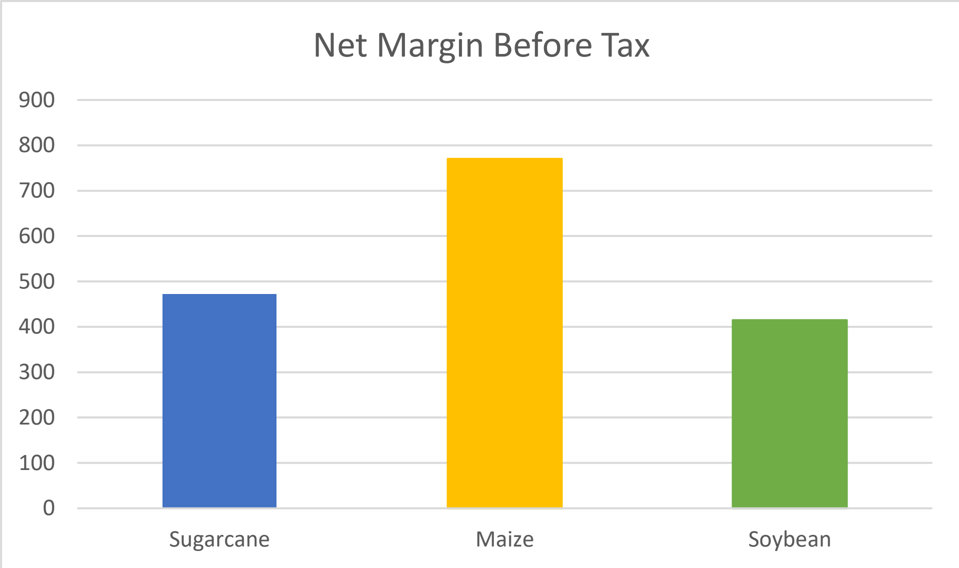

Figure 16: Net margin before tax for intensified yields.

5.6 Discussion Natural Resources Module

The Natural Resources module provides an analysis of the most important energy crops and their potential as feedstock for bioenergy developments. The information obtained in the module is summarised in this section and provides an answer to RSQ2.

To what extent can food crops supply the feedstock required for bioenergy developments? And which option is most suitable for increased production?

The viability of expanding production of energy crops to be used as feedstock has been analysed in this section by considering three separate scenarios. The first scenario focuses on yield intensification of existing crops to increase the total feedstock available whilst keeping the agricultural area constant. The current crop yields for the selected crops are lower than the potential yields for the area and therefore intensification offers potential for increased production. The potential feedstocks available through intensification for the selected crops are presented in table 4.[4] The potential feedstock is directly dependent on the current production area and therefore improvements in soybean production yields will have the largest impact due to the size of the current production area compared to the others. The potential increase in soybean yields and production demonstrate the availability of biomass as feedstock for biodiesel production. With respect to ethanol production, both maize and sugarcane crops can supply additional feedstock for bioenergy production. Although maize offers slightly higher potential, the land area required to supply this is much larger than sugarcane due to

[4] The planned production in table 4 should be exclusively for non-bioenergy purposes, however, to focus on the future potential production, the total current production for each crop has been used. This allows for the assessment of the feedstock available to increase biofuel production without affecting the current production used for food, bioenergy, and exports.

the much lower yield. Therefore, sugarcane crops offer increased feedstock potential when compared to maize.

The second option available is a change of crops scenario whereby an existing crop is replaced with an energy crop to increase the feedstock of the replacement crop. In this section, the crops selected are maize and sugarcane as they are both feedstock for ethanol production. The use of food crops in bioenergy developments in Argentina is not a major problem as they are net exporters of their key food crops and therefore a surplus already exists. Sugarcane has been chosen as the replacement crop due to the higher potential exhibited in the intensification option. Furthermore, as over 50% of maize produced is exported, a decrease in maize production will not affect food security and makes it a viable option. Additionally, when considering the techno-economic analysis, sugarcane shows to be more profitable than maize and therefore is a suitable replacement crop.

The final option available, extensification, assesses the viability of increasing the overall agricultural area whilst the yield remains the same. The data computed in this section are supported by data collected in the Country Status module which show that 54% of the land mass of Argentina is currently used as agricultural area and therefore the extensification option is not recommended. Further increases in agricultural land could have a detrimental effect on both biodiversity and deforestation and is therefore the least attractive option.

When considering the results of the crop budget tool, maize is the most profitable crop when comparing the intensified options. The agro-economic analysis is somewhat limited due to the nature of the simplified crop budget. This is caused by a lack of recent data and the volatile nature of the Argentine economy which complicates the comparison between maize and soybeans against sugarcane. The assumptions made are required to achieve the results necessary, however, the lack of available data is a limitation to this crop budget and current datasets would be much more useful to assess the crops analysed.

The most suitable option depends on the biofuel to be produced. Biodiesel production would benefit from intensification of soybean yields and would provide sufficient levels of feedstock considering the current land area used for production. Considering the increase in production of biomass feedstock suitable for ethanol production, the change of crops option is more suitable as sugarcane has much greater yields and would provide increased feedstock potential when compared to intensification. However, this change is limited to northern regions and therefore southern regions should consider increasing irrigation to facilitate intensification of maize to increase biomass availability.

Chapter 6: Energy End Use Module

The full results for this module and all the data discussed within it are presented in Appendix 4 and are summarised in this chapter.

6.1 Introduction

The Energy End-Use module is the final level of analysis and consists of a techno-economic and a socio-economic evaluation of the potential bioenergy routes available. The module consists of the following five submodules: Intermediate or Final Products, Heating and Cooking, Rural Electrification, and Heat and Power and Transport. Each submodule uses specific types of biomass feedstock and focusses on a final energy form. The overall breakdown of the module is shown in figure 18 below.

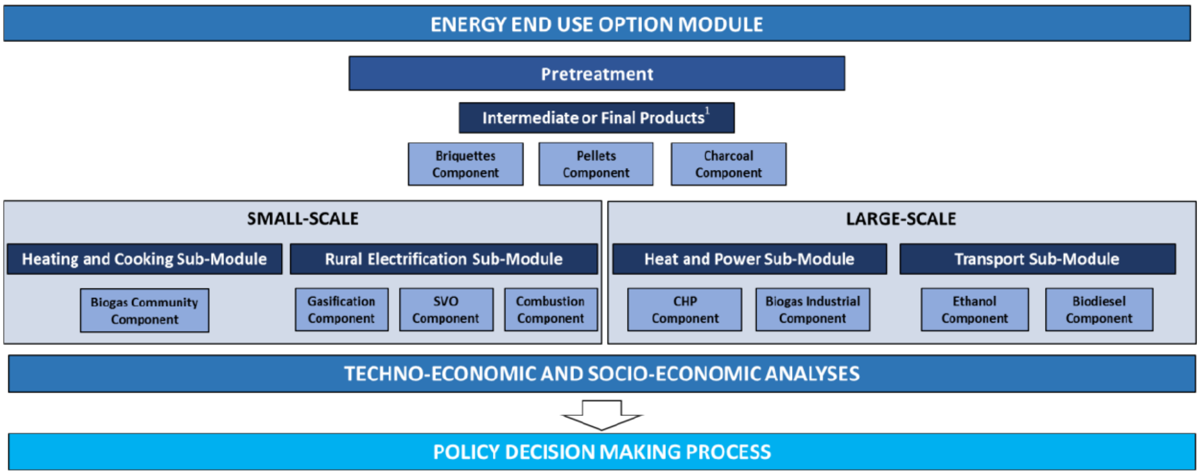

Figure 17: Energy End Use Module Breakdown.

Furthermore, since the Natural Resources module results were obtained using the Crops submodule, the submodule options for the Energy End Use are limited to either Heat and Power or Transport. Considering the country context and the current bioenergy networks available, the Transport submodule is the most relevant for Argentina. Especially when considering that maize and soy produce diesel substitutes which are primarily used as transport fuels.

The Transport submodule evaluates the potential production of biofuels from the available feedstock calculated in the Crop Production section. The production of ethanol and biodiesel are assessed using various scenarios relating to feedstock production (Own Production, Mixed and Outgrowers) and biofuel plant sizes and provide an overview to the profitability of the pathway. Furthermore, the transport submodule provides information on the most suitable plant size, feedstock type and assesses the quantity of biofuels available and the potential for job creation.

6.2 Scope and Objectives

The objective of this module is to provide a preliminary assessment of potential bioenergy pathways and the economic analysis of such a pathway. The scope of this analysis is focussed on liquid biofuels and is linked to the results obtained in the Natural Resources module. A comparison between the selected energy crops is also performed and helps to select the most suitable feedstock.

6.3 Biofuel Demand

As discussed in the previous module, Argentina already produces the biofuels required to meet the current blending mandates and is one of the world's leading exporters of biodiesel. However, the potential to expand the biofuel market exists, and the various pathways should be analysed to identify the most promising route. Furthermore, by changing the blending target in the tool, an analysis can be performed on the viability of supplying the increased mandate from the current feedstock available. These results are presented in figure 19.

Domestic fossil fuel consumption

	Consumption	Unit		Consumption	Unit
Diesel	9,926	ML/year	**Gasoline**	5,510	ML/year

Domestic blending target

	Blending target	Biofuel demand		Blending target	Biofuel demand
Biodiesel (ML/year)	10%	993	**Ethanol (ML/year)**	12%	661

Biofuel production and trade

	Domestic production	Imports	Exports	Net balance
Biodiesel (ML/year)	1,890	0	893	996
Ethanol (ML/year)	870	0	0	870

Target domestic biofuel production

Biodiesel (ML/year)	**-897**
Ethanol (ML/year)	**-208**

Figure 18: Fuel Consumption and Blending Mandates used to calculate required national biofuel volume.

Assuming blending mandates are increased to 20% for both biodiesel and ethanol, the required production would be 1,985 and 1,102 ML, respectively. Increasing the blending mandate to 20% would almost double the biofuel market and would provide additional uses for feedstocks (figure 20).

Domestic blending target

	Blending target	Biofuel demand		Blending target	Biofuel demand
Biodiesel (ML/year)	20%	1,985	**Ethanol (ML/year)**	20%	1,102

Biofuel production and trade

	Domestic production	Imports	Exports	Net balance
Biodiesel (ML/year)		0	893	- 893
Ethanol (ML/year)		0	0	-

Target domestic biofuel production

Biodiesel (ML/year)	**1,985**
Ethanol (ML/year)	**1,102**

Figure 19: Target production at enhanced blending mandates of 20%.

6.4 Data Entry for Liquid Biofuels

This section of the tool collects the required data to perform the techno-economic and socio-economic analyses. Feedstock, labour, and land data are obtained from the Crop Budget tool and are combined with country specific data relating to costs. These include cost of utilities and chemicals, cost of transportation and storage, labour costs, and pricing for the co-products manufactured.

Due to the extreme economic situation currently experienced by Argentina, some assumptions have been made in the selection of financial parameters. These assumptions are:

- The loan interest rate and the discount rate have been assumed to minimise the impact that the exorbitant values would have on the analysis.
- The discount rate is set to 10% instead of 42% as it is a more representative for a developing country like Argentina.
- The loan interest rate is assumed to be 0%. This mitigates the current interest rate of 38%, which have been set to control inflation, and which greatly impact the profitability of financed projects. Therefore, the required capital is assumed available without the need of loans.
- The loan ratios and loan terms are also set to 0 as no loan is required.

6.5 Processing Costs

The processing costs for each energy crop analysed are calculated using the data entered in the data entry section of the spreadsheet. As discussed in the introduction, three feedstock production scenarios are considered to provide flexibility to the results; these are: Own Production, Mixed and Outgrowers. These scenarios are each assessed with respect to four differently sized process plants operating at 5, 25, 50 and 100 ML/year. Table 8, below, provides an example of the processing cost table created by the tool.

Table 8: Processing Costs for Production of Ethanol from Sugarcane Feedstock.

	Capacities (Million litres per year)			
	5	25	50	100
	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	*Financial Assessment Sc 1 (5 ML/year)*	*Financial Assessment Sc 1 (25 ML/year)*	*Financial Assessment Sc 1 (50 ML/year)*	*Financial Assessment Sc 1 (100 ML/year)*
Scenario 2: Mixed	*Financial Assessment Sc 2 (5 ML/year)*	*Financial Assessment Sc 2 (25 ML/year)*	*Financial Assessment Sc 2 (50 ML/year)*	*Financial Assessment Sc 2 (100 ML/year)*
Scenario 3: Outgrowers	*Financial Assessment Sc 3 (5 ML/year)*	*Financial Assessment Sc 3 (25 ML/year)*	*Financial Assessment Sc 3 (50 ML/year)*	*Financial Assessment Sc 3 (100 ML/year)*

Feedstock	Unit	Unit Price (USD)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Sugarcane Scenario 1	t	$ 27.19	61,728	$ 1,678,395	308,642	$ 8,391,975	617,284	$ 16,783,951	1,234,568	$ 33,567,901
Sugarcane Scenario 2	t	$ 28.11	61,728	$ 1,735,432	308,642	$ 8,677,160	617,284	$ 17,354,321	1,234,568	$ 34,708,642
Sugarcane Scenario 3	t	$ 29.50	61,728	$ 1,820,988	308,642	$ 9,104,938	617,284	$ 18,209,877	1,234,568	$ 36,419,753

Total Production Costs (USD/year)

	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)
Scenario 1								
Total operating costs	$ 2,526,938	$ 0.51	$ 10,877,398	$ 0.44	$ 21,990,595	$ 0.44	$ 44,120,332	$ 0.44
Total fixed costs	$ 2,195,412	$ 0.44	$ 5,159,045	$ 0.21	$ 8,192,812	$ 0.16	$ 13,838,443	$ 0.14
Total other costs	$ 132,530	$ 0.03	$ 235,707	$ 0.01	$ 411,469	$ 0.01	$ 754,649	$ 0.01
Total production costs scenario 1 (USD/year)	$ 4,854,880		$ 16,272,150		$ 30,594,875		$ 58,713,424	
Total production costs scenario 1 (USD/l)		$ 0.97		$ 0.65		$ 0.61		$ 0.59
Scenario 2								
Total operating costs	$ 2,583,975	$ 0.52	$ 11,162,584	$ 0.45	$ 22,560,965	$ 0.45	$ 45,261,073	$ 0.45
Total fixed costs	$ 2,195,412	$ 0.44	$ 5,159,045	$ 0.21	$ 8,192,812	$ 0.16	$ 13,838,443	$ 0.14
Total other costs	$ 132,530	$ 0.03	$ 235,707	$ 0.01	$ 411,469	$ 0.01	$ 754,649	$ 0.01
Total production costs scenario 2 (USD/year)	$ 4,911,917		$ 16,557,335		$ 31,165,246		$ 59,854,165	
Total production costs scenario 2 (USD/l)		$ 0.98		$ 0.66		$ 0.62		$ 0.60
Scenario 3								
Total operating costs	$ 2,669,531	$ 0.53	$ 11,590,361	$ 0.46	$ 23,416,521	$ 0.47	$ 46,972,184	$ 0.47
Total fixed costs	$ 2,195,412	$ 0.44	$ 5,159,045	$ 0.21	$ 8,192,812	$ 0.16	$ 13,838,443	$ 0.14
Total other costs	$ 132,530	$ 0.03	$ 235,707	$ 0.01	$ 411,469	$ 0.01	$ 754,649	$ 0.01
Total production costs scenario 3 (USD/year)	$ 4,997,473		$ 16,985,113		$ 32,020,801		$ 61,565,276	
Total production costs scenario 3 (USD/l)		$ 1.00		$ 0.68		$ 0.64		$ 0.62

Considering the trends in the three scenarios, the feedstock price is the main factor affecting the cost of production. The most profitable scenario is Own Production due to obtaining the feedstock at production cost compared to market price. On the contrary, the Outgrowers scenario is the costliest as the feedstock must be purchased at market value and transported to the processing plant. As expected, savings related to increases in plant capacity occur, and the cost per litre becomes significantly cheaper at 100 ML plants versus 5 ML plants. The operational costs have the smallest variation at higher capacities due to the feedstock price remaining equal throughout whereas the fixed costs greatly decrease at higher capacities. The data for both maize and soybeans are presented in Appendix 4.

6.6 Results Transport Submodule

6.6.1 Summary of Results by Feedstock

This section of the results provides an individual summary for each feedstock option analysed. There are three areas of analysis where results are provided. These are:

Production Cost and Investment: The production cost of biofuel is compared against the market rate price of both traditional fossil fuels and biofuels. Furthermore, the required investment for the plant and the share of production costs are also presented in this section.

Operating Results: The available feedstock is assessed in practical terms to identify the most suitable plant size and the potential each crop has, to both provide employment opportunities, and meet the blending target.

Financial Analysis: The economic feasibility of the various scenarios is compared in this section and provides a basis for identifying economically viable options. Both NPV and IRR results are presented in this section.

The results for Maize will be presented in this section of the report whilst the results for other crops will be included in appendix 4.

6.6.1.2 Maize Result Summary

Production Cost and Investment

Figure 20 shows the results relating to production cost and investment. Comparing the cost to produce ethanol to the equivalent price of gasoline, it can be observed that the production costs are higher at lower capacities and when feedstock is outgrown. With respect to the current market rate of ethanol, the cost of production is higher for all scenarios and capacities when compared to the current market rate of ethanol, this indicates that they will not provide a return on investment.

The total investment required for differing capacities is not linear and larger capacities plants are cheaper to build. This is due to the minimum costs of establishing a plant being very large compared to increasing the plant capacity. Therefore, the minimum number of viable plants should be aimed for and plant capacity should be maximised wherever possible.

The share of production costs for the three scenarios are presented below. A number of trends can be observed from the split in costs. As plant capacity increases, the cost of feedstock as a percentage also increases due to the increase in fixed costs versus operational costs. The same is true for the chemical inputs required as raw materials in the process. The share of operational costs remains relatively stable for both labour and energy costs. The greatest change in the share of prices is in the depreciation and maintenace costs as these aren't linear and therefore become cheaper at increased capacities. The trends observed are true for all three scenarios at differing capacities. As expected, the feedstock costs for the Outgrowers scenario is much higher than that of the Own Production and therefore the overall cost of production for the third scenario is always the most costly.

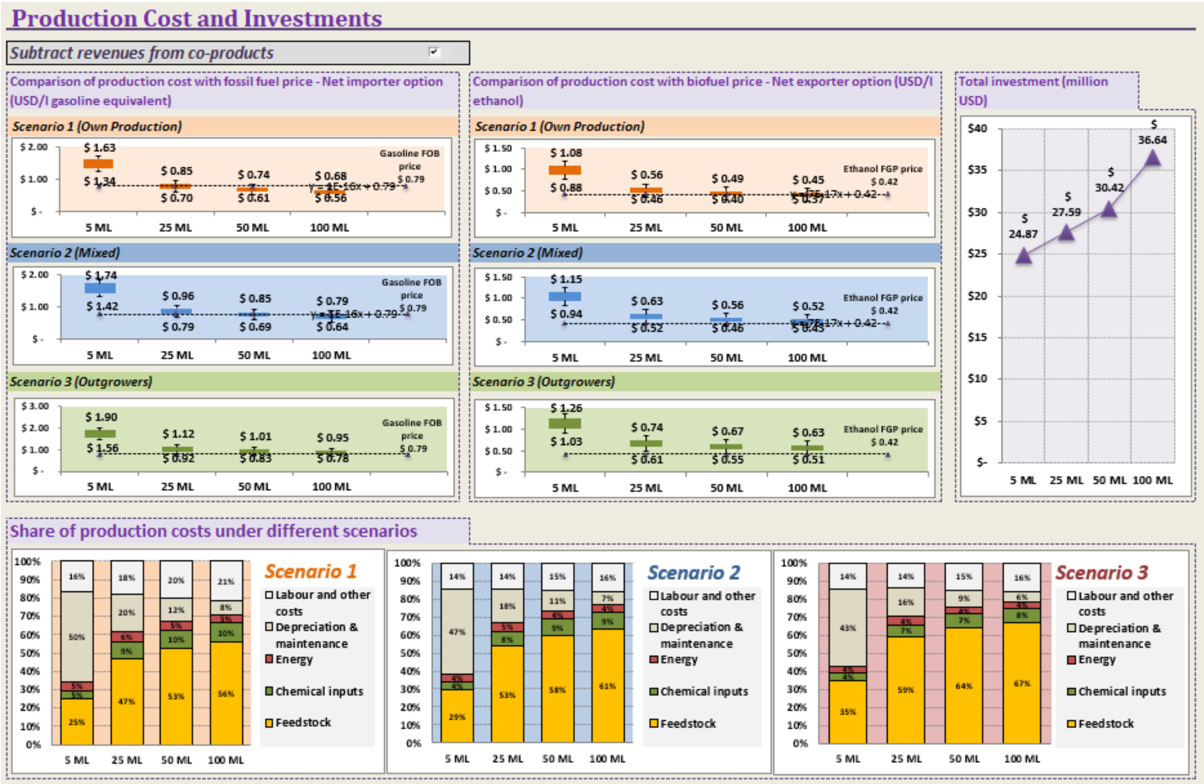

Figure 20: Production Cost and Investment results for maize.

Figure 21 compares the available feedstock with the required feedstock for the various capacities. It can be observed that there is sufficient maize biomass to supply a total of eight 100 ML capacity plants. Maximising the plant number and capacity could provide up to 800 jobs in the sector.

As shown in the biofuel demand section, the current blending demand for ethanol is met. To assess the potential of maize, the overall production of ethanol was set at zero and the blending mandate was increased to E15 (15% ethanol blend). The current available maize feedstock would be able to supply 98% of the new demand. This demonstrates the very significant biofuel potential which maize provides as sufficient feedstock potential exists to double the blending mandate. Results presented in figure 22.

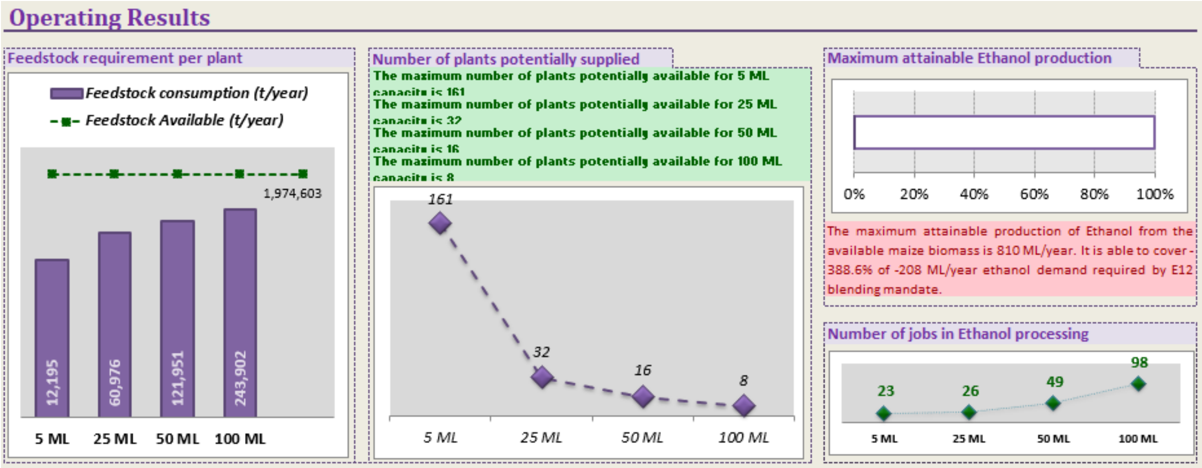

Figure 21: Operating results for ethanol production from maize feedstock.

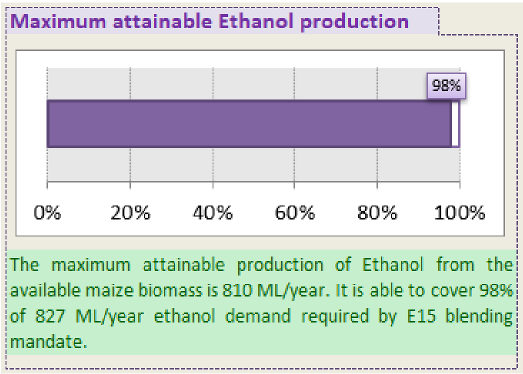

Figure 22: Percentage of ethanol mandate met by available maize biomass

The financial results (figure 23) for maize demonstrate the current difficulty in achieving a profit due to the current prize freeze on biofuels. Under the current pricing, only a marginal profit can be achieved at 100 ML capacities in the Own Production scenarios. As the share of costs indicates, the elevated cost of feedstock is one of the main limitations to achieving profits. These results include the sale of co-products (raw glycerol and soybean meal) which provide additional funds of 0.412 $/L.

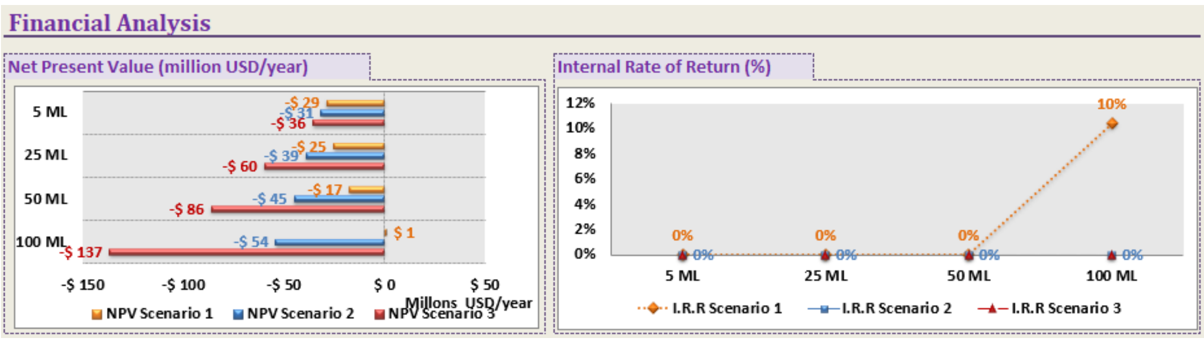

Figure 23: Financial analysis results for maize.

6.6.2 Summary of Comparative Results

The individual results presented in the previous sections are used in this section to perform a comparative analysis of the various options. By comparing these directly, a better understanding can be achieved with respect to the most suitable or promising feedstock options and the ability to meet current and future blending mandates.

Biofuel Production and Plants

For sugarcane, by considering the E12 (12% ethanol blend) blending mandate, the available feedstock could supply up to 127% of the total. Furthermore, if the blending mandate were raised to E15, the available sugarcane feedstock would be able to supply 102% of the required ethanol. Considering maize at the current blending mandate, it would be able to supply 122% of the total amount required. At an E15 blending mandate, it would be able to supply 98% of the required ethanol. The available soybeans feedstock can provide up to 65% of the current B10 blending mandate.

It should be noted that the available feedstock does not include the current feedstock used for biofuel production. Therefore, the available feedstock is being assessed at a higher capacity than required which helps to guarantee food security is safeguarded.

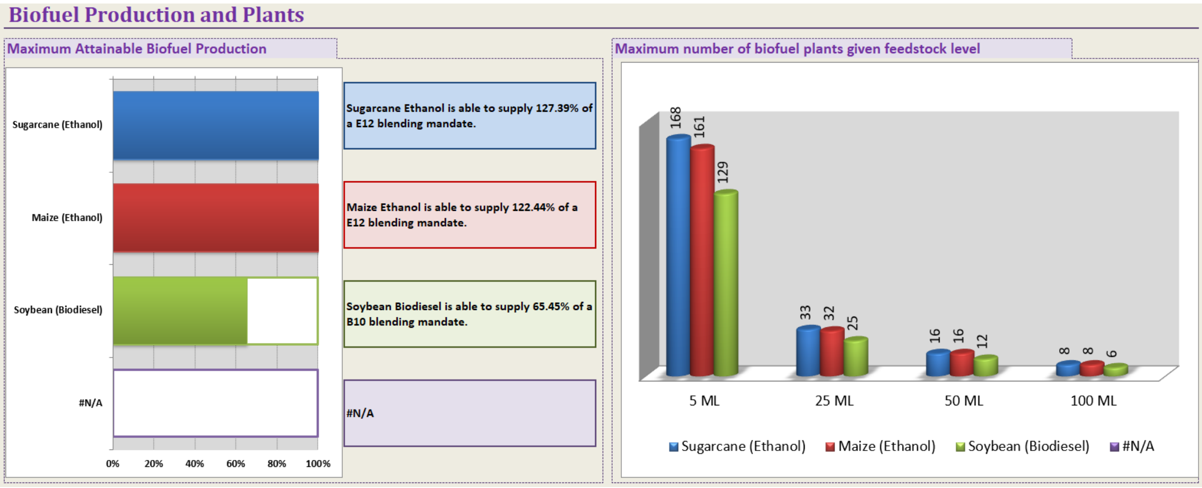

Figure 24: Comparative results for providing blending mandate and plants available.

Comparison of Economic Results

The economic results of the three feedstocks analysed are presented in figure 25 below. Only the results for the own production scenario are presented as the only feasible scenario is within these results. As was discussed in the results for maize in the previous section, the current price freeze relating to biofuels has had a large effect on the market and has limited the ability to generate a profit. Under the current pricing mechanism, only maize under the Own Production scenario at the highest capacity can generate a profit. The lack of feasible production has been warned by the major biofuels producers as the increased costs of feedstock oils and chemical inputs due to the high rates of inflation has not been addressed by the price freeze of biofuels. Therefore, although the current situation is unattainable, a detailed study of the current situation relating to costs and effective actions would change the current scenario.

Comparison of Economic Results

Scenario 1 (own production)

Production Costs

Biodiesel	Biodiesel FGP price			$ 0.63	Diesel FGP price			$ 0.72
	USD/L Biodiesel				USD/L Diesel Equivalent			
	5 ML	25 ML	50 ML	100 ML	5 ML	25 ML	50 ML	100 ML
3 Soybean	$ 1.03	$ 0.90	$ 0.84	$ 0.84	$ 1.12	$ 0.97	$ 0.91	$ 0.91
# #N/A								

Ethanol	Ethanol FOB price			$ 0.42	Gasoline FOB price			$ 0.79
	USD/L Ethanol				USD/L Gasoline Equivalent			
	5 ML	25 ML	50 ML	100 ML	5 ML	25 ML	50 ML	100 ML
1 Sugarcane	$ 0.97	$ 0.65	$ 0.61	$ 0.59	$ 1.47	$ 0.99	$ 0.93	$ 0.89
2 Maize	$ 0.98	$ 0.51	$ 0.44	$ 0.41	$ 1.48	$ 0.77	$ 0.67	$ 0.62
# #N/A								

Net Present Value (NPV) and Internal Rate of Return

Biodiesel	NPV (Million USD/year)				IRR (%)			
	5 ML	25 ML	50 ML	100 ML	5 ML	25 ML	50 ML	100 ML
3 Soybean	-$ 20.52	-$ 66.05	-$ 101.98	-$ 201.64	Not feasible	Not feasible	Not feasible	Not feasible
# #N/A								

Ethanol	NPV (Million USD/year)				IRR (%)			
	5 ML	25 ML	50 ML	100 ML	5 ML	25 ML	50 ML	100 ML
1 Sugarcane	-$ 26.93	-$ 54.11	-$ 87.88	-$ 54.81	Not feasible	Not feasible	Not feasible	Not feasible
2 Maize	-$ 28.71	-$ 25.31	-$ 17.30	$ 0.99	Not feasible	Not feasible	Not feasible	10%
# #N/A								

Figure 25: Comparison of economic results for the feedstocks assessed.

6.6.3 Labour Analysis Results

This section of the results presents the data relevant to the socio-economic impact of the potential biofuel pathways studied. This includes the potential for job creation, the land use required, and the labour required to operate the plants.

The results presented below are for plant capacities of 100 ML and the other results are presented in Appendix 4.

Labour Results for 100 ML plants

When considering the labour requirements by plant, it can be observed that the Own Production scenario requires much lower labour intensity than the other two scenarios. Although this ensures that the price is cheapest and can be produced competitively, depending on the needs and regional situation it may be more appropriate to select scenario 2 or 3. This would help to generate additional employment which might be more significant than a cheaper production cost of biofuels. Furthermore, when comparing all the feedstocks, the production of soybean has the highest labour intensity.

As with the labour requirements, the land requirements are also much more significant in the production of soybean. This is reflected in the total country area that is planted with each crop as soybean occupies a much larger amount of agricultural land than sugarcane or maize. When comparing the ethanol-producing energy crops, it can be observed that sugarcane requires a lower land area than maize. This is due to the much higher yields that sugarcane offer, even considering that less maize feedstock is required in ethanol production.

Finally, the share of jobs in both the production and processing sections of the pathway are compared. The jobs related to processing the feedstock into biofuel remain constant at all scenarios and feedstock types. Hereby, 126 jobs are required to process the feedstock into biofuels. The main difference between the job creation is related to the feedstock-production, with the Own Production scenario requiring the least number of workers and the Outgrowers scenario requiring the highest number of workers. Furthermore, the jobs relating to feedstock-production are less technical than those of feedstock-processing. This means that independently of the scenario selected for production, the amount of technical and specialised jobs would not change significantly as most jobs are created in the feedstock production phase. It is worth noting that biofuel production is not a major job generator due to the high levels of mechanised harvesting.

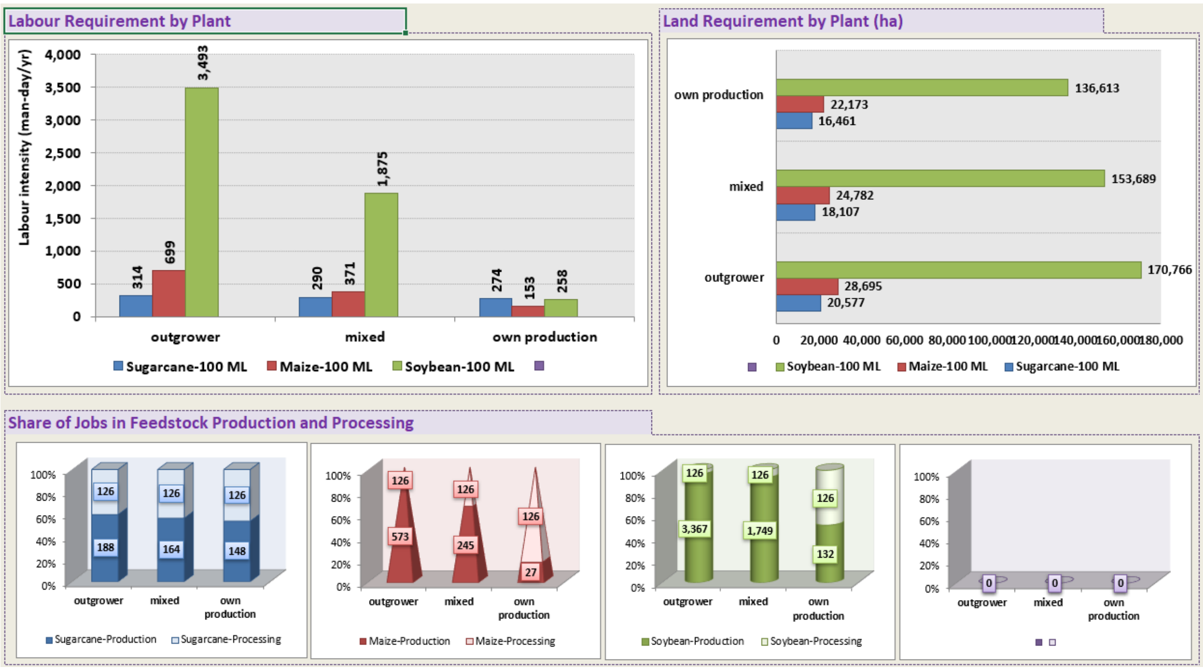

Figure 26: Comparative labour results for all feedstock options at plant capacities of 100 ML.

6.7 Discussion Energy End Use Module

The Energy End Use module provides both a techno-economic and a socio-economic analysis of the potential uses for the feedstock assessed in the Natural Resources module. The main findings from the module are summarised in this section and addresses RSQ3.

What is the current state regarding the production of biofuels in Argentina? Is increasing the production of biofuels for the transport sector a viable option? What impact has the current price freeze had on the profitability of biofuel production?

Considering the country needs, the most suitable Energy End Use option is the transport submodule, and therefore this is the pathway analysed. Furthermore, the crops data obtained in the Natural Resources module form the basis for the data required in this submodule. As was stated in the Country Status module, Argentina currently supplies 100% of the required biofuels to meet the blending mandate set by the government. Additionally, Argentina is one of the leading global exporters of biodiesel and exports just under 50% of biodiesel produced. With respect to the internal biofuel market, as discussed in Chapter 2, there has been a price freeze in place since December 2019 (recently updated in October 2020). This freeze is due to the high inflation the country is experiencing and was meant to help stabilise the economy. However, as can be confirmed in the results obtained in this section, the price freeze, coupled with rising inflation, has created an economically unsustainable situation for the producers of biofuel. As seen in the financial analysis section for each feedstock type, the current market price is not sufficient to provide a profitable scenario to produce biofuels, even considering the recent price increase. With respect to maize, a minimal profit can be obtained under the first scenario at capacities of 100 ML. The impact which the price freeze has had on the market is significant and therefore should be a main point of consideration to improve the internal biofuel market. Furthermore, Argentina has also experienced a considerable reduction in the consumption of fossil fuels due to the current global pandemic. This leads to a direct reduction in the amount of biofuel required to meet the blending mandates, which has also impacted the profitability of the industry.

The results presented in this section consider the impact that raising the blending mandates would have on feedstock availability. As can be observed in the operation results section for each feedstock, the maximum attainable biofuel production is assessed against a hypothetical blending mandate. For ethanol production, due to the availability of two feedstock options, the current production total is assumed to be zero. This helps to understand the full potential of both sugarcane and maize feedstock to produce ethanol. For sugarcane alone, a total of 102% of the E15 mandate could be achieved. For maize, a total of 98% of the E15 mandate could be supplied. The ability of both crops to supply around 100% of the total amount of ethanol required in a hypothetical E15 mandate demonstrates the viability of supplying an increased ethanol mandate. The maximum attainable production of biodiesel was assessed at a hypothetical blending mandate of B20, assuming the current production of biodiesel remains constant. Under this scenario, the available soybean feedstock would be able to produce up to 680% of the required blending increase (10%). Furthermore, considering that Argentina is a net importer of fossil fuels, increasing the required biofuel mandate would reduce the need to import fossil fuels and would improve the sustainability of the internal energy sector. Therefore, it can be assumed that increasing the production of biofuels in the transport sector is a viable option when considering feedstock availability and safeguarding food security. However, the increase in production would have to be accompanied by either a rise in the blending mandates (preferable) or an increase in biofuel exports (added uncertainty).

Chapter 7: Conclusion

7.1 Main Research Question

The three research sub-questions provide information relating to the results presented in Chapters 4, 5 and 6, and are included at the end of those sections. This final discussion section will aim to provide an answer for the main research question and will use the information obtained in the previous result chapters. The research objective should be met by providing an answer to the main research question.

Can an increase in the blending mandate of Argentina be supported by the available biomass feedstock whilst safeguarding food security?

The current instability in the economy, and the expiry in May 2021 of the National Law 26.093 which has regulated the bioenergy industry since 2006, offer the distinct possibility to make significant changes to the industry. One of the main policy considerations consists in the increase to the blending mandates to resemble the Brazilian model more closely. An increase in blending mandates could both improve the demand in the industry and reduce the GHG emissions from the transport sector. Furthermore, the current reliance on imported fossil fuels would be greatly minimised with a blending increase. However, a significant rise in the blending mandate could have serious impacts on food security and could have a minimum impact on GHG emissions.

In Chapter 6, the hypothetical increases in the blending mandates which might be experienced in the coming years was assessed against the existing processing technologies. The blending mandates were set at 15% and 20% for ethanol and biodiesel, respectively. The potential feedstock available in Argentina was estimated in Chapters 4 and 5 and is used as the basis for the results in Chapter 6. Using the results from the previous modules helps to ensure that the hypothetical feedstock available is safeguarded with respect to food security. This is because the net trading position and the main food crops are considered and, wherever possible, main food crops are not included in production. With respect to ethanol, there are two main crops used in Argentina in the production, sugarcane, and maize.

Considering an E15 blending mandate, both these crops can potentially supply the necessary feedstock, with maize providing 98% and sugarcane providing 102% of the total amount. As both crops are used in the production of ethanol, the impact of an increase in this blending mandate would be minimal on both food crops. Therefore, the increase of the blending mandate of ethanol could be achieved with minimal repercussions on food security. Furthermore, considering the export quantities for maize presented in Chapter 4, these alone offer sufficient feedstock to supply the increase in blending mandates. Whilst inflation makes exports more competitive, imports become more expensive. Considering that Argentina imports a significant amount of oil, substituting this with domestic biofuels would offer improvements in climate change mitigation and could also help to stabilise the cost of energy during this period of high inflation.

The production of biodiesel in Argentina is based on soybean oil as feedstock. The blending mandate considered for biodiesel is double the current mandate (B20). Although in practical terms blending mandates are expected to receive incremental increases, analysing the potential to deliver the B20 blend allows for a larger margin of error and is an added layer of safety against detrimental effects on food security. The current feedstock availability of soybean can supply 234% of the biomass to increase the blending mandate from 10% to 20%. Furthermore, considering the export results presented in Chapter 4, soybean is one of the major agricultural exports accounting for 46.6% of the total when all forms of soybean are considered (raw, cake and oil). The export of soybean oil demonstrates the excess feedstock available as this forms the basis to produce biodiesel. Concurrently, Argentina is a major exporter of refined biodiesel, however the recent ban in the US on Argentinian products and the limitations placed on first-generation biofuels in the European Union have caused uncertainty within key markets and may reduce available exports. Therefore, an increased blending mandate could also be supplied by existing production if international markets cannot maintain current exports.

Although second- and third-generation biomass options are preferable to the increased sustainability of the industry, the existing expertise and technologies should be considered when rapid change is desirable. The expiry of the existing law and the current issues faced by the industry offer an opportunity to increase the market share of biofuels and support the industry through increase blending mandates. An increase in blending capacity should be accompanied by a guarantee that food security will not be negatively affected. As has been demonstrated through this analysis, the effective management of food crops can guarantee both increases in biofuel blending and ensure that food prices remain relatively stable, excluding inflation. Furthermore, improvements to energy security are also possible due to the substitution of imported fuels for domestically produced biofuels.

7.2 Research Limitations

One of the key limitations on the study was the time available to perform the analysis. A more in-depth analysis could have been undertaken with more time to assess other aspects of the bioenergy industry such as forest and crop residues or the use of sugar molasses as the feedstock for biofuels as well as other potential end use options.

Another important limitation was the data availability. Due to the country's economic volatility and high rates of inflation, there were several datasets that either were not available or were not complete. Hence, some datasets needed to be extrapolated from previous years. Although the costings of sugarcane production were adjusted for inflation, the accuracy of extrapolating the costings using only inflation raised some precision issues.

Furthermore, the exact blending mandates which should be adopted and the implementation of such cannot be answered by this analysis. A further survey analysis of various stakeholders, including biomass and biofuel producers, could be performed to gain further insight into the needs of the industry and the best available improvements.

7.3 Future Research Direction

The direction which future research could take is manifold. The BEFS detailed analysis tool would help to provide added depth to the research and would provide a more complete understanding of the most effective bioenergy pathways available. As Argentinian agriculture differs greatly between regions, ensuring a more detailed regional analysis could provide specific policy to help develop marginalised regions. This is especially important in northern rural areas where average GDP is much lower when compared to the regions closer to the capital.

An environmental assessment of the impact that a blending increase will have on GHG emission should be performed to fully comprehend the environmental benefits associated with increased capacities. This would help to ensure climate change targets are met and could help to persuade the relevant parties of the environmental impact of this policy.

Although the current bioenergy market is dominated by first-generation biofuels, the research and development of more modern options should be performed. Furthermore, incorporating new bioenergy sources into existing infrastructure would help the transition from first-generation to future biofuels. This would enable flexibility in the market and would allow for the future substitution of energy crops with more sustainable feedstocks such as residues or algae-based biofuels.

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Appendix 1

The Country Status module results are presented in full in this section and form the basis of Chapter 4.

BEFS Rapid Appraisal
Country Status Module

COUNTRY OVERVIEW

COUNTRY: Argentina

<< BACK Start | NEXT >> Net Trade Position for Key Food Crops

BEFS Rapid Appraisal for the country

Enter data into white cells | Grey cells are calculated

POPULATION

Parameter (unit)	Value	Year	User-defined value	Year
Total population (1000 inhab)	43,417	2015	44,781	2019
Rural population (%)	8%		8%	2019
Urban population (%)	92%		92%	2019
Population density (inhab/km2)	15.9		16.4	2019
Number of households			12,171,675.0	2010
Rural households (%)			-	2010
Urban households (%)			-	2010
Source:	FAO, 2017: FAOSTAT		2020: UNDATA; Censo Argentino, 2010: INDEC.g	

ECONOMIC AND AGRICULTURAL INDICATORS

Parameter (unit)	Value	Year	User-defined value	Year
GDP per capita (current US$)	12,449.22	2016	14,400	2019
GDP per capita (constant 2010 US$)	10,148.51	2016	10043	2018
GDP/capita, PPP (const. 2011, int. $)	18,479.44	2016	20611	2018
Inflation, consumer prices (annual %)	10.62%	2013	54%	2019
Agriculture, value added (% of GDP)	7.56%	2016	7%	2019
Livestock, value added (% of Agricultural Value Added)	33.87%	2014		
Source:	The World Bank, 2017: WDI; FAO 2017		The World Bank, 2020: WDI	

LAND AND LIVESTOCK

Parameter	1000 ha	% of land area	Year	User-defined value	Year
Country area	278,040		2014	278,040	2020
Land area	273,669	100%	2014	273,669	2020
Agricultural area	148,700	54.34%	2014	148,712	2016
Arable land	39,200	14.32%	2014	39,189	2016
Permanent crops	1,000	0.37%	2014	1,095	2016
Forest area	27,409	10.02%	2014	26,814	2016
LSUs per 100 people, total population (LSU)	100		2014	-	-
Source:	FAO, 2017: FAOSTAT			AO, 2020: FAOSTAT; The World Bank, 2020: WD	

FOOD SECURITY AND ENERGY USE

Parameter (unit)	Value	Year	User-defined value	Year
Energy use (kg of oil eq. per capita)	2015.2	2014	2,030	2014
Electric power consumption (kWh per capita)	3052.4	2014	3,075	2014
Access to electricity (% of population)	100.0%	2014	100%	2018
GDP per unit of energy use (constant 2011 PPP $ per kg of oil equivalent)	9.3	2014	10	2014
Undernourished population (%)	5.0%	2015	5%	2017
Poverty headcount ratio at national poverty line (% of pop.)	-	-	32%	2018
Source:	The World Bank, 2017: WDI		The World Bank, 2020: WDI	

WATER

Parameter (unit)	Value	Year	User-defined value	Year
Long-term average precipitation (mm/year)	591	2014	591	2017
Total internal renewable water resources (10^9 m3/year)	292.0	2014	292	2017
Source:	FAO, 2017. Aquastat		FAO, 2020: Aquastat	

WATER

Parameter (unit)	Value	Year	User-defined value	Year
Total area equipped for irrigation (1000 ha)	2360.00	2014	2357	2014
Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal)	73.93%	2014	74%	2014
Source:	FAO, 2017. Aquastat		FAO, 2020: Aquastat	

FOOD SUPPLY AND KEY FOODSTUFFS

Rank	Food commodity	Food supply (kcal/capita/day)	Share in total food supply
1	Wheat and Products	896	27.7%
2	Sugar (Raw Equivalent)	396	12.2%
3	Bovine Meat	337	10.4%
4	Sunflowerseed Oil	269	8.3%
5	Milk - Excluding Butter	205	6.3%
6	Poultry Meat	182	5.6%
7	Maize and Products	95	2.9%
8	Rice and products	85	2.6%
9	Pig meat	82	2.5%
10	Potatoes and products	69	2.1%
	Subtotal	**2,616**	**80.8%**
	Total food supply	**3,239**	100%
Source:	*FAO, 2017. FAOSTAT*	***Year:***	**2017**

AGRICULTURAL TRADE - KEY COMMODITIES

Rank	Trade commodity	Export quantity (t)	Export value (1000 US$)	Export unit value (US$/t)	Share in total value of exports
1	Cake, soybeans	28,255,419	9,081,554	321	27.2%
2	Maize	23,706,382	3,883,602	164	11.6%
3	Oil, soybean	4,972,587	3,725,822	749	11.2%
4	Soybeans	7,400,920	2,732,359	369	8.2%
5	Wheat	13,099,133	2,361,855	180	7.1%
6	Meat, cattle, boneless (beef & veal)	203,825	1,282,110	6,290	3.8%
7	Wine	224,689	806,853	3,591	2.4%
8	Oil, sunflower	758,433	602,142	794	1.8%
9	Groundnuts, prepared	373,767	556,619	1,489	1.7%
10	Barley	2,564,500	456,491	178	1.4%
		Subtotal	25,489,407		**76%**
	Total value of export of agricultural commodities		33,361,357		
Source:	*FAO, 2017: FAOSTAT*		***Year:***	**2017**	

AGRICULTURAL PRODUCTION

Rank	Crop Item	Production Quantity (tonnes)	Area harvested (ha)	Yield (hg/ha)
1	Maize	43,462,323	7,138,620	60,883
2	Soybeans	37,787,927	16,318,060	23,157
3	Sugar Cane	19,039,561	426,192	446,737
4	Wheat	18,518,045	5,822,173	31,806
5	Barley	5,061,069	1,209,995	41,827
6	Sunflower Seed	3,537,545	1,678,031	21,082
7	Grapes	2,573,311	218,233	117,916
8	Potatoes	2,340,103	72,442	323,033
9	Lemons and Limes	1,989,400	57,665	344,993
10	Sorghum	1,563,445	437,463	35,739
Source:	*FAO, 2018: FAOSTAT*	***Year:***	*2018*	

Rank	Crop Item	Production Quantity (tonnes)	Area harvested (ha)	Yield (hg/ha)
11	Rice, paddy	1,367,968	198,170	69,030
12	Oranges	1,006,779	46,023	218,756
13	Vegetables, fresh nes	960,810	62,910	152,727
14	Groundnuts, with shell	921,231	443,864	20,755
15	Seed cotton	813,692	319,285	25,485
16	Onions, dry	707,496	27,388	258,323
17	Tomatoes	653,485	16,551	394,832
18	Pears	565,697	24,553	230,398
19	Apples	510,478	23,958	213,072
20	Oats	491,713	218,399	22,514
Source:	*FAO, 2018: FAOSTAT*		***Year:***	*2018*

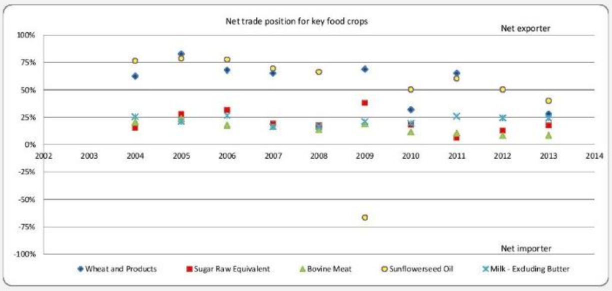
<< BACK Country Overview | NEXT >> Energy Balance

Country: *Argentina*

BEFS Rapid Appraisal for the country

Enter data into white cells | Grey cells are calculated

Net Trade Position for key food crops in the past 10 years



Food crop 1 *Wheat and Products*

Year	Production (t)	Import (t)	Stock variation (t)	Export (t)	Domestic supply (t)	NET TRADE POSITION %	position
2004	16,139,170	8,021	- 1,266,222	10,075,576	4,805,393	62.4%	Net exporter
2005	12,721,980	6,189	2,635,039	10,536,830	4,826,379	82.8%	Net exporter
2006	14,662,940	9,398	250,000	9,988,819	4,933,519	68.1%	Net exporter
2007	16,486,530	8,400	- 808,518	10,745,811	4,940,601	65.1%	Net exporter
2008	8,508,156	7,547	6,333,744	9,992,741	4,856,706	117.4%	Net exporter
2009	9,123,399	10,365	2,079,232	6,285,092	4,927,904	68.8%	Net exporter
2010	16,067,930	8,043	- 5,847,083	5,109,964	5,118,926	31.8%	Net exporter
2011	14,683,480	7,036	- 400,000	9,575,378	4,715,138	65.2%	Net exporter
2012	8,134,409	5,289	9,272,171	12,562,944	4,848,925	154.4%	Net exporter
2013	9,315,049	3,894	- 1,453,082	2,615,156	5,250,704	28.0%	Net exporter

Source: FAO, 2020: FAOSTAT

Food crop 2 *Sugar Raw Equivalent*

Year	Production (t)	Import (t)	Stock variation (t)	Export (t)	Domestic supply (t)	NET TRADE POSITION %	position
2004	1,815,840	17,478	40,288	295,107	1,578,500	15.3%	Net exporter
2005	2,138,826	13,488	117,957	611,248	1,659,022	27.9%	Net exporter
2006	2,469,642	10,157	- 53,739	791,220	1,634,840	31.6%	Net exporter
2007	2,197,957	13,596	- 146,463	430,733	1,634,356	19.0%	Net exporter
2008	2,447,764	44,787	- 387,252	473,750	1,631,549	17.5%	Net exporter
2009	2,255,521	16,275	238,741	873,373	1,637,165	38.0%	Net exporter
2010	2,038,191	45,284	1,808	413,421	1,668,246	18.1%	Net exporter
2011	2,094,273	59,663	- 269,537	186,687	1,697,712	6.1%	Net exporter
2012	2,188,654	10,096	- 197,102	292,685	1,708,963	12.9%	Net exporter
2013	1,788,848	9,873	258,584	323,661	1,733,643	17.5%	Net exporter

Source: FAO, 2020: FAOSTAT

Food crop 3 *Bovine Meat*

Year	Production (t)	Import (t)	Stock variation (t)	Export (t)	Domestic supply (t)	NET TRADE POSITION %	position
2004	3,024,000	3,458	-	619,438	2,408,019	20.4%	Net exporter
2005	3,130,800	3,803	-	736,939	2,397,664	23.4%	Net exporter
2006	3,033,600	4,382	-	540,040	2,497,943	17.7%	Net exporter
2007	3,223,700	4,384	-	528,133	2,699,951	16.2%	Net exporter
2008	3,131,902	3,700	-	423,249	2,712,353	13.4%	Net exporter
2009	3,378,460	1,968	-	640,483	2,739,944	18.9%	Net exporter
2010	2,630,163	2,248	-	302,087	2,330,324	11.4%	Net exporter
2011	2,498,954	3,178	-	257,476	2,244,656	10.2%	Net exporter
2012	2,594,336	1,790	-	213,423	2,382,702	8.2%	Net exporter
2013	2,822,000	187	-	233,103	2,589,084	8.3%	Net exporter

Source: FAO, 2020: FAOSTAT

Food crop 4 *Sunflowerseed Oil*

Year	Production (t)	Import (t)	Stock variation (t)	Export (t)	Domestic supply (t)	NET TRADE POSITION %	position
2004	1,208,500	1,530	125,000	925,541	409,489	76.5%	Net exporter
2005	1,523,400	1,170	86,500	1,200,267	410,804	78.7%	Net exporter
2006	1,579,600	176	70,000	1,228,699	421,077	77.8%	Net exporter
2007	1,223,500	2,222	50,000	854,302	421,420	69.6%	Net exporter
2008	1,740,060	92	- 163,000	1,155,609	421,543	66.4%	Net exporter
2009	- 1,418,821	225	- 48,000	945,592	425,454	-66.6%	Net importer
2010	1,127,698	67	- 110,000	567,628	450,138	50.3%	Net exporter
2011	1,489,706	152	- 150,000	899,148	440,711	60.3%	Net exporter
2012	1,541,580	66	- 320,000	773,858	447,788	50.2%	Net exporter
2013	1,074,724	57	- 200,000	429,776	445,005	40.0%	Net exporter

Source: FAO, 2020: FAOSTAT

Food crop 5 *Milk - Excluding Butter*

Year	Production (t)	Import (t)	Stock variation (t)	Export (t)	Domestic supply (t)	NET TRADE POSITION %	position
2004	8,100,000	69,420	250	2,121,056	6,048,615	25.3%	Net exporter
2005	9,908,941	66,784	-	2,165,033	7,810,692	21.2%	Net exporter
2006	10,493,570	32,072	-	2,823,621	7,702,022	26.6%	Net exporter
2007	9,822,337	40,990	-	1,630,379	8,232,948	16.2%	Net exporter
2008	10,320,320	34,603	-	1,744,157	8,610,767	16.6%	Net exporter
2009	10,366,290	40,224	-	2,224,410	8,182,103	21.1%	Net exporter
2010	10,307,520	44,497	-	2,043,321	8,308,696	19.4%	Net exporter
2011	11,206,260	40,227	-	2,939,047	8,307,440	25.9%	Net exporter
2012	11,238,900	95,080	-	2,839,522	8,494,458	24.4%	Net exporter
2013	11,183,750	78,588	-	2,781,645	8,480,693	24.2%	Net exporter

Source: FAO, 2020: FAOSTAT

ENERGY BALANCE

<< BACK
Net Trade Position

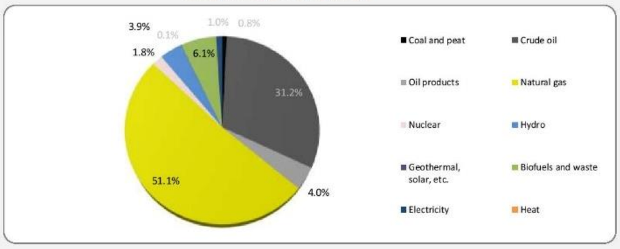
NEXT >>
Energy Demand

Country: *Argentina*

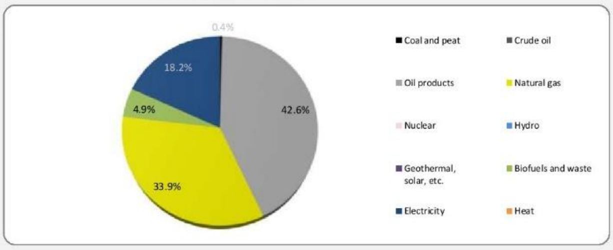
BEFS Rapid Appraisal for the country

Enter data into white cells | Grey cells are calculated

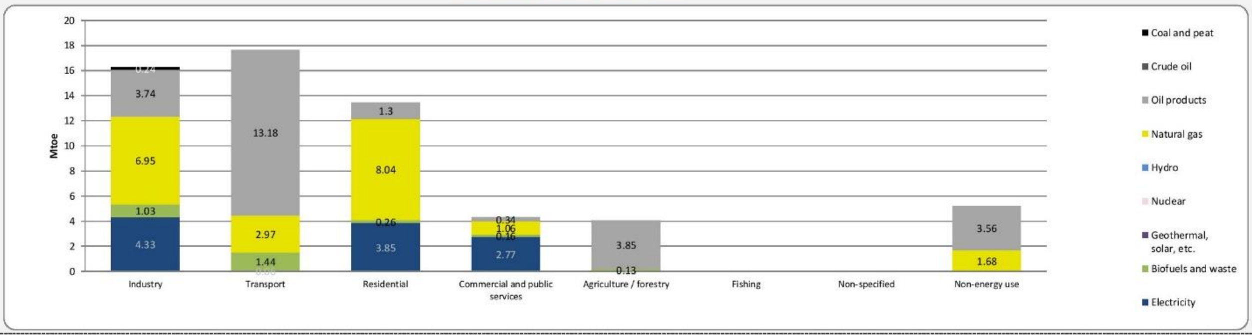
Total primary energy supply



Final energy consumption



Final energy consumption by sector



Simplified aggregated energy balance

Unit: Mtoe	Coal and peat	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geothermal, solar, etc.	Biofuels and waste	Electricity	Heat	Total
Total primary energy supply	**1**	**28**	**4**	**45**	**2**	**3**	**0**	**5**	**1**	**0**	**88**
Production	0	28		36	2	3	0	5			74
Import	1	1	5	9					1		17
Export	0	1	2	0					0		3
Final consumption	**0**	**0**	**26**	**21**	**0**	**0**	**0**	**3**	**11**	**0**	**61**
Industry	0		4	7				1	4		16
Transport			13	3				1	0		18
Residential			1	8				0	4		13
Commercial and public services			0	1				0	3		4
Agriculture / forestry			4					0	0		4
Fishing											0
Non-specified											0
Non-energy use			4	2							5

Source: IEA, 2020: Sankey Data **Year:** 2017

CURRENT ENERGY DEMAND AT NATIONAL LEVEL

Country: ***Argentina***

<< BACK
Energy Balance

BEFS Rapid Appraisal for **the country**

Enter data into white cells | Grey cells are calculated

CLIMATE PLEDGES OF INDC/NDC

Mitigation Type	Relative emission reduction	**Mitigation Summary**	Argentina's goal is to reduce GHG emissions by 15% in 2030 with respect to projected BAU emissions for that year. The goal includes, inter alia, actions linked to: the promotion of sustainable forest management, energy efficiency, biofuels, nuclear power, renewable energy, and transport modal shift. The criteria for selecting the actions include the potential for reducing /capturing GHG emissions and associate co-benefits, as well as the possibility of applying nationally developed technologies. Argentina could increase its reduction goal under the following conditions: a) Adequate and predictable international financing; b) support for transfer, innovation and technology development; c) support for capacity building. In this case, a reduction of 30% GHG emissions could be achieved by 2030 compared to projected BAU emissions in the same year.
Mitigation Target	15% unconditional, 30% conditional		
Baseline	BAU		
Target Year	2030		

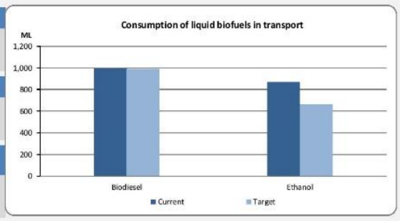
Source: IGES INDC & NDC Database. Institute for Global Environmental Strategies 2017-03

Fuel consumption in transport sector (excluding aviation)

Fossil fuels		Production	Import	Export	Consumption
Diesel	(ML/year)	8,170.96	1,783.51	28.37	**9,926.10**
Gasoline	(ML/year)	5,104.27	406.00	-	**5,510.27**

Liquid biofuels		Production	Import	Export	Consumption
Biodiesel	(ML/year)	1,889.60	-	893	**996.39**
Ethanol	(ML/year)	869.53	-	-	**869.53**

	Blending mandate (%)	Target consumption (ML/year)
Biodiesel	10%	**992.61**
Ethanol	12%	**661.23**



Appendix 2

The Natural Resources module results are presented in full in this section and form the basis of Chapter 5.

Food and Agriculture Organization of the United Nations

BEFS Rapid Appraisal
Natural Resources Module

BEFS

COUNTRY: *Argentina*

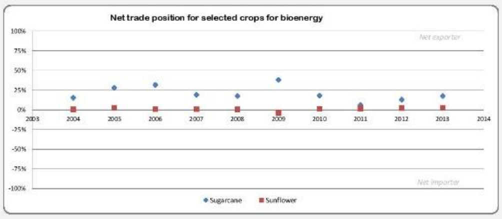
<< BACK Crop Production

NEXT >> Select an Option for Additional Production

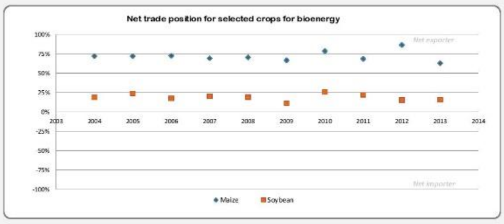
BEFS Rapid Appraisal for: the country

Enter data into white cells | Grey cells are calculated

Net Trade Position for selected crops for bioenergy in the past 10 years



Net Trade Position for selected crops for bioenergy in the past 10 years



Input required data:

Crop 1 — ***Sugarcane***

Year	Production (t)	Import (t)	Stock variation (t)	Export (t)	Domestic supply (t)	NET TRADE POSITION %	position
2004	1815840	17478	40288	295107	1578500	15.3%	Net exporter
2005	2138826	13488	117957	611748	1659022	27.9%	Net exporter
2006	2469642	10157	-53739	791220	1634840	31.6%	Net exporter
2007	2197957	13596	-146463	430733	1634356	19.0%	Net exporter
2008	2447764	44787	-387252	473750	1631549	17.5%	Net exporter
2009	2255521	16275	238741	873373	1637165	38.0%	Net exporter
2010	2038191	45284	-1808	413421	1668246	18.1%	Net exporter
2011	2094273	59663	-269537	186687	1697712	6.1%	Net exporter
2012	2188654	10096	-197102	292685	1708963	12.9%	Net exporter
2013	1788848	9873	258584	323661	1733643	17.5%	Net exporter

Source: FAOSTATS; 2013

Crop 2 — ***Sunflower***

Year	Production (t)	Import (t)	Stock variation (t)	Export (t)	Domestic supply (t)	NET TRADE POSITION %	position
2004	3160672	28,094	0	44,844	3143922	0.5%	Net exporter
2005	3662109	8701	20000	104357	3586453	2.6%	Net exporter
2006	3759736	19929	-18000	44856	3716809	0.7%	Net exporter
2007	3497732	34464	-300000	59653	3172543	0.7%	Net exporter
2008	4650365	27318	-350000	46420	4281263	0.4%	Net exporter
2009	2483437	203336	900000	72045	3514728	-3.7%	Net importer
2010	2232034	37963	600000	70136	2799861	1.4%	Net exporter
2011	3671748	9265	0	74414	3606599	1.8%	Net exporter
2012	3340520	5051	450000	80316	3715255	2.3%	Net exporter
2013	3104420	8799	-400000	87183	2626036	2.5%	Net exporter

Source: FAOSTATS; 2013

Crop 3 — ***Maize***

Year	Production (t)	Import (t)	Stock variation (t)	Export (t)	Domestic supply (t)	NET TRADE POSITION %	position
2004	14950820	5900	200000	10761896	4394824	71.9%	Net exporter
2005	20482570	5101	0	14722042	5765629	71.9%	Net exporter
2006	14445540	6987	200000	10482906	5969621	72.5%	Net exporter
2007	21755360	7181	0	15076044	6686497	69.3%	Net exporter
2008	22016930	7801	0	15501294	6523436	70.4%	Net exporter
2009	13121380	4355	0	8752814	4372921	66.7%	Net exporter
2010	22663100	9059	0	17841697	4830462	78.7%	Net exporter
2011	23799830	6283	-1500000	16345221	5960892	68.7%	Net exporter
2012	21196640	7858	2800000	18326989	5677508	86.4%	Net exporter
2013	32119210	3217	-4000000	20241040	7881387	63.0%	Net exporter

Source: FAOSTATS; 2013

Crop 4 — ***Soybean***

Year	Production (t)	Import (t)	Stock variation (t)	Export (t)	Domestic supply (t)	NET TRADE POSITION %	position
2004	31576750	559481	-274300	6519808	25342122	18.9%	Net exporter
2005	38289740	747802	1081027	9962117	30156451	24.1%	Net exporter
2006	40537360	712526	835830	7872870	34212846	17.7%	Net exporter
2007	47482780	2245494	290119	11842543	38175850	20.2%	Net exporter
2008	46238088	2891907	-3712112	11733593	33684290	19.1%	Net exporter
2009	30993380	824013	4426565	4291708	31952250	11.2%	Net exporter
2010	52675460	2042	-143277	13616015	38918209	25.8%	Net exporter
2011	48888540	13019	1263160	10820035	39344684	22.1%	Net exporter
2012	40100200	10298	1285559	6158412	35237645	15.3%	Net exporter
2013	49306200	4968	-4920096	7782685	36608387	15.8%	Net exporter

Source: FAOSTATS; 2013

INTENSIFICATION

COUNTRY: *Argentina*

<< BACK Crops Component | NEXT >> Select an Option for Additional Production

BEFS Rapid Appraisal for: the country

Enter data into white cells | Grey cells are calculated

Parameter	Unit	Crop 1 *Sugarcane*	Crop 2 *Sunflower*	Crop 3 *Maize*	Crop 4 *Soybean*
		Current production			
Current yield	t/ha	60.00	2.00	6.30	3.20
No. of harvests/year		1	1	1	1
Annual production	t/year	22,500,000	3,300,000	32,000,000	51,000,000
Total production area	ha	375,000	1,650,000	5,079,365	15,937,500
		Intensified production (Potential production on the same area with increased yields)			
Water supply	Select	Irrigation	Irrigation	Irrigation	Irrigation
Input level	Select	High	High	High	High
Intensified yield	t/ha	77	2.10	8.50	4.00
No. of harvests/year		1	1	1	1
Potential production	t/year	28,875,000	3,465,000	43,174,603	63,750,000
Total production area	ha	375,000	1,650,000	5,079,365	15,937,500
		Planned production for non-bioenergy purposes (food, feed, export, etc.)			
Planned production	t/year	28,000,000	3,400,000	41,200,000	60,200,000
Area of production	ha	363,636	1,619,048	4,847,059	15,050,000

Potential production for bioenergy

		Sugarcane	*Sunflower*	*Maize*	*Soybean*
Potential production	t/year	875,000	65,000	1,974,603	3,550,000
Area of production	ha	11,364	30,952	232,306	887,500

10-year average of annual production at country level (based on FAOSTAT2005-2014)

Parameter	Unit	Crop 1 *Sugarcane*	Crop 2 *Sunflower*	Crop 3 *Maize*	Crop 4 *Soybean*
Yield	t/ha	72.80	1.73	6.61	2.62
Annual production	t	24,864,693	3,245,418	22,461,438	44,790,161

Potential yields based on Global Agro-Ecological Zoning

Crop		*Sugarcane*	*Sunflower*	*Maize*	*Soybean*
Water supply		*Irrigation*	*Irrigation*	*Irrigation*	*Irrigation*
Input level		*High*	*High*	*High*	*High*
Soil suitability class:					
Country average	t/ha	97.70	4.03	14.23	4.90
Suitable/very suitable	t/ha	111.69	4.18	14.76	5.13
Moderately suitable	t/ha	83.25	2.97	9.85	3.42

Potential yields are available for:

- rainfed production: low input level and intermediate input level,

- irrigated production: high input level and intermediate input level.

Clear data

Food and Agriculture Organization of the United Nations

BEFS Rapid Appraisal
Natural Resources Module

BEFS Bioenergy and Food Security Projects

CHANGE OF CROPS

COUNTRY: *Argentina*

<< BACK Crops Component | NEXT >> Select an Option for Additional Production

BEFS Rapid Appraisal for: the country

Enter data into white cells | Grey cells are calculated

Select a current crop and the crop for bioenergy:

Current crop: Maize | **Crop for bioenergy**: Sugarcane

Current crop

Parameter	Unit	*Maize*
		Current production
Yield	t/ha	6.30
No. of crop cycles		1.0
Annual production	t/year	32,000,000
Production area	ha	5,079,365.08
		Planned production
Annual production	t/year	31,000,000
Area required	ha	4,920,634.92

Crop for bioenergy

Parameter	Unit	*Sugarcane*
		Planned production
Yield	t/ha	60.00
No. of harvests/year		1.0

Potential production for bioenergy

Annual production	t/year	9,523,809.52
Area required	ha	158,730.16

Clear data

10-year average of annual production at country level (based on FAOSTAT2005-2014)

Maize	Unit	Parameter	Unit	*Sugarcane*
6.61	t/ha	Yield (t/ha)	t/ha	72.80
22,461,438	t/year	Annual production (t/year)	t/year	24,864,693

Potential yields based on Global Agro-Ecological Zoning

Low	Intermediate	High		Low	Intermediate	High
Irrigation			Water supply	Irrigation		
Low	Intermediate	High	Input level	Low	Intermediate	High
	t/ha		*Soil suitability class*		t/ha	
n/a	8.63	14.23	Country average	n/a	59.38	97.70
n/a	9.86	14.76	Suitable/very suitable	n/a	72.27	111.69
n/a	6.41	9.85	Moderately suitable	n/a	52.29	83.25

Potential yields are available for:

- rainfed production: low input level and intermediate input level,

- irrigated production: high input level and intermediate input level.

EXTENSIFICATION

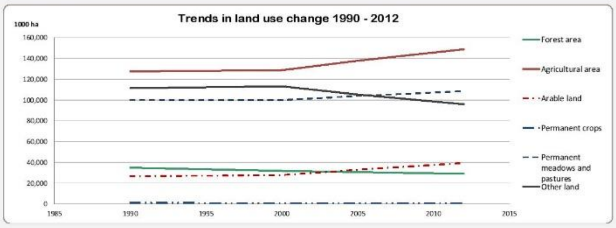
COUNTRY: *Argentina*

<< BACK Crop Production | NEXT >> Results of Crop Production

BEFS Rapid Appraisal for: the country

Enter data into white cells | Grey cells are calculated

	Land use area (FAOSTAT, FRA)				*Land use change*								
Year	1990	2000	2005	2012	1990-2000		2000-2005		2005-2012		2000-2012		
Land use class	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	%	1000 ha	%	1000 ha	%	1000 ha	%	Annual rate of change %
Forest area	34,793	31,861	30,599	28,920	-2,932.00	-8.43	-1,262.00	-3.96	-1,678.60	-5.49	-2,940.60	-9.23	-0.92
Agricultural area	127,565	128,510	137,798	148,791	945.00	0.74	9,288.00	7.23	10,993.00	7.98	20,281.00	15.78	1.58
Arable land	26,575	27,640	32,898	39,291	1,065.00	4.01	5,257.50	19.02	6,393.50	19.43	11,651.00	42.15	4.22
Permanent crops	1,020	1,000	1,000	1,000	-20.00	-1.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Permanent meadows and pastures	99,970	99,870	103,900	108,500	-100.00	-0.10	4,030.00	4.04	4,600.00	4.43	8,630.00	8.64	0.86
Other land	111,311	113,298	105,273	95,958	1,987.00	1.79	-8,025.00	-7.08	-9,315.40	-8.85	-17,340.40	-15.31	-1.53

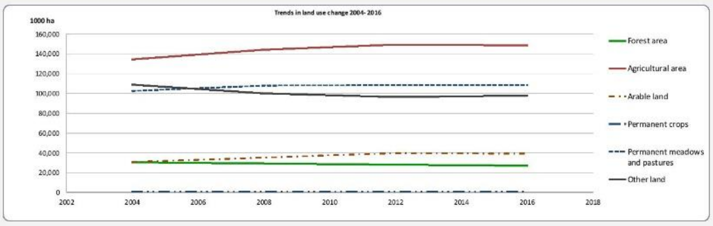


Trends in land use change, conclusion and recommendations

Forest area	In the period 2000 - 2010 a decrease of forest area was recorded. This could be an indication of deforestation at country level. Total forest areadecreased by 2,940,600 ha, i.e. by 9.23%.
Agricultural area	In the same period, the total agricultural area increased by 20,281,000 ha, i.e. by 15.78%.
Arable land	Thereby, the arable land (area under annual crops) increased by 11,651,000 ha, i.e. by 42.15%,
Grassland	and the grassland area (permanent meadows and pastures) increased by 8,630,000 ha, i.e. by 8.64%.
Conclusion and recommendations	Data on land use change during the period 2000-2010 indicate that the expansion of the agricultural area may be one of the key drivers of deforestation. Therefore policy measures and actions aiming at the increase of agricultural yields without further expansion of agrioultural area are strongly recommended.

Country specific data (user defined data)

	Land use area				*Land use change*								
Year	2004	2008	2012	2016	2004-2008		2008-2012		2012-2016		2004-2016		
Land use class	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	%	1000 ha	%	1000 ha	%	1000 ha	%	Annual rate of change %
Forest area	30,521	29,232	28,002	27,112	-1,288.80	-4.22	-1,229.60	-4.21	-890.40	-3.18	-3,408.80	-11.17	-1.12
Agricultural area	134,345	144,261	149,254	148,700	9,916.00	7.38	4,993.00	3.46	-554.00	-0.37	14,355.00	10.69	1.07
Arable land	30,775	35,261	39,754	39,200	4,486.00	14.58	4,493.00	12.74	-554.00	-1.39	8,425.00	27.38	2.74
Permanent crops	1,000	1,000	1,000	1,000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Permanent meadows and pastures	102,570	108,000	108,500	108,500	5,430.00	5.29	500.00	0.46	0.00	0.00	5,930.00	5.78	0.58
Other land	108,803	100,176	96,412	97,857	-8,627.00	-7.93	-3,764.00	-3.76	1,445.00	1.50	-10,946.00	-10.06	-1.01



Trends in land use change, conclusion and recommendations

Forest area	In the period 2004-2016 a decrease of forest area was recorded. This could be an indication of deforestation at country level. Total forest areadecreased by 3,408,800 ha, i.e. by 11.17%.
Agricultural land	In the same period, the total agricultural area increased by 14,355,000 ha, i.e. by 10.69%.
Arable land	Thereby, the arable land (area under annual crops) increased by 8,425,000 ha, i.e. by 27.38%,
Grassland	and the grassland area (permanent meadows and pastures) increased by 5,930,000 ha, i.e. by 5.78%.
Conclusion and recommendations	Data on land use change during the period 2000-2010 indicate that the expansion of the agricultural area may be one of the key drivers of deforestation. Therefore policy measures and actions aiming at the increase of agricultural yields without further expansion of agricultural area are strongly recommended.

EXTENSIFICATION - EXPANSION AREA

COUNTRY: *Argentina*

<< BACK Extensification | NEXT >> Results of Crop Production

BEFS Rapid Appraisal for: the country

Enter data into white cells | Grey cells are calculated

Calculation of area needed for planned production of selected crops

Parameter	Unit	Crop 1 *Sugarcane*	Crop 2 *Sunflower*	Crop 3 *Maize*	Crop 4 *Soybean*
		Planned production			
Production	t/year				
Water supply		Select	Select	Select	Select
Input level		Select	Select	Select	Select
Expected yield	t/ha				
No. of crop cycles					
Area required	ha	0.00	0.00	0.00	0.00
Initial land use class					
Idle cropland	%	100%	100%	100%	100%
Grassland	%				
Sparse vegetation	%				
Shrubland	%				
Forest area	%	0%	0%	0%	0%
Degraded land	%				
Other land	%				
Total	%	*100%*	*100%*	*100%*	*100%*

		Crop 1	Crop 2	Crop 3	Crop 4
10-year average of annual production at country level (based on FAOSTAT2005-2014)					
Parameter	Unit	Sugarcane	Sunflower	Maize	Soybean
Yield	t/ha	72.80	1.73	6.61	2.62
Annual production	t	24,864,693	3,245,418	22,461,438	44,790,161
Potential yields based on Global Agro-Ecological Zoning					
Crop		Sugarcane	Sunflower	Maize	Soybean
Water supply		Select	Select	Select	Select
Input level		Select	Select	Select	Select
Soil suitability class:					
Country average	t/ha	n/a	n/a	n/a	n/a
Suitable/very suitable	t/ha	n/a	n/a	n/a	n/a
Moderately suitable	t/ha	n/a	n/a	n/a	n/a

Potential yields are available for:

- rainfed production: low input level and intermediate input level,

- irrigated production: high input level and intermediate input level.

CROP PRODUCTION RESULTS

COUNTRY: *Argentina*

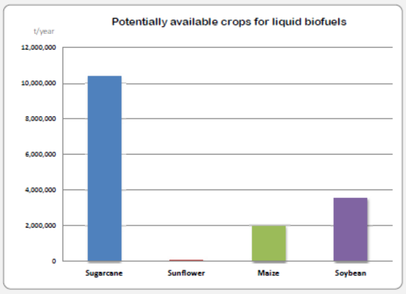
<< BACK Crop Production | NEXT >> Crop Budget

BEFS Rapid Appraisal for: the country

Enter data into white cells | Grey cells are calculated

Potential production for bioenergy

		Crop 1 Sugarcane	Crop 2 Sunflower	Crop 3 Maize	Crop 4 Soybean
TOTAL	**t/year**	**10,398,810**	**65,000**	**1,974,603**	**3,550,000**
Additional production option		***Intensification***			
Potential production	t/year	875,000	65,000	1,974,603	3,550,000
Intensified yield	t/ha	77.00	2.10	8.50	4.00
No. of harvests/year	#/year	1	1	1	1
Area of production	ha	11,364	30,952	232,306	887,500
Additional production option		***Change of crops***			
Potential production	t/year	9,523,810	-	-	-
Yield	t/ha	60.00	-	-	-
No. of harvests/year		1	-	-	-
Area of production	ha	158730	-	-	-
Additional production option		***Extensification***			
Potential production	t/year	0	0	0	0
Yield	t/ha	0.00	0.00	0.00	0.00
No. of harvests/year		0	0	0	0
Area of production	ha	0	0	0	0



CROP PRODUCTION RESULTS

COUNTRY: *Argentina*

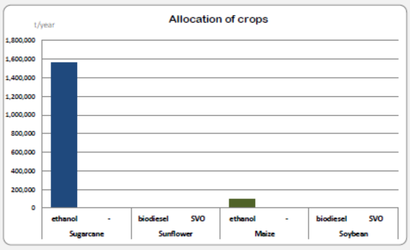
<< BACK Crop Production | NEXT >> Crop Budget

BEFS Rapid Appraisal for: the country

Enter data into white cells | Grey cells are calculated

Define the allocation of crops for bioenergy production

		Crop 1 Sugarcane	Crop 2 Sunflower	Crop 3 Maize	Crop 4 Soybean
TOTAL	*t/year*	*10,398,810*	*65,000*	*1,974,603*	*3,550,000*
Transport (crops that will be used for production of biodiesel and ethanol)					
biofuel type		*ethanol*	*biodiesel*	*ethanol*	*biodiesel*
% of total		15%		5%	
t/year		1,559,821	0	98,730	0
Electricity and/or Heat (crops that will be used for production of straight vegetable oil for electricity and/or heat)					
biofuel type		-	*SVO*	-	SVO
% of total		0%		0%	
t/year		0	0	0	0



Clear data

Appendix 3

CROP BUDGET SOY

Assumptions (Rainfed)

Yield (t/ha)		
	3.2	CURRENT YIELD
	4	assumed intensified yield, based on GAEZ. Rainfed

				UTA ($)	Exch.rate (March 2018)				Exch.rate (avg. 2018)
				727.96	20.3				20.3
		Inta informe - Marzo 2018 (53/85)		Market price ($/t)	Market price (USD/t)	Assumed intensified yield		Market price ($/t)	Market price (USD/t)
				5,975.00	294.33			5,975.00	294.33
ITEM	**UNIT**	**RATE/ha**	**Unit Price**	**$/ha**	**USD/ha**	**RATE/ha**	**Unit Price**	**$/ha**	**USD/ha**
Soya grain - yield; revenue	t/ha	**3.20**	**5,975.00**	19,120.00	941.87	**4.00**	**5,975.00**	23,900.00	1,177.34
VARIABLE COSTS									
Seed	Kg	80.00	12.57	1,005.60	49.54	90.00	12.57	1,131.30	55.73
Inputs (fertilizers and agrochemicals)									
Fertilizers	kg/ha	50.00	11.76	588.00	28.97	62.00	11.76	729.12	35.92
agrochemicals (herbicides/pesticides)		15.69	107.67	1,688.80	83.19	20.00	107.67	2,153.40	106.08
Labour (prepartion of land, planting, afterplanting, harvesting)									
Land prep, planting and post planting	UTA/ha	1.00	1,747.10	1,747.10	86.06	1.00	1819.895	1,819.90	89.65
Harvesting	8% Revenue			1,529.60	75.35			1,912.00	94.19
Irrigation									
water, electricity	mm			0.00	0.00			0.00	0.00
Total Variable Costs (TVC)				**6,559.10**	**323.11**			**7,745.72**	**381.56**
FIXED COSTS									
Capital costs (land rental/interst on capital)	per ha	1.00	6,601.00	6,601.00	325.17	1.00		7,735.92	381.08
Total production costs per ha	per ha			**13,160.10**	**648.28**			**15,481.64**	**762.64**
Production costs per tonne	per tonne			**4,112.53**	**202.59**			**4,838.01**	**190.66**
					91.75				103.67
				USD/ha	293.59			USD/ha	414.6975862

CROP BUDGET SUGRCANE

Assumptions

Yield (t/ha)		
	60	CURRENT YIELD
	75	GAEZ HIGH LEVEL INPUT

					Exch.rate (avg. 2015)					Exch.rate (avg. 2015)
					9					9
		Sugarcane 2015		Market price ($/t)	Market price (USD/t)		Sugarcane 2015		Market price ($/t)	Market price (USD/t)
				265.50	29.50				265.50	29.50
ITEM	**UNIT**	**RATE/ha**	**Unit Price**	**$/ha**	**USD/ha**		**RATE/ha**	**Unit Price**	**$/ha**	**USD/ha**
Sugarcane - yield; revenue	t/ha	**60.00**	**265.50**	15,930.00	1,770.00		**75.00**	**265.50**	19,912.50	2,212.50
VARIABLE COSTS										
Seed	tonnes	12.00	240.00				12.00	240.00		
Inputs (fertilizers and agrochemicals)										
Fertilizers	kg/ha	180.00	4.41	793.80	88.20		210.00	4.41	926.10	102.90
agrochemicals (herbicides/pesticides)		7.60	68.29	519.00	57.67		8.10	67.50	546.75	60.75
extras				148.38	16.49				148.38	16.49
Labour (prepartion of land, planting, afterplanting, harvesting)										
Manual (Man-days)		0.50	367.92	183.96	20.44		0.38	547.08	207.89	23.10
Machinery (Hours)		2.50	299.23	748.08	83.12		3.00	310.14	930.41	103.38
Harvesting	$/tonne	60.00	70.00	4,200.00	420.00		75.00	70.00	5,250.00	525.00
Irrigation										
water, electricity	mm	4.00	527.92	2,111.68	234.63		4.00	527.92	2,111.68	234.63
Total Variable Costs (TVC)				**8,704.90**	**920.54**				**10,121.21**	**1066.25**
FIXED COSTS										
Capital costs (land rental/interst on capital)	per ha			6,068.66	674.30				6,068.66	674.30
Total production costs per ha	per ha			**14,773.56**	**1594.84**				**16,189.87**	**1740.54**
Production costs per tonne	per tonne			**246.23**	**26.58**				**269.83**	**23.21**
					2.92					6.29
				USD/ha	175.1601111				USD/ha	471.9577333

CROP BUDGET MAIZE

Assumptions

Yield (t/ha)	*8.5/9.5*	*CURRENT Yi*	*9.50*
	11	*GAEZ HIGH*	*11.00*

					Exch.rate (avg. 2018)					Exch.rate (avg. 2017)
					20.3	*17.3*				*20.3*
		Inta informe - Marzo 2018 (p. 45/85)		Market price ($/t)	Market price (USD/t)		*Inta informe - Marzo 2018 (p. 80/85)*		Market price ($/t)	Market price (USD/t)
				3,583.00	**176.50**				**3,583.00**	**176.50**
ITEM	**UNIT**	**RATE/ha**	**Unit Price**	**$/ha**	**USD/ha**		**RATE/ha**	**Unit Price**	**$/ha**	**USD/ha**
Maiz - yield; revenue	t/ha	**8.50**	**3,583.00**	30,455.50	1,500.27		**11.00**	**3,500.00**	39,413.00	1,896.55
VARIABLE COSTS										
Seed	Bags	0.90	3,040.65	2,736.59	134.81		1.00	3,040.65	3,040.65	149.79
Inputs (fertilizers and agrochemicals)										
Fertilizers	kg/ha	170.00	9.76	1,658.40	81.69		475.00	7.42	3,523.45	173.57
agrochemicals (herbicides/pesticides)		15.60	63.87	996.40	49.08		8.60	104.30	896.99	44.19
Labour (prepartion of land, planting, afterplanting, harvesting)										
Land prep, planting and post planting	UTA/ha	1.00	1,455.92	1,455.92	71.72		1.00	1,346.72	1,346.72	66.34
Harvesting	8% Revenue			2,436.44	120.02				3,153.04	155.32
Irrigation										
water, electricity	mm	0.00	0.00	0.00	0.00		1,010.00	9.12	9,211.20	453.75
Total Variable Costs (TVC)				**9,283.75**	**457.33**				**21,172.05**	**1042.96**
FIXED COSTS										
Capital costs (land rental/interst on capital)	per ha	1.00	6,815.78	6,815.78	335.75		1.00	6,815.78	2,607.00	128.42
Total production costs per ha	per ha			**16,099.53**	**793.08**				**23,779.05**	**1171.38**
Production costs per tonne	per tonne			**1,894.06**	**93.30**				**2,161.73**	**106.49**
					83.20					70.01
				USD/ha	707.1906404				USD/ha	770.15

Appendix 4

The Energy End Use module results are presented in full in this section and form the basis of Chapter 6.

FUEL CONSUMPTION AND BLENDING TARGETS FOR LIQUID BIOFUELS

<< BACK Start | *Liquid Biofuels Process Description* | NEXT >> Data Entry

Domestic fossil fuel consumption

	Consumption	Unit		Consumption	Unit
Diesel	9,926	ML/year	Gasoline	5,510	ML/year

Domestic blending target

	Blending target	Biofuel demand		Blending target	Biofuel demand
Biodiesel (ML/year)	10%	993	Ethanol (ML/year)	12%	661

Biofuel production and trade

	Domestic production	Imports	Exports	Net balance
Biodiesel (ML/year)	1,890	0	893	996
Ethanol (ML/year)	870	0	0	870

Target domestic biofuel production

Biodiesel (ML/year)	-897
Ethanol (ML/year)	-208

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BEFSRA_TRANSPORT TOOL RESULTS REPORT

DATA ENTRY FOR LIQUID BIOFUELS

<< BACK Start | Load Default Values | Clear Data | Liquid Biofuels Process Description | Biofuel Demand

Use white cells to input data | Grey cells are used for calculations

Feedstock Availability and Cost

	Feedstock 1	Feedstock 2	Feedstock 3	Feedstock 4
	Ethanol	Ethanol	Biodiesel	Please Select
Feedstock	Sugarcane	Maize	Soybean	
Feedstock potential (t/year)	10,398,810	1,974,603	3,550,000	
Feedstock cost (cost of production) - Own production (USD/t)	$ 27.19	$ 106.16	$ 190.66	
Feedstock cost (market price) - Outgrower (USD/t)	$ 29.50	$ 172.41	$ 294.33	
Feedstock storage cost (USD/t)	$ 5.00	$ 5.00	$ 5.00	
	Storage Calculator 1	Storage Calculator 2	Storage Calculator 3	Storage Calculator 4
	Production Cost 1	Production Cost 2	Production Cost 3	Production Cost 4

Biofuel Production Cost and Financial Parameters

Chemical inputs*

Biodiesel inputs	USD/t	Ethanol inputs	USD/t	Ethanol inputs	USD/t
Methanol	$ 320	Ammonia	$ 570	Lime	$ 50
Sodium hydroxide	$ 380	Yeast	$ 1,820	Alpha-amylase	$ 3,000
Hexane	$ 330	Sulfuric acid	$ 200	Glucoamylase	$ 3,000

http://www.icis.com/chemicals/channel-info-chemicals-a-z/

Utilities

		Unit
Heat carrier	$ 1.00	USD/t steam
Water	$ 0.79	USD/m³
Electricity	$ 0.09	USD/kWh

Labour

		Unit		
Unskilled worker	$ 1.40	USD/person-hour	Working days per year	260
Skilled worker	$ 3.00	USD/person-hour		
Miscellaneous cost (%)	5%			

Transportation

		Unit
Feedstock (farm to plant)	$ 0.07	USD/t/km

Storage

		Unit		
Biodiesel storage cost	$ 0.30	USD/l/year	Storage rate of biodiesel	20%
Ethanol storage cost	$ 0.30	USD/l/year	Storage rate of ethanol	20%

Other costs

Maintenance (%)	10%
Plant overhead (%)	15%
General and administrative (%)	6%

Price of co-products

		Unit			Unit
Raw glycerol	$ 800.00	USD/t	DDGS	$ 90.00	USD/t
Meal	$ 355.00	USD/t			

http://www.icis.com/chemicals/channel-info-chemicals-a-z/ http://www.indexmundi.com/commodities/?commodity=soybean-meal

Price of transport fuels and net trade balance

		Unit			Unit
Net trade position – fossil fuels	Net importer		Is the main port located at the main city in the Country?		yes
Net trade position – biofuels	Net exporter				
Diesel FOB price	$ 0.72	USD/l	Biodiesel FGP price	$ 0.63	USD/l

Food and Agriculture Organization of the United Nations

BEFS

BEFSRA_TRANSPORT TOOL RESULTS REPORT

Gasoline FOB price	$ 0.79 USD/l	Ethanol FGP price	$ 0.42 USD/l

Financial parameters

Discount rate (%)	10%
Loan interest rate (%)	0%
Loan term (years)	-

Investment cost update

Plant Cost Index during 11/2020	160.00

http://base.intratec.us/home/ic-index

Loan ratio

5 ML/year	
25 ML/year	
50 ML/year	
100 ML/year	

Labour and Land Parameters

		Sugarcane	Maize	Soybean
Crop yield (t/ha)	*Outgrowers*	60.00	8.50	3.20
Labour manual (person-day/ha)	*Outgrowers*	1.80	5.00	5.00
Labour machinery (person-hour/ha)	*Outgrowers*	4.60	1.50	1.00
Crop Yield (t/ha)	*Own Production*	75.00	11.00	4.00
Labour manual (person-day/ha)	*Own Production*	1.70	0.00	0.00
Labour machinery (person-hour/ha)	*Own Production*	5.10	2.50	2.00

NEXT >> Summary of Results - Comparative

NEXT >> Summary of Results - by Feedstock

NEXT >> Summary of Results - Labour

PROCESSING COSTS FOR ETHANOL PRODUCTION FROM SUGARCANE

<< BACK Data Entry | Biofuel Demand | Liquid Biofuels Process Description | NEXT >> Summary of Results - Comparative | NEXT >> Summary of Results - by Feedstock | NEXT >> Summary of Results - Labour

Use white cells to input data | Grey cells are used for calculations

Summary of Feedstock and Storage

Feedstock available (t/year)	10,398,810
Ethanol storage cost (USD/l)	$ 0.30
Storage rate of ethanol	20%
Feedstock storage cost (USD/t)	$ 5.00

Storage Calculator 1

Financial Parameters

Discount rate (%)	10%
Loan interest rate (%)	0%
Loan term (years)	0

Investment Cost Update

Plant Cost Index during 11/2020	160

Transport Distance of Feedstock / Transport Quantity

Distance SIZE 1 (5 ML) (km)	10	Size 1 (t/year)	61,728
Distance SIZE 2 (25 ML) (km)	15	Size 2 (t/year)	308,642
Distance SIZE 3 (50 ML) (km)	25	Size 3 (t/year)	617,284
Distance SIZE 4 (100 ML) (km)	30	Size 4 (t/year)	1,234,568

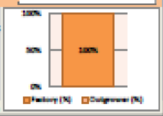
Feedstock Production Schemes

Scenario 1: Own Production — *Exclude Scenario 1*

Description: 100% of Sugarcane feedstock produced directly by processing plant

Feedstock Price = 100%*Production Cost

$ 27.19

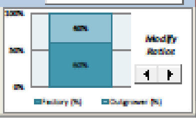


Scenario 2: Mixed — *Exclude Scenario 2*

Description: 60% of Sugarcane feedstock produced directly by processing plant, and 40% provided by outgrowers at market price.

Feedstock Price = 60%*Production Cost + 40%*Market Price

$ 28.11

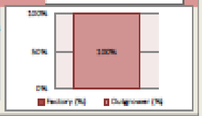


Scenario 3: Outgrowers — *Exclude Scenario 3*

Description: 100% of Sugarcane feedstock is provided by outgrowers at market price.

Feedstock Price = 100%*Market Price

$ 29.50



Show Costing Details

	Capacities (Million litres per year): 5	25	50	100
	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	*Financial Assessment Sc 1 (5 ML/year)*	*Financial Assessment Sc 1 (25 ML/year)*	*Financial Assessment Sc 1 (50 ML/year)*	*Financial Assessment Sc 1 (100 ML/year)*
Scenario 2: Mixed	*Financial Assessment Sc 2 (5 ML/year)*	*Financial Assessment Sc 2 (25 ML/year)*	*Financial Assessment Sc 2 (50 ML/year)*	*Financial Assessment Sc 2 (100 ML/year)*
Scenario 3: Outgrowers	*Financial Assessment Sc 3 (5 ML/year)*	*Financial Assessment Sc 3 (25 ML/year)*	*Financial Assessment Sc 3 (50 ML/year)*	*Financial Assessment Sc 3 (100 ML/year)*

Feedstock	Unit	Unit Price (USD)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Sugarcane Scenario 1	t	$ 27.19	61,728	$ 1,678,395	308,642	$ 8,391,975	617,284	$ 16,783,951	1,234,568	$ 33,567,901
Sugarcane Scenario 2	t	$ 28.11	61,728	$ 1,735,432	308,642	$ 8,677,160	617,284	$ 17,354,321	1,234,568	$ 34,708,642
Sugarcane Scenario 3	t	$ 29.50	61,728	$ 1,820,988	308,642	$ 9,104,938	617,284	$ 18,209,877	1,234,568	$ 36,419,753

Total Production Costs (USD/year)

	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)
Scenario 1								
Total operating costs	$ 2,526,938	$ 0.51	$ 10,877,398	$ 0.44	$ 21,990,595	$ 0.44	$ 44,120,332	$ 0.44
Total fixed costs	$ 2,195,412	$ 0.44	$ 5,159,045	$ 0.21	$ 8,192,812	$ 0.16	$ 13,838,443	$ 0.14
Total other costs	$ 132,530	$ 0.03	$ 235,707	$ 0.01	$ 411,469	$ 0.01	$ 754,649	$ 0.01
Total production costs scenario 1 (USD/year)	$ 4,854,880		$ 16,272,150		$ 30,594,875		$ 58,713,424	
Total production costs scenario 1 (USD/l)		$ 0.97		$ 0.65		$ 0.61		$ 0.59
Scenario 2								
Total operating costs	$ 2,583,975	$ 0.52	$ 11,162,584	$ 0.45	$ 22,560,965	$ 0.45	$ 45,261,073	$ 0.45
Total fixed costs	$ 2,195,412	$ 0.44	$ 5,159,045	$ 0.21	$ 8,192,812	$ 0.16	$ 13,838,443	$ 0.14
Total other costs	$ 132,530	$ 0.03	$ 235,707	$ 0.01	$ 411,469	$ 0.01	$ 754,649	$ 0.01
Total production costs scenario 2 (USD/year)	$ 4,911,917		$ 16,557,335		$ 31,165,246		$ 59,854,165	
Total production costs scenario 2 (USD/l)		$ 0.98		$ 0.66		$ 0.62		$ 0.60
Scenario 3								
Total operating costs	$ 2,669,531	$ 0.53	$ 11,590,361	$ 0.46	$ 23,416,521	$ 0.47	$ 46,972,184	$ 0.47
Total fixed costs	$ 2,195,412	$ 0.44	$ 5,159,045	$ 0.21	$ 8,192,812	$ 0.16	$ 13,838,443	$ 0.14
Total other costs	$ 132,530	$ 0.03	$ 235,707	$ 0.01	$ 411,469	$ 0.01	$ 754,649	$ 0.01
Total production costs scenario 3 (USD/year)	$ 4,997,473		$ 16,985,113		$ 32,020,801		$ 61,565,276	
Total production costs scenario 3 (USD/l)		$ 1.00		$ 0.68		$ 0.64		$ 0.62

PROCESSING COSTS FOR ETHANOL PRODUCTION FROM MAIZE

<< BACK Data Entry | Biofuel Demand | Liquid Biofuels Process Description | NEXT >> Summary of Results - Comparative | NEXT >> Summary of Results - by Feedstock | NEXT >> Summary of Results - Labour

Use white cells to input data | Grey cells are used for calculations

Summary of Feedstock and Storage

Feedstock available (t/year)	1,974,603
Ethanol storage cost (USD/l)	$ 0.30
Storage rate of ethanol	20%
Feedstock storage cost (USD/t)	$ 5.00

Storage Calculator 2

Financial Parameters

Discount rate (%)	10%
Loan interest rate (%)	0%
Loan term (years)	0

Investment Cost Update

Plant Cost Index during 11/2020	160

Transport Distance of Feedstock / Transport Quantity

Distance SIZE 1 (5 ML) (km)	10	Size 1 (t/year)	12,195
Distance SIZE 2 (25 ML) (km)	15	Size 2 (t/year)	60,976
Distance SIZE 3 (50 ML) (km)	25	Size 3 (t/year)	121,951
Distance SIZE 4 (100 ML) (km)	30	Size 4 (t/year)	243,902

Feedstock Production Schemes

Scenario 1: Own Production — *Exclude Scenario 1*

Description: 100% Maize feedstock produced directly by processing plant.

Feedstock Price = 100%*Production Cost

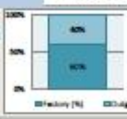
$ 106.16

Scenario 2: Mixed — *Exclude Scenario 2*

Description: 60% of Maize feedstock produced directly by processing plant, and 40% provided by outgrowers at market price.

Feedstock Price = 60%*Production Cost + 40%*Market Price

$ 132.66



Modify Ratios

Scenario 3: Outgrowers — *Exclude Scenario 3*

Description: 100% of Maize feedstock is provided by outgrowers at market price.

Feedstock Price = 100%*Market Price

$ 172.41

Show Costing Details

	Capacities (Million litres per year)			
	5	25	50	100
	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	*Financial Assessment Sc 1 (5 ML/year)*	*Financial Assessment Sc 1 (25 ML/year)*	*Financial Assessment Sc 1 (50 ML/year)*	*Financial Assessment Sc 1 (100 ML/year)*
Scenario 2: Mixed	*Financial Assessment Sc 2 (5 ML/year)*	*Financial Assessment Sc 2 (25 ML/year)*	*Financial Assessment Sc 2 (50 ML/year)*	*Financial Assessment Sc 2 (100 ML/year)*
Scenario 3: Outgrowers	*Financial Assessment Sc 3 (5 ML/year)*	*Financial Assessment Sc 3 (25 ML/year)*	*Financial Assessment Sc 3 (50 ML/year)*	*Financial Assessment Sc 3 (100 ML/year)*

Feedstock	Unit	Unit Price (USD)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Maize Scenario 1	t	$ 106.16	12,195	$ 1,294,634	60,976	$ 6,473,171	121,951	$ 12,946,341	243,902	$ 25,892,683
Maize Scenario 2	t	$ 132.66	12,195	$ 1,617,805	60,976	$ 8,089,024	121,951	$ 16,178,049	243,902	$ 32,356,098
Maize Scenario 3	t	$ 172.41	12,195	$ 2,102,561	60,976	$ 10,512,805	121,951	$ 21,025,610	243,902	$ 42,051,220

Total Production Costs (USD/year)

	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)
Scenario 1								
Total operating costs	$ 2,121,410	$ 0.42	$ 8,930,478	$ 0.36	$ 17,533,621	$ 0.35	$ 34,912,153	$ 0.35
Total fixed costs	$ 2,939,457	$ 0.59	$ 4,599,793	$ 0.18	$ 6,625,606	$ 0.13	$ 10,699,177	$ 0.11
Total other costs	$ 151,655	$ 0.03	$ 256,173	$ 0.01	$ 430,895	$ 0.01	$ 796,554	$ 0.01
Total production costs scenario 1 (USD/year)	$ 5,212,522		$ 13,786,444		$ 24,590,122		$ 46,407,885	
Total production costs scenario 1 (USD/l)		$ 1.04		$ 0.55		$ 0.49		$ 0.46
Scenario 2								
Total operating costs	$ 2,444,581	$ 0.49	$ 10,546,332	$ 0.42	$ 20,765,328	$ 0.42	$ 41,375,567	$ 0.41
Total fixed costs	$ 2,939,457	$ 0.59	$ 4,599,793	$ 0.18	$ 6,625,606	$ 0.13	$ 10,699,177	$ 0.11
Total other costs	$ 151,655	$ 0.03	$ 256,173	$ 0.01	$ 430,895	$ 0.01	$ 796,554	$ 0.01
Total production costs scenario 2 (USD/year)	$ 5,535,692		$ 15,402,298		$ 27,821,830		$ 52,871,299	
Total production costs scenario 2 (USD/l)		$ 1.11		$ 0.62		$ 0.56		$ 0.53
Scenario 3								
Total operating costs	$ 2,929,337	$ 0.59	$ 12,970,112	$ 0.52	$ 25,612,889	$ 0.51	$ 51,070,689	$ 0.51
Total fixed costs	$ 2,939,457	$ 0.59	$ 4,599,793	$ 0.18	$ 6,625,606	$ 0.13	$ 10,699,177	$ 0.11
Total other costs	$ 151,655	$ 0.03	$ 256,173	$ 0.01	$ 430,895	$ 0.01	$ 796,554	$ 0.01
Total production costs scenario 3 (USD/year)	$ 6,020,449		$ 17,826,078		$ 32,669,390		$ 62,566,421	
Total production costs scenario 3 (USD/l)		$ 1.20		$ 0.71		$ 0.65		$ 0.63

PROCESSING COSTS FOR BIODIESEL PRODUCTION FROM SOYBEAN

<< BACK Data Entry | *Biofuel Demand* | *Liquid Biofuels Process Description* | NEXT >> Summary of Results - Comparative | NEXT >> Summary of Results - by Feedstock | NEXT >> Summary of Results - Labour

Use white cells to input data | Grey cells are used for calculations

Summary of Feedstock and Storage

Feedstock available (t/year)	3,550,000
Ethanol storage cost (USD/l)	$ 0.30
Storage rate of biodiesel	20%
Feedstock storage cost (USD/t)	$ 5.00

Storage Calculator 3

Financial Parameters

Discount rate (%)	10%
Loan interest rate (%)	0%
Loan term (years)	0

Investment Cost Update

Plant Cost Index during 11/2020	160

Transport Distance of Feedstock / Transport Quantity

Transport Distance of Feedstock		Transport Quantity	
Distance SIZE 1 (5 ML) (km)	5	Size 1 (t/year)	27,322
Distance SIZE 2 (25 ML) (km)	10	Size 2 (t/year)	136,612
Distance SIZE 3 (50 ML) (km)	20	Size 3 (t/year)	273,224
Distance SIZE 4 (100 ML) (km)	30	Size 4 (t/year)	546,448

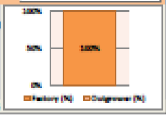
Feedstock Production Schemes

Scenario 1: Own Production — *Exclude Scenario 1*

Description: 100% of Soybean feedstock produced directly by processing plant.

Feedstock Price = 100%*Production Cost

$ 190.66

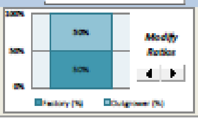


Scenario 2: Mixed — *Exclude Scenario 2*

Description: 50% of Soybean feedstock produced directly by processing plant, and 50% provided by outgrowers at market price.

Feedstock Price = 50%*Production Cost + 50%*Market Price

$ 242.50

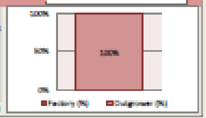


Scenario 3: Outgrowers — *Exclude Scenario 3*

Description: 100% of Soybean feedstock is provided by outgrowers at market price.

Feedstock Price = 100%*Market Price

$ 294.33



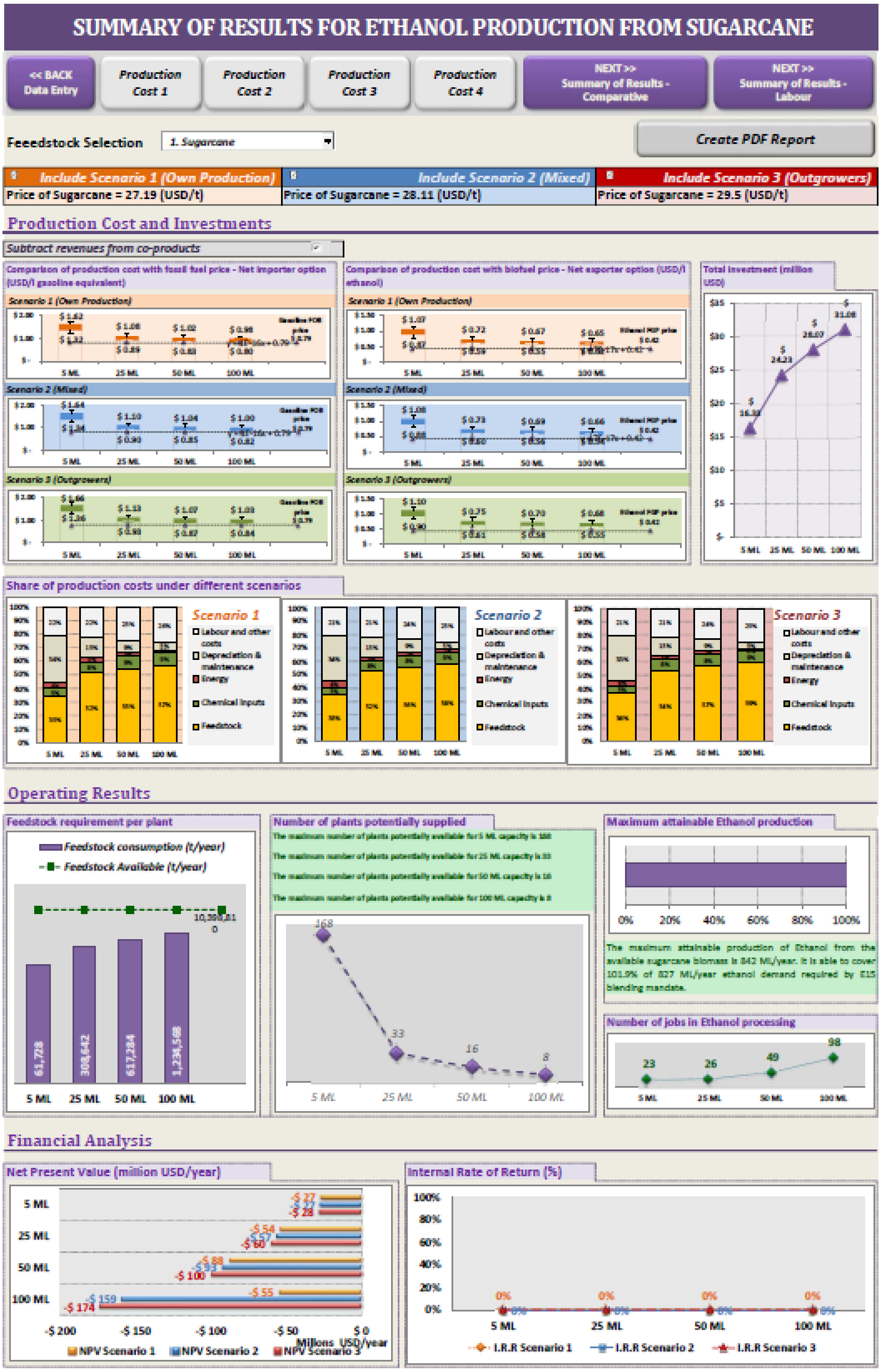
Show Costing Details

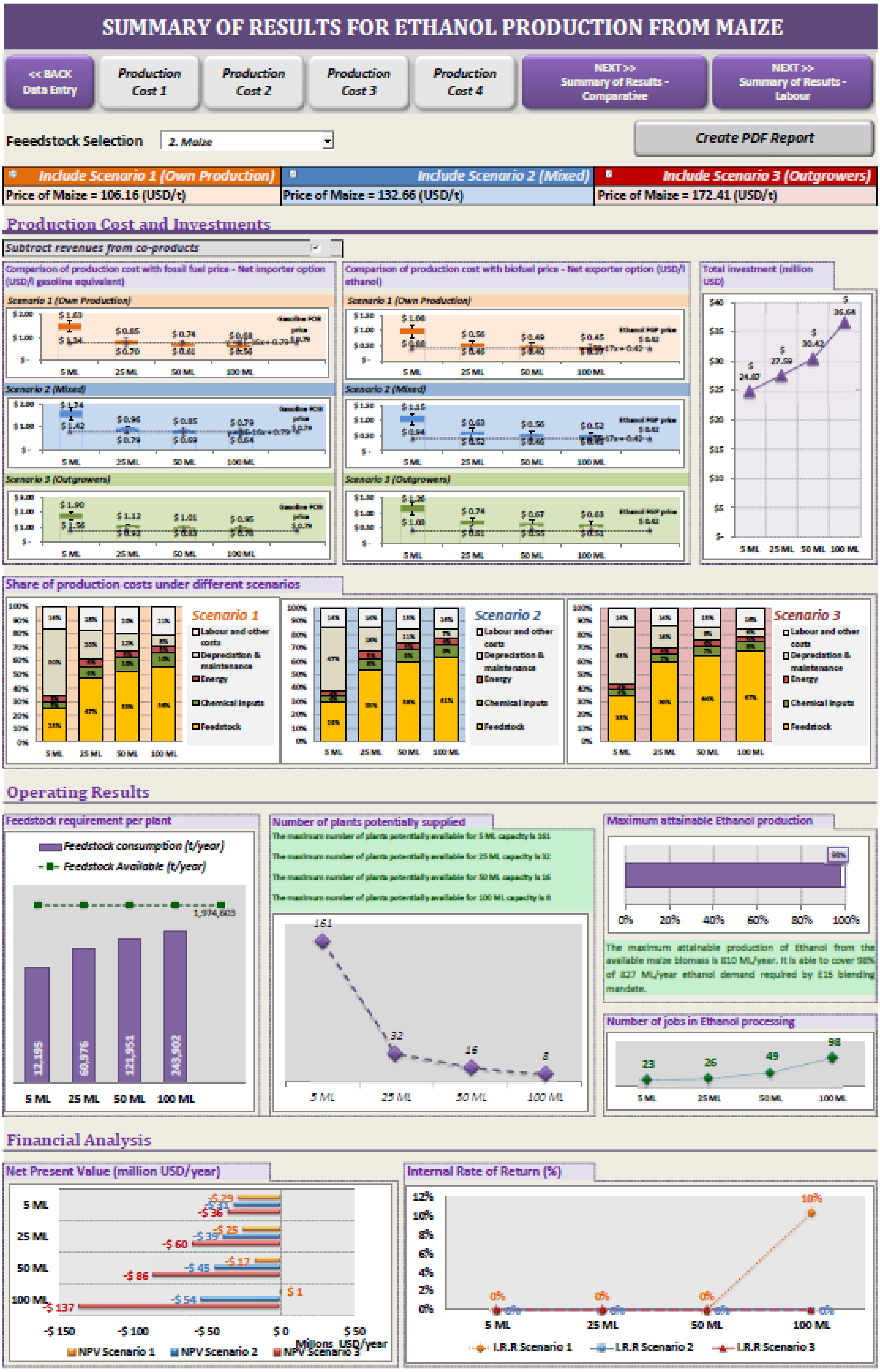
	Capacities (Million litres per year)			
	5	25	50	100
	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000	Operating hours per year 8,000
Scenario 1: Own Production	*Financial Assessment Sc 1 (5 ML/year)*	*Financial Assessment Sc 1 (25 ML/year)*	*Financial Assessment Sc 1 (50 ML/year)*	*Financial Assessment Sc 1 (100 ML/year)*
Scenario 2: Mixed	*Financial Assessment Sc 2 (5 ML/year)*	*Financial Assessment Sc 2 (25 ML/year)*	*Financial Assessment Sc 2 (50 ML/year)*	*Financial Assessment Sc 2 (100 ML/year)*
Scenario 3: Outgrowers	*Financial Assessment Sc 3 (5 ML/year)*	*Financial Assessment Sc 3 (25 ML/year)*	*Financial Assessment Sc 3 (50 ML/year)*	*Financial Assessment Sc 3 (100 ML/year)*

Feedstock	Unit	Unit Price (USD)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)	Quantity (Unit)	Total (USD/year)
Soybean Scenario 1	t	$ 190.66	27,322	$ 5,209,290	136,612	$ 26,046,448	273,224	$ 52,092,896	546,448	$ 104,185,792
Soybean Scenario 2	t	$ 242.50	27,322	$ 6,625,546	136,612	$ 33,127,732	273,224	$ 66,255,464	546,448	$ 132,510,929
Soybean Scenario 3	t	$ 294.33	27,322	$ 8,041,803	136,612	$ 40,209,016	273,224	$ 80,418,033	546,448	$ 160,836,066

Total Production Costs (USD/year)

	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)	Total (USD/year)	Total (USD/l)
Scenario 1								
Total operating costs	$ 6,111,695	$ 1.22	$ 28,187,800	$ 1.13	$ 56,257,528	$ 1.13	$ 112,674,404	$ 1.13
Total fixed costs	$ 1,027,696	$ 0.21	$ 3,711,284	$ 0.15	$ 6,668,949	$ 0.13	$ 12,178,615	$ 0.12
Total other costs	$ 116,677	$ 0.02	$ 210,666	$ 0.01	$ 382,199	$ 0.01	$ 727,927	$ 0.01
Total production costs scenario 1 (USD/year)	$ 7,256,068		$ 32,109,749		$ 63,308,676		$ 125,580,946	
Total production costs scenario 1 (USD/l)		$ 1.45		$ 1.28		$ 1.27		$ 1.26
Scenario 2								
Total operating costs	$ 7,527,952	$ 1.51	$ 35,269,084	$ 1.41	$ 70,420,096	$ 1.41	$ 140,999,540	$ 1.41
Total fixed costs	$ 1,027,696	$ 0.21	$ 3,711,284	$ 0.15	$ 6,668,949	$ 0.13	$ 12,178,615	$ 0.12
Total other costs	$ 116,677	$ 0.02	$ 210,666	$ 0.01	$ 382,199	$ 0.01	$ 727,927	$ 0.01
Total production costs scenario 2 (USD/year)	$ 8,672,325		$ 39,191,033		$ 77,471,244		$ 153,906,082	
Total production costs scenario 2 (USD/l)		$ 1.73		$ 1.57		$ 1.55		$ 1.54
Scenario 3								
Total operating costs	$ 8,944,209	$ 1.79	$ 42,350,368	$ 1.69	$ 84,582,665	$ 1.69	$ 169,324,677	$ 1.69
Total fixed costs	$ 1,027,696	$ 0.21	$ 3,711,284	$ 0.15	$ 6,668,949	$ 0.13	$ 12,178,615	$ 0.12
Total other costs	$ 116,677	$ 0.02	$ 210,666	$ 0.01	$ 382,199	$ 0.01	$ 727,927	$ 0.01
Total production costs scenario 3 (USD/year)	$ 10,088,582		$ 46,272,317		$ 91,633,812		$ 182,231,219	
Total production costs scenario 3 (USD/l)		$ 2.02		$ 1.85		$ 1.83		$ 1.82


SUMMARY OF RESULTS FOR ETHANOL PRODUCTION FROM SUGARCANE
<< BACK Data Entry
Production Cost 1
Production Cost 2
Production Cost 3
Production Cost 4
NEXT >> Summary of Results - Comparative
NEXT >> Summary of Results - Labour
Feedstock Selection
1. Sugarcane
Create PDF Report
Include Scenario 1 (Own Production)
Include Scenario 2 (Mixed)
Include Scenario 3 (Outgrowers)
Price of Sugarcane = 27.19 (USD/t)
Price of Sugarcane = 28.11 (USD/t)
Price of Sugarcane = 29.5 (USD/t)
Production Cost and Investments
Subtract revenues from co-products
Scenario 1 (Own Production)
Scenario 2 (Mixed)
Scenario 3 (Outgrowers)
Share of production costs under different scenarios
Scenario 1
Scenario 2
Scenario 3
Labour and other costs
Depreciation & maintenance
Energy
Chemical inputs
Feedstock
Operating Results
Feedstock requirement per plant
Feedstock consumption (t/year)
Feedstock Available (t/year)
Number of plants potentially supplied
Maximum attainable Ethanol production
Number of jobs in Ethanol processing
Financial Analysis
Net Present Value (million USD/year)
Internal Rate of Return (%)
NPV Scenario 1
NPV Scenario 2
NPV Scenario 3
I.R.R Scenario 1
I.R.R Scenario 2
I.R.R Scenario 3


SUMMARY OF RESULTS FOR ETHANOL PRODUCTION FROM MAIZE
<< BACK Data Entry
Production Cost 1
Production Cost 2
Production Cost 3
Production Cost 4
NEXT >> Summary of Results - Comparative
NEXT >> Summary of Results - Labour
Feeedstock Selection
2. Maize
Create PDF Report
Include Scenario 1 (Own Production)
Include Scenario 2 (Mixed)
Include Scenario 3 (Outgrowers)
Price of Maize = 106.16 (USD/t)
Price of Maize = 132.66 (USD/t)
Price of Maize = 172.41 (USD/t)
Production Cost and Investments
Subtract revenues from co-products
Comparison of production cost with fossil fuel price - Net importer option (USD/l gasoline equivalent)
Comparison of production cost with biofuel price - Net exporter option (USD/l ethanol)
Total investment (million USD)
Scenario 1 (Own Production)
Scenario 2 (Mixed)
Scenario 3 (Outgrowers)
Gasoline FOB price
Ethanol FOP price
5 ML
25 ML
50 ML
100 ML
Share of production costs under different scenarios
Scenario 1
Scenario 2
Scenario 3
Labour and other costs
Depreciation & maintenance
Energy
Chemical inputs
Feedstock
Operating Results
Feedstock requirement per plant
Feedstock consumption (t/year)
Feedstock Available (t/year)
1,974,603
12,195
60,976
121,951
243,902
Number of plants potentially supplied
The maximum number of plants potentially available for 5 ML capacity is 161
The maximum number of plants potentially available for 25 ML capacity is 32
The maximum number of plants potentially available for 50 ML capacity is 16
The maximum number of plants potentially available for 100 ML capacity is 8
161
32
16
8
Maximum attainable Ethanol production
98%
0%
20%
40%
60%
80%
100%
The maximum attainable production of Ethanol from the available maize biomass is 810 ML/year. It is able to cover 98% of 827 ML/year ethanol demand required by E15 blending mandate.
Number of jobs in Ethanol processing
23
26
49
98
Financial Analysis
Net Present Value (million USD/year)
-$ 29
-$ 31
-$ 36
-$ 25
-$ 39
-$ 60
-$ 17
-$ 45
-$ 86
$ 1
-$ 54
-$ 137
-$ 150
-$ 100
-$ 50
$ 0
$ 50
Millions USD/year
NPV Scenario 1
NPV Scenario 2
NPV Scenario 3
Internal Rate of Return (%)
10%
0%
I.R.R Scenario 1
I.R.R Scenario 2
I.R.R Scenario 3

SUMMARY OF RESULTS FOR BIODIESEL PRODUCTION FROM SOYBEAN

<< BACK Data Entry	*Production Cost 1*	*Production Cost 2*	*Production Cost 3*	*Production Cost 4*	NEXT >> Summary of Results - Comparative	NEXT >> Summary of Results - Labour

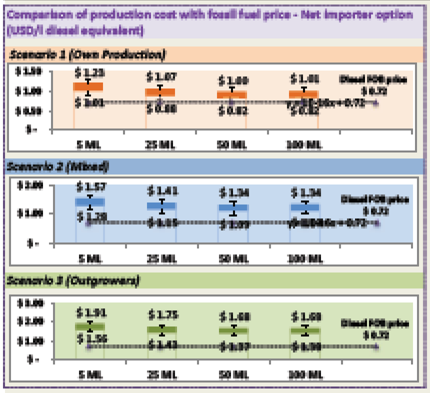
Feeedstock Selection *3. Soybean* — *Create PDF Report*

Include Scenario 1 (Own Production)	*Include Scenario 2 (Mixed)*	*Include Scenario 3 (Outgrowers)*
Price of Soybean = 190.66 (USD/t)	Price of Soybean = 242.5 (USD/t)	Price of Soybean = 294.33 (USD/t)

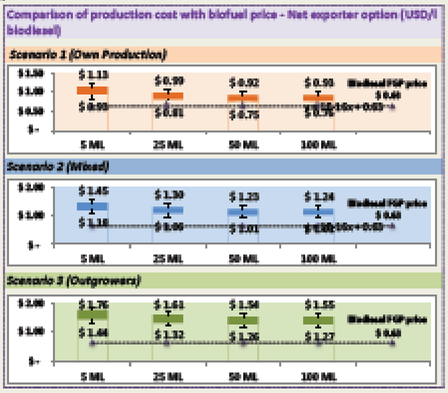
Production Cost and Investments

Subtract revenues from co-products

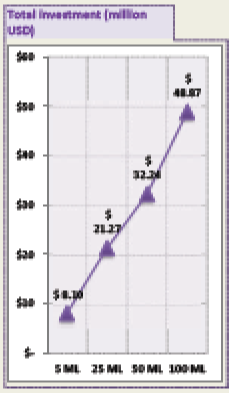
Comparison of production cost with fossil fuel price - Net importer option (USD/l diesel equivalent)



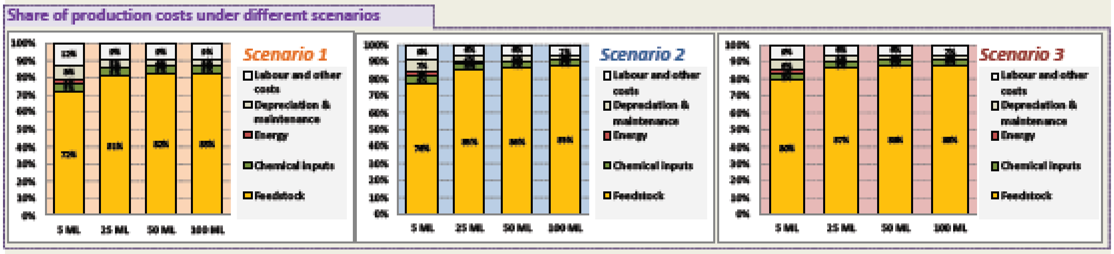
Comparison of production cost with biofuel price - Net exporter option (USD/l biodiesel)



Total investment (million USD)

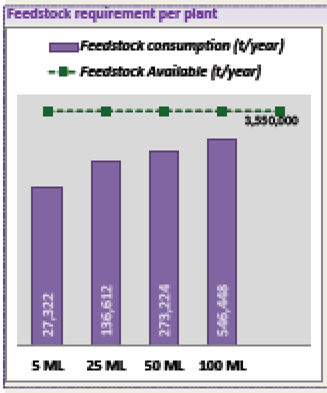


Share of production costs under different scenarios



Operating Results

Feedstock requirement per plant



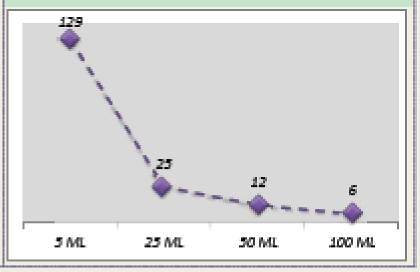
Number of plants potentially supplied

The maximum number of plants potentially available for 5 ML capacity is 129

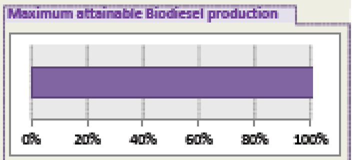
The maximum number of plants potentially available for 25 ML capacity is 25

The maximum number of plants potentially available for 50 ML capacity is 12

The maximum number of plants potentially available for 100 ML capacity is 6

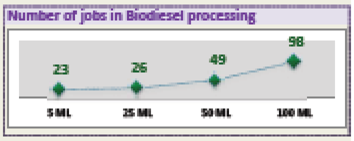


Maximum attainable Biodiesel production



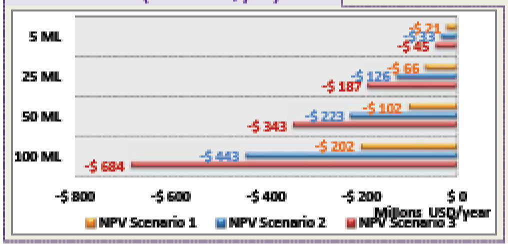
The maximum attainable production of Biodiesel from the available soybean biomass is 650 ML/year. It is able to cover 679.5% of 96 ML/year biodiesel demand required by B20 blending mandate.

Number of jobs in Biodiesel processing

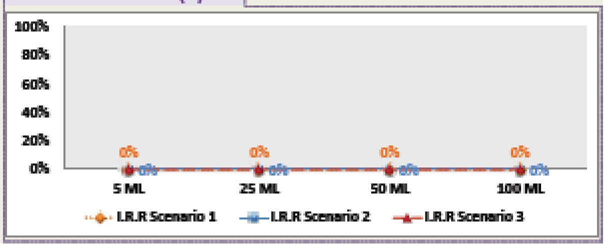


Financial Analysis

Net Present Value (million USD/year)



Internal Rate of Return (%)



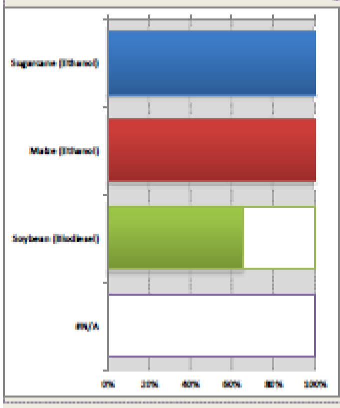
SUMMARY OF RESULTS COMPARATIVE

<< BACK Data Entry	Production Cost 1	Production Cost 2	Production Cost 3	Production Cost 4	NEXT >> Summary of Results - by Feedstocks	NEXT >> Summary of Results - Labour

Create PDF Report

Biofuel Production and Plants

Maximum Attainable Biofuel Production



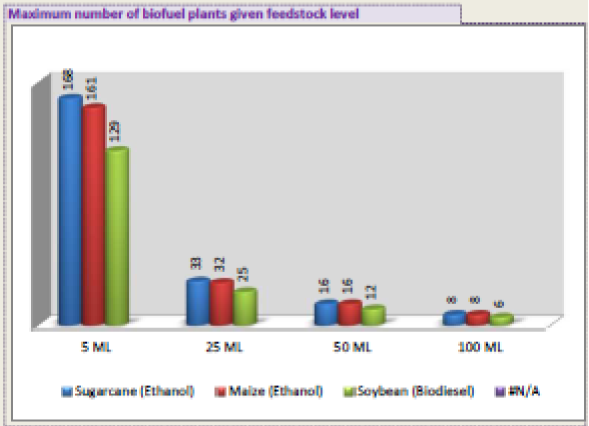
Sugarcane Ethanol is able to supply 127.39% of a E12 blending mandate.

Maize Ethanol is able to supply 122.44% of a E12 blending mandate.

Soybean Biodiesel is able to supply 65.45% of a B10 blending mandate.

#N/A

Maximum number of biofuel plants given feedstock level



Comparison of Economic Results

Scenario 1 (own production)

Production Costs

Biodiesel	Biodiesel FGP price $0.63 – USD/L Biodiesel 5 ML	25 ML	50 ML	100 ML	Diesel FGP price $0.72 – USD/L Diesel Equivalent 5 ML	25 ML	50 ML	100 ML
3 Soybean	$ 1.03	$ 0.90	$ 0.84	$ 0.84	$ 1.12	$ 0.97	$ 0.91	$ 0.91
# #N/A								

Ethanol	Ethanol FOB price $0.42 – USD/L Ethanol 5 ML	25 ML	50 ML	100 ML	Gasoline FOB price $0.79 – USD/L Gasoline Equivalent 5 ML	25 ML	50 ML	100 ML
1 Sugarcane	$ 0.97	$ 0.65	$ 0.61	$ 0.59	$ 1.47	$ 0.99	$ 0.93	$ 0.89
2 Maize	$ 0.98	$ 0.51	$ 0.44	$ 0.41	$ 1.48	$ 0.77	$ 0.67	$ 0.62
# #N/A								

Net Present Value (NPV) and Internal Rate of Return

Biodiesel	NPV (Million USD/year) 5 ML	25 ML	50 ML	100 ML	IRR (%) 5 ML	25 ML	50 ML	100 ML
3 Soybean	-$ 20.52	-$ 66.05	-$ 101.98	-$ 201.64	Not feasible	Not feasible	Not feasible	Not feasible
# #N/A								

Ethanol	NPV (Million USD/year) 5 ML	25 ML	50 ML	100 ML	IRR (%) 5 ML	25 ML	50 ML	100 ML
1 Sugarcane	-$ 26.90	-$ 54.11	-$ 87.88	-$ 54.81	Not feasible	Not feasible	Not feasible	Not feasible
2 Maize	-$ 28.71	-$ 25.31	-$ 17.30	$ 0.99	Not feasible	Not feasible	Not feasible	10%
# #N/A								

Scenario 2 (Mixed)

Production Costs

Biodiesel	Biodiesel FGP price $0.63 – USD/L Biodiesel 5 ML	25 ML	50 ML	100 ML	Diesel FGP price $0.72 – USD/L Diesel Equivalent 5 ML	25 ML	50 ML	100 ML
3 Soybean	$ 1.31	$ 1.18	$ 1.12	$ 1.13	$ 1.43	$ 1.28	$ 1.22	$ 1.22
# #N/A								

Ethanol	Ethanol FOB price $0.42 – USD/L Ethanol 5 ML	25 ML	50 ML	100 ML	Gasoline FOB price $0.79 – USD/L Gasoline Equivalent 5 ML	25 ML	50 ML	100 ML
1 Sugarcane	$ 0.98	$ 0.66	$ 0.62	$ 0.60	$ 1.49	$ 1.00	$ 0.94	$ 0.91
2 Maize	$ 1.04	$ 0.58	$ 0.51	$ 0.47	$ 1.58	$ 0.87	$ 0.77	$ 0.72
# #N/A								

Net Present Value (NPV) and Internal Rate of Return

Biodiesel	NPV (Million USD/year) 5 ML	25 ML	50 ML	100 ML	IRR (%) 5 ML	25 ML	50 ML	100 ML
3 Soybean	-$ 32.58	-$ 126.33	-$ 222.55	-$ 442.79	Not feasible	Not feasible	Not feasible	Not feasible
# #N/A								

Ethanol	NPV (Million USD/year) 5 ML	25 ML	50 ML	100 ML	IRR (%) 5 ML	25 ML	50 ML	100 ML
1 Sugarcane	-$ 27.41	-$ 56.54	-$ 92.74	-$ 159.04	Not feasible	Not feasible	Not feasible	Not feasible
2 Maize	-$ 31.46	-$ 39.07	-$ 44.82	-$ 54.04	Not feasible	Not feasible	Not feasible	Not feasible
# #N/A								

Scenario 3 (Outgrowers)

Production Costs

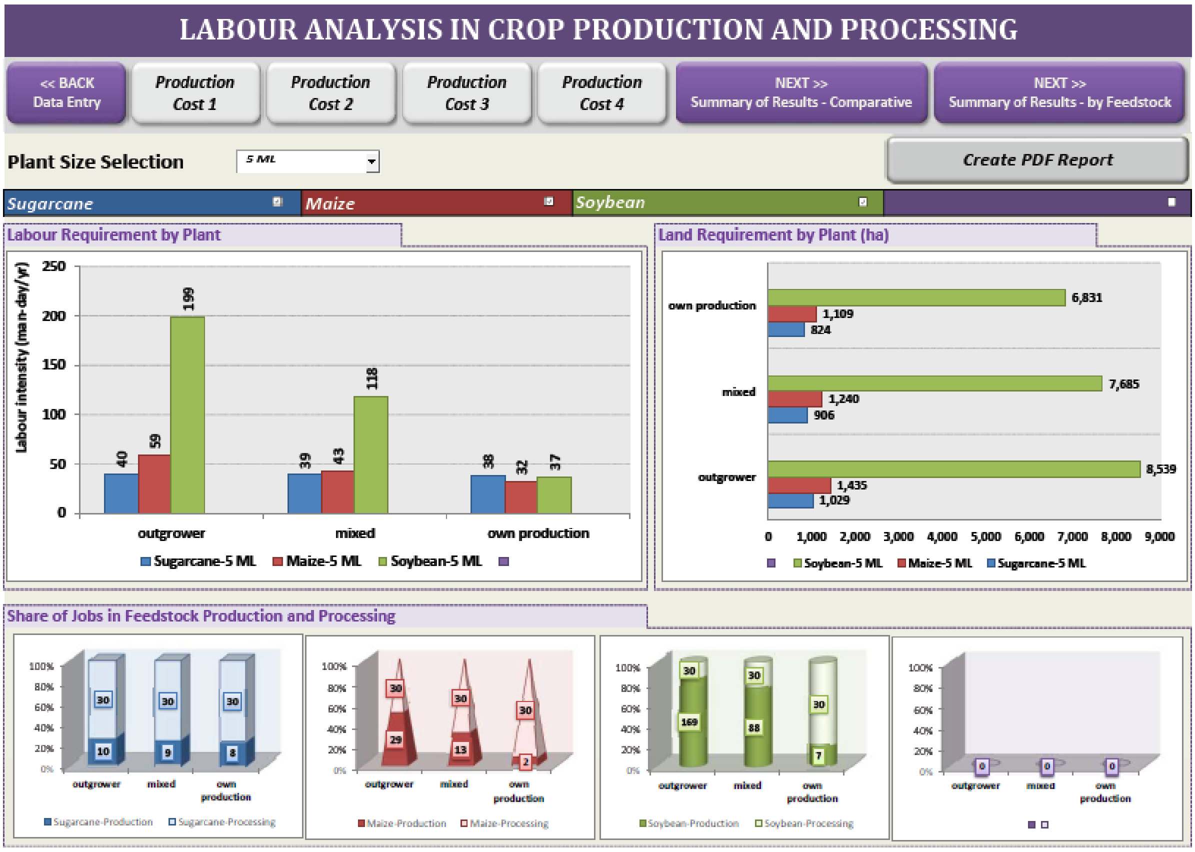
Biodiesel	Biodiesel FGP price $0.63 – USD/L Biodiesel 5 ML	25 ML	50 ML	100 ML	Diesel FGP price $0.72 – USD/L Diesel Equivalent 5 ML	25 ML	50 ML	100 ML
3 Soybean	$ 1.60	$ 1.46	$ 1.40	$ 1.41	$ 1.73	$ 1.59	$ 1.52	$ 1.53
# #N/A								

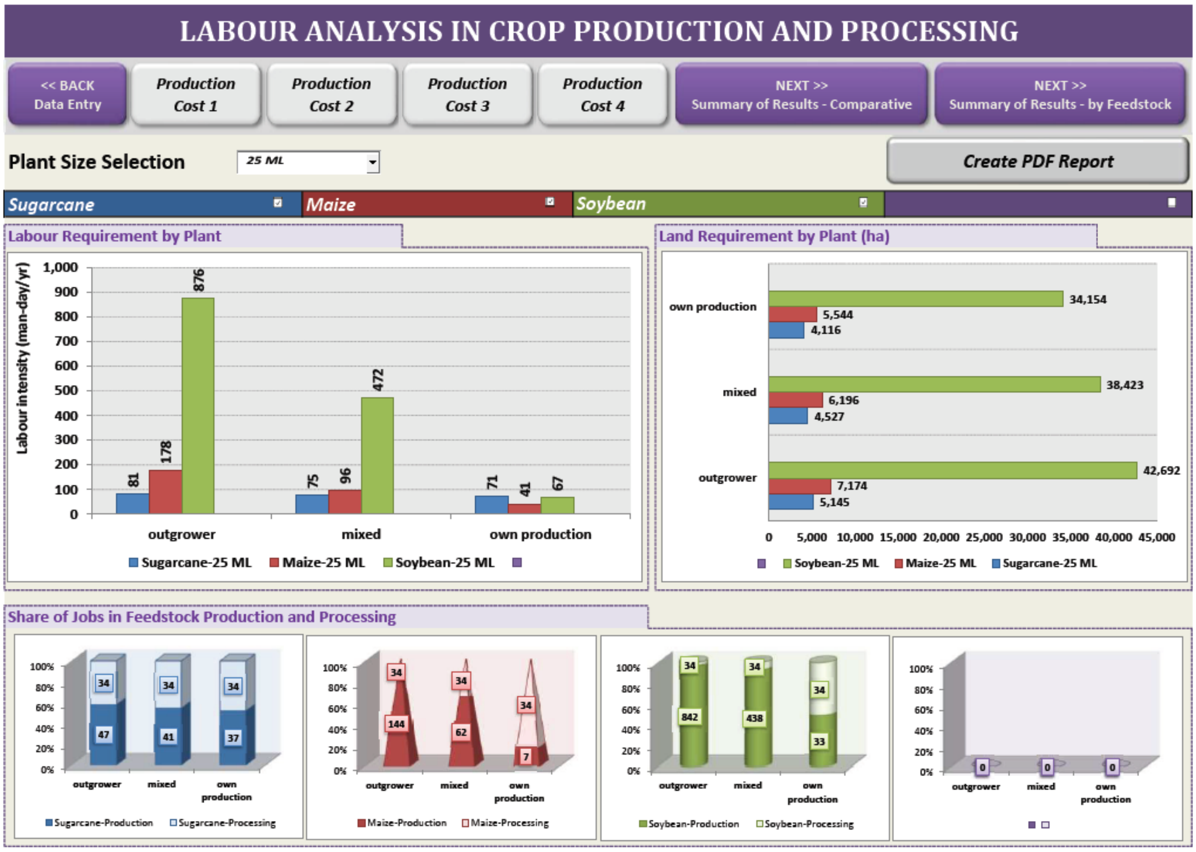
Ethanol	Ethanol FOB price $0.42 – USD/L Ethanol 5 ML	25 ML	50 ML	100 ML	Gasoline FOB price $0.79 – USD/L Gasoline Equivalent 5 ML	25 ML	50 ML	100 ML
1 Sugarcane	$ 1.00	$ 0.68	$ 0.64	$ 0.62	$ 1.51	$ 1.03	$ 0.97	$ 0.93
2 Maize	$ 1.14	$ 0.67	$ 0.61	$ 0.57	$ 1.73	$ 1.02	$ 0.92	$ 0.86
# #N/A								

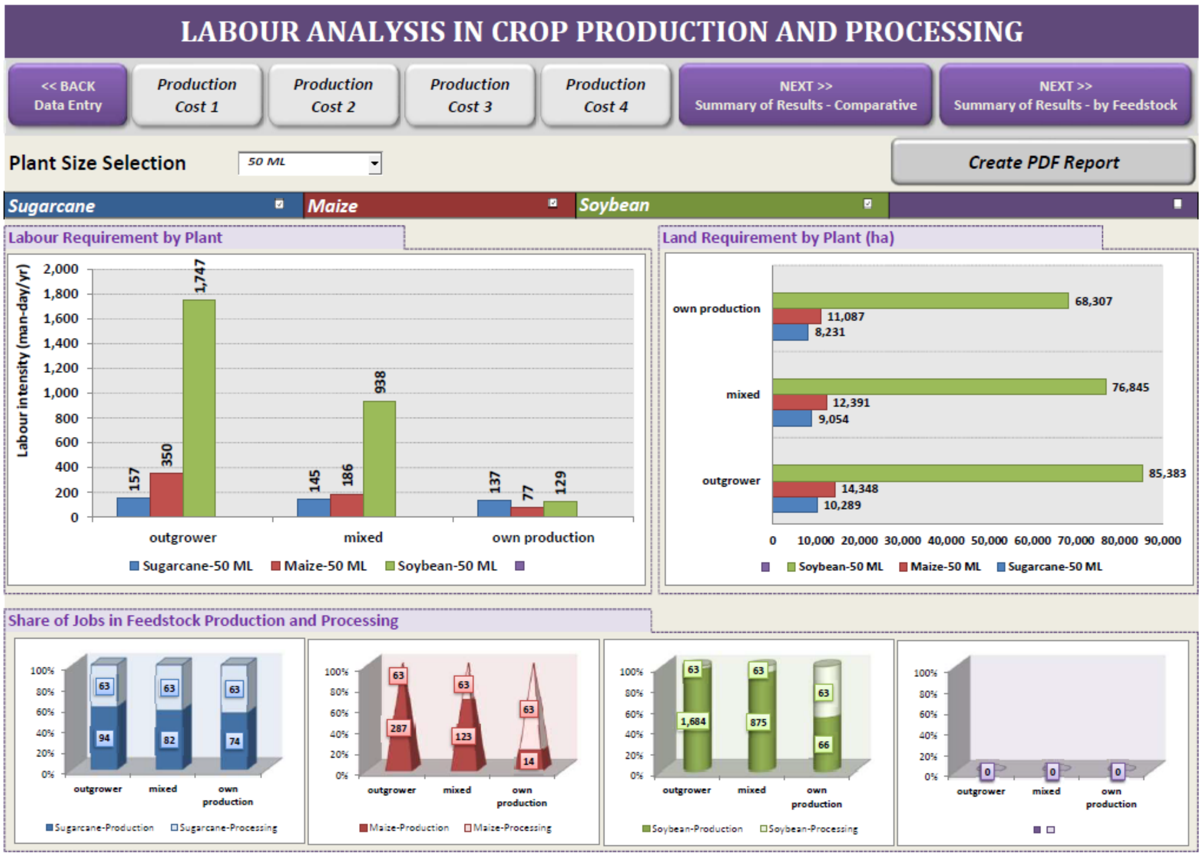
Net Present Value (NPV) and Internal Rate of Return

Biodiesel	NPV (Million USD/year) 5 ML	25 ML	50 ML	100 ML	IRR (%) 5 ML	25 ML	50 ML	100 ML
3 Soybean	-$ 44.64	-$ 186.62	-$ 343.13	-$ 683.94	Not feasible	Not feasible	Not feasible	Not feasible
# #N/A								

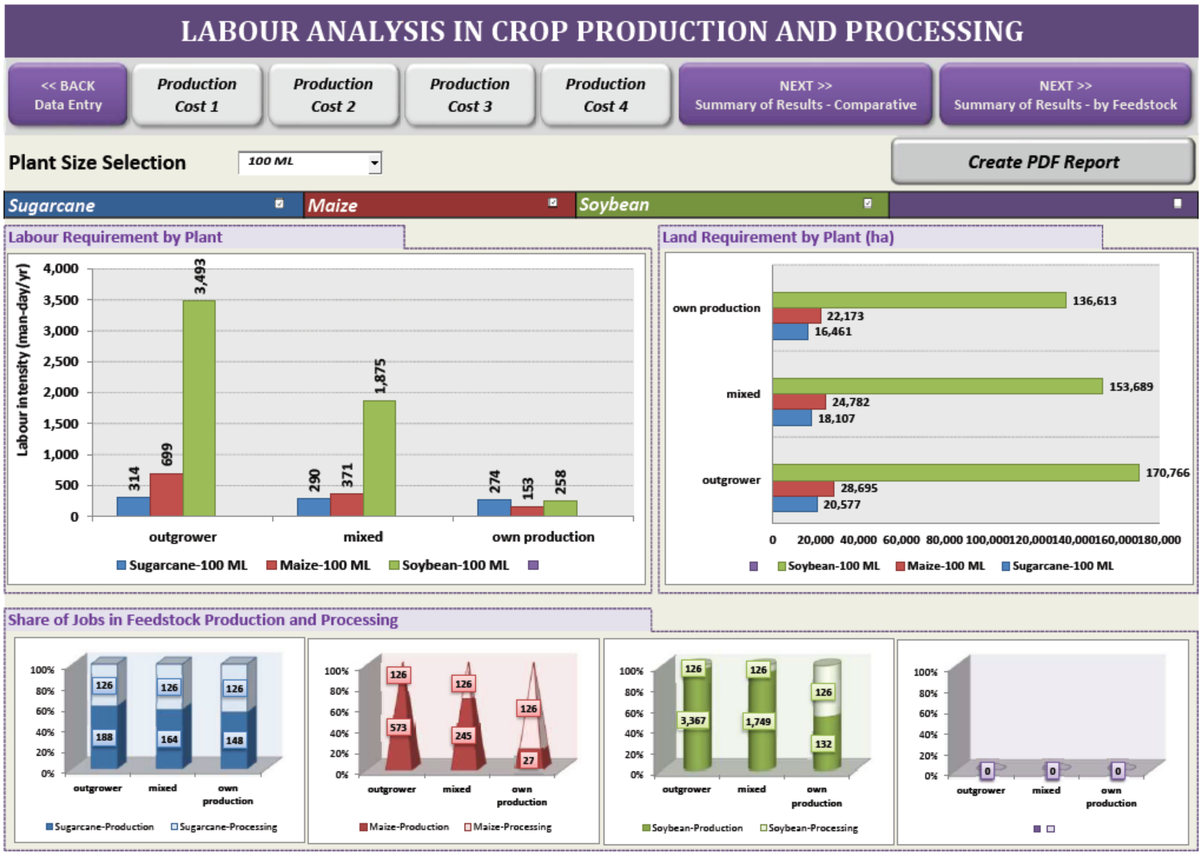
Ethanol	NPV (Million USD/year) 5 ML	25 ML	50 ML	100 ML	IRR (%) 5 ML	25 ML	50 ML	100 ML
1 Sugarcane	-$ 28.14	-$ 60.18	-$ 100.02	-$ 171.61	Not feasible	Not feasible	Not feasible	Not feasible
2 Maize	-$ 35.59	-$ 59.71	-$ 86.09	-$ 136.58	Not feasible	Not feasible	Not feasible	Not feasible
# #N/A								


LABOUR ANALYSIS IN CROP PRODUCTION AND PROCESSING
<< BACK Data Entry
Production Cost 1
Production Cost 2
Production Cost 3
Production Cost 4
NEXT >> Summary of Results - Comparative
NEXT >> Summary of Results - by Feedstock
Plant Size Selection
5 ML
Create PDF Report
Sugarcane
Maize
Soybean
Labour Requirement by Plant
Labour intensity (man-day/yr)
outgrower
mixed
own production
40 59 199
39 43 118
38 32 37
Sugarcane-5 ML
Maize-5 ML
Soybean-5 ML
Land Requirement by Plant (ha)
own production 6,831 1,109 824
mixed 7,685 1,240 906
outgrower 8,539 1,435 1,029
Soybean-5 ML
Maize-5 ML
Sugarcane-5 ML
Share of Jobs in Feedstock Production and Processing
Sugarcane-Production
Sugarcane-Processing
Maize-Production
Maize-Processing
Soybean-Production
Soybean-Processing


LABOUR ANALYSIS IN CROP PRODUCTION AND PROCESSING
<< BACK Data Entry
Production Cost 1
Production Cost 2
Production Cost 3
Production Cost 4
NEXT >> Summary of Results - Comparative
NEXT >> Summary of Results - by Feedstock
Plant Size Selection
25 ML
Create PDF Report
Sugarcane
Maize
Soybean
Labour Requirement by Plant
Labour intensity (man-day/yr)
outgrower
mixed
own production
81 178 876
75 96 472
71 41 67
Sugarcane-25 ML
Maize-25 ML
Soybean-25 ML
Land Requirement by Plant (ha)
own production 34,154 5,544 4,116
mixed 38,423 6,196 4,527
outgrower 42,692 7,174 5,145
Soybean-25 ML
Maize-25 ML
Sugarcane-25 ML
Share of Jobs in Feedstock Production and Processing
Sugarcane-Production
Sugarcane-Processing
Maize-Production
Maize-Processing
Soybean-Production
Soybean-Processing



LABOUR ANALYSIS IN CROP PRODUCTION AND PROCESSING
<< BACK Data Entry
Production Cost 1
Production Cost 2
Production Cost 3
Production Cost 4
NEXT >> Summary of Results - Comparative
NEXT >> Summary of Results - by Feedstock
Plant Size Selection
50 ML
Create PDF Report
Sugarcane
Maize
Soybean
Labour Requirement by Plant
Labour intensity (man-day/yr)
outgrower
mixed
own production
Sugarcane-50 ML
Maize-50 ML
Soybean-50 ML
Land Requirement by Plant (ha)
Soybean-50 ML
Maize-50 ML
Sugarcane-50 ML
Share of Jobs in Feedstock Production and Processing
Sugarcane-Production
Sugarcane-Processing
Maize-Production
Maize-Processing
Soybean-Production
Soybean-Processing



LABOUR ANALYSIS IN CROP PRODUCTION AND PROCESSING
<< BACK Data Entry
Production Cost 1
Production Cost 2
Production Cost 3
Production Cost 4
NEXT >> Summary of Results - Comparative
NEXT >> Summary of Results - by Feedstock
Plant Size Selection
100 ML
Create PDF Report
Sugarcane
Maize
Soybean
Labour Requirement by Plant
Labour intensity (man-day/yr)
outgrower
mixed
own production
Sugarcane-100 ML
Maize-100 ML
Soybean-100 ML
Land Requirement by Plant (ha)
Soybean-100 ML
Maize-100 ML
Sugarcane-100 ML
Share of Jobs in Feedstock Production and Processing
Sugarcane-Production
Sugarcane-Processing
Maize-Production
Maize-Processing
Soybean-Production
Soybean-Processing