Introduction[1]

During the last few years the global energy market has been increasingly influenced by uncertainties linked to climate change and by the vulnerability due to a gradual exhaustion of fossil fuels versus an increasing demand of energy. This has provoked an intensive search for alternative energy sources, which could substitute for continuously diminishing fossil reserves. Among these alternative sources, biofuels have become especially important, due to their potential use in vehicles and internal combustion engines with no need for relevant substantial modifications.

Governments have reacted to this situation by promoting biofuels through laws, decrees and regulations that in many cases established a mandatory share of biofuels in their domestic fuel consumption, as well as tax and credit incentives. These actions have created new markets for biofuels, with a strong influence of State intervention.

Different research centers, environmental NGOs and several stakeholders have raised the issue of the possible threats posed by an uncontrolled expansion of biofuels production in the world. The public sector has reacted to this problem by requesting its regulatory agencies to make rules applicable to biofuel production. Said agencies turned to research centers and groups in search of scientific criteria and basis for the rules in preparation.

The current situation shows that speeds are asymmetrical and that lots of doubts and unsolved problems persist in the scientific field, forcing parties to move forward in spite of a great degree of uncertainty. This reality can be observed in all areas, and although the progress of regulations has not stopped, certain measures are being taken to correct possible mistakes due to a lack of strong scientific basis.

Studies focus on the energetic balances of each alternative, greenhouse gas emissions and global impact caused by the expansion of each feedstock used to produce these biofuels.

During the last couple of years, activity on this issue has been very intense, and different initiatives exist, coming from governments as well as from national and international institutes and organizations. Among them, we can mention the initiatives promoted by the European Council, the United States Government, Global Bioenergy Partnership and the Roundtable on Sustainable Biofuels.

Since 2005, INTA has participated in different technological and scientific for a committed to study the sustainable production of biofuels around the world.

INTA has strengthened partnerships with the main research centers working on the subject and has exchanged knowledge and information about Argentina, which in most cases was unknown.

In spite of the uncertain economic, financial and environmental perspectives, the European Union decided to introduce policies based on more environment-friendly production, marketing and consumption of biofuels, under the influence of a growing widespread concern, both of citizens and of private and public organizations, for the increase in greenhouse gas emissions.

Hence, in addition to all the requirements that biofuels have to meet, such as quality standards, economic competitiveness, or availability in sufficient quantities as to meet mass consumption, we can point out a series of analysis based on the extremes of the production-consumption chain, like crop planting and final use by consumers.

In view of the above facts, it is important to be able to measure all possible environmental benefits of biofuels, in order to improve them and to compare them with the fossil fuels they are replacing.

This kind of measurement and analysis, known as the Life Cycle Analysis (LCA), allows to quantify all impacts of the production and consumption of alternative fuels (from the original feedstock up to the final use of the product), making possible to assess their feasibility.

[1] This report prepared by INTA is a follow up of the first two studies submitted to DG TREN and JRC during 2008 and 2009 and it should be read it and analyze as part of them.

Argentina has become a relevant party in the world biodiesel market, with a production of more than 1.3 million tons of biodiesel and exports over 1.300 million USD in 2008. The raw material used for the production of these significant volumes of biodiesel (soybean oil in the case of Argentina) is a by-product of soy meal (that is, the vegetable protein used in animal feeding). This soybean by-product is turned into biodiesel. The country production is linked to higher quantity, positive projections of consumption and external market opportunities. In this regard, it is very important to establish the environmental characteristics of the production, in order to show compliance with goals and regulations both of the European and the American market.

Because of this, INTA, within the framework of its National Bioenergy Program, is currently carrying out specific studies on the main topics regarding this energy, with special emphasis on biodiesel, given its strategic importance as a manufactured export product from Argentina.

Objectives

The Directive 2008/28/EC on the promotion of the use of energy from renewable sources published on June 2009, fixed in Annex V typical and default values for biofuels from different feedstuff with no net carbon emissions from land-use change. For the particular case of soybean biodiesel, it is stated a typical value of 40% and a default value of 31% which is below the minimum required level.

INTA via Argentine Embassy at Brussels has submitted two reports to DG TREN and JRC introducing new data and new values in order to modify the current GHG savings typical and default value for soybean biodiesel. This third study is an updated version of the first papers with new data and a regionalization approach for Argentine soybean production, including GHG emissions at processing level (crushing facilities).

The general objective of the present study is to establish, analyze, compare and evaluate the energetic consumption and greenhouse gas (GHG) emissions of soy-based biodiesel production in Argentina, throughout different regions.

The specific objectives are:

- Introduce the use of the software *"The CO_2 Bioenergy Tool"*. Version 2.1b., as a methodological tool for the calculation of the energetic consumption and GHG emissions of soy-based biodiesel.
- Compare different scenarios of energetic consumption and GHG emissions in the production of soy-based biodiesel in Argentina, establishing whether there are significant differences among them, and on what stage(s) of the production chain these significant differences are more obvious.
- Obtain "real values and data" to the national soybean biodiesel production, with respect to the energetic consumption and GHG emissions, so as to be able to compare domestic scenarios with those proposed and introduced in the European legislation by different institutions from the European Union.
- Compare the basic data used in the different studies in Argentina with those used by the European Commission Joint Research Centre (JRC).

Materials and Methods

For the calculation of energetic consumption and GHG emissions in the production of soy-based biodiesel in Argentina, the software *"Greenhouse gas calculator for biofuels"* Version 2.1b (available for free at: http://www.senternovem.nl/gave_english/co2_tool/index.as and developed by the

SenterNovem Agency of the Dutch Government) was used. This software was developed within the framework of the GAVE Program (*Climate Neutral Gaseous and Liquid Energy Carriers*) of the Dutch Government, being its main objective to collaborate with different governmental agencies and other stakeholders, in order to reach sustainable and environmentally friendly production, marketing and consumption of biofuels, both in the Netherlands and in the European Union.

For the analysis of energy consumption and GHG emissions, this software considers the following assumptions (Hamelinck *et al.*, 2008):

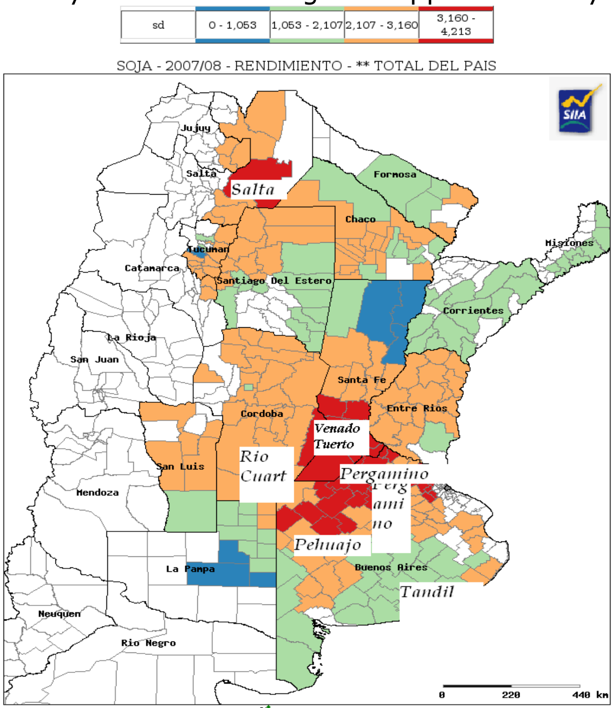
- Energy efficiencies are the same, both in biofuels and in the fossil fuels they replace. Therefore, traveling along any given distance requires the same amount of fuel, being it a biofuel or a conventional fuel. The energy efficiency of conventional diesel is 2,08 MJ/km, being the same efficiency applicable to soy-based biodiesel.
- The analysis of energy consumption and GHG emissions is comparable between the entire production chain and transportation of a given biofuel and the entire production chain and transportation of the fossil fuel it replaces.
- Up to present, the production chain of soy-based biodiesel is not known in its entirety, neither in Argentina nor in the United States. This means that more studies and additional information are required, in order to strengthen the data and assumptions used in energy consumption and GHG emissions studies.
- All the table parameters in the software can be calculated from three different types of values:
    - *Conservative values*, which are the worst values available in the market.
    - *Typical values*, which are medium values available in the market.
    - *Best practice values*, which are the best values available in the market or the values provided by the user. Different local values were introduced in this study, taking into account, for each scenario analyzed, Argentina's reference values derived from INTA's own research and from surveys carried out by the industry.
- A change in results of 5% or more, due to a change in any of the *parameters or conservative*, *typical or best practice values*, is considered significant:
    - If the results of the calculation of GHG emissions change at least 2% or more, compared to the reference fossil fuel (in the case of soy-based biodiesel, it would be conventional diesel).
    - If the result of the parameter or value changes 20% or more, contributing this variation greatly in the change of the final results.

On the basis of a relative scale, according to which the lower energy consumption or GHG emissions scenario represents 100% of the energy consumption or emission in any of the stages, its percentage differences with respect to the highest energy consumption or emissions scenario were determined. Based on this and according to the software assumptions, these differences were used as a tool to determine, where they exist, significant differences between parameters and values.

ARGENTINA Soybean Yields 2007/2008 – MAIN PRODUCTION AREAS

Parameters used for the Argentine case

The study consists in a regional approach study on GHG emissions for soybean production in different regions of the country. Soybean represents more than 40% of total crop production in Argentina (campaign 2008-2009) accounting 30 millions tons. The production is spread around central and north region of Argentina (see Figure above).



The areas under research by this study means around 85% of total soybean production in Argentina, giving a significant value to the conclusions of this paper.

Soybean Production 2008-2009
Table I

SOYBEAN PRODUCTION 2008/09[2]

PROVINCE	Production – Millions Tons
BUENOS AIRES	6.743.391
CORDOBA	11.172.286
ENTRE RIOS	1.143.897
LA PAMPA	210.355
SANTA FE	8.082.856
SALTA	1.311.296
CATAMARCA	115.000
CORRIENTES	28.000
CHACO	654.973
STGO. ESTERO	394.082
MISIONES	222
FORMOSA	4.650
SAN LUIS	295.900
JUJUY	19.715
TUCUMAN	763.046
COUNTRY TOTAL	30.939.669

Source: SAGPyA. 2009

[2] - Campaign 2008-2009 suffered severe drought, which drop soybean production. The forecast for this season is around 52 millions tons.

In Argentina, since the introduction of GM varieties in soybean (Round Up Ready, or RR), a new agricultural paradigm has been adopted and expanded within the country, considering it very popular among farmers.

"No-tillage" is a conservation practice widely used in many developing countries, especially in South America. No-till is a productive system based on the absence of tillage, but including crop rotations and permanent soil coverage via stubble or crops on its surface. It has changed the former production patterns and has promoted a new type of agricultural production, much more capable to join the need to increase productivity for the ever growing global demand and environmentally friendly practices to take care of our natural resources. No-till promotes a rational and sustainable use of the agricultural ecosystems' basic resources such as soil, water, air and biodiversity. Thus, production under the no-till system results in a more productive and sustainable agriculture. In order to reach this goal, no-till system must be performed within a framework that enhances crop rotation, integrated pest, management, nutrient restoration and a rational and professional use of external supplies. These practices as a whole are known as "good agricultural practices" (Gap's). No-till is considered as a system only if GAP´s are implemented, thus attaining high levels of productivity, while maintaining the natural resources productive capacity. For the purpose of this study, NT SAT: No Till state of the Art is considered as the above mentioned good agricultural practices.

From a wider, systemic and comprehensive point of view, the no-till farming system changed the agricultural paradigm associated to the use of the soil and to the management of the productive environment or agro-ecosystem. Thanks to the use of no-tillage (as opposed to the tillage system), agronomic ecosystems are no longer vulnerable and productive lands have been extended without experiencing environmental risks. Soil productivity has increased as well, due to better chemical and physical fertility and a more efficient water economy. No-till has reduced fossil fuel consumption, lessened carbon dioxide emissions (due to the absence of tillage) and promoted carbon sequestration (due to the increase in organic materials) helping to mitigate the greenhouse effect (AAPRESID, 2005).

Introduced some 30 years ago, Conservation Agriculture is currently practiced on 100 million hectares of land across the world. Soil is disturbed as little as possible and is seeded directly through existing mulch cover = as for this study NT: No till practice. Conservation Agriculture was shown at the meeting to produce returns and benefits in a variety of situations including large commercial farms in South America, smallholder plots in Africa and high production systems in temperate Asia. No-till is a type of Conservation Agriculture.

Frequent tillage (CA=Conventional practice) can often destroy the organic balance of soils resulting in soil degradation and poor productivity over time. One major problem is that degraded soils become compacted and so absorb less water, which then tends to run off the surface, taking topsoil with it. Fields become less resistant to water stress and the water table is no longer resupplied by water filtering through, worsening the effects of droughts.

Inputs for the agriculture stage, feedstock transportation, drying and storage, crushing, etherification and transport of biodiesel for different production scenarios in Argentina

Table II

Type of Agriculture*[1]		**CA**	**NT SAT**	**NT**	**NT**	**NT**	**NT**
Stage		**Zone of reference**					
Agriculture		**Southeast of Buenos Aires (Tandil)**	**South of Santa Fe (Venado Tuerto)**	**North of Bs. As./South of Santa Fe (Pergamino)**	**West of Buenos Aires (Pehuajo)**	**South of Córdoba (Rio Cuarto)**	**Salta**
Feedstock (Kg/ha/year)*[2]	**Soybean**	2.800	4.500	3.600	3.600	2.750	2.750
Energy consumption (MJ/ha/year) *[3]	**Diesel**	1.575	998	998	998	998	998
Fertilizers*[4] **(Kg/ha/year)**	**Nitrogen**	10	14	4,4	4,4	0	0
	P_2O_5	23	78	21	21	0	0
	K_2O	0	0	0	0	0	0
Feedstock transportation*[5]							
Transport (km)	**Conv. Diesel truck**	614	191	139,9	436	395	1130
Drying and storage							
Feedstock (Kg/Kg)	**Soybean**	1	1	1	1	1	1
Energy Consumption	**Electricity***[6a] **(KWh/ton)**	1,2	1,2	1,2	1,2	1,2	1,2
	Natural gas*[6b] **(MJ/ton)**	141	141	141	141	141	141
	Conv. Diesel*[7] **(MJ/ton)**	3	3	3	3	3	3
Crushing							
By-product (Kg/Kg of seed)	**Vegetable oil**	0.194	0,194	0,194	0,194	0,194	0,194
	Meal	0,714	0,714	0,714	0,714	0,714	0,714
Energy Consumption[8]	**Electricity (KWh/ton s)**	34,3	34,3	34,3	34,3	34,3	34,3
	Natural Gas MJ/ton[9]	4770	4770	4770	4770	4770	4770
	Hexane[10] **(MJ/ton)**	4,66	4,66	4,66	4,66	4,66	4,66
Estherification							
By-product (Kg/Kg oil)	**Biodiesel**	0,95	0,95	0,95	0,95	0,95	0,95
(Kg/Kg oil)	**Glycerine**[11]	0,12	0,12	0,12	0,12	0,12	0,12
Energy use	**Electricity (KWh/ton bio**[12]	34,8	34,8	34,8	34,8	34,8	34,8
	Natural gas MJ/Ton biod[13]	1499	1499	1499	1499	1499	1499
	Methanol (Kg/ton seeds)	99	99	99	99	99	99
Biodiesel transportation							
Transport (km)*[14]	**Diesel ship**	12.091	12.091	12.091	12.091	12.091	12.091
	Diesel truck*[15]	15	15	15	15	15	15

*[1] Type of Agriculture: CA: Conventional Agriculture, NT SAT: No Till with State of the Art Technology, NT: No Till

*[2] Average yields for each area according to *Márgenes Agropecuarios* Magazine (2008).

*[3] The energy consumption for the first stage, "Agriculture", was estimated according to Donato & Huerga (2007)

*[4] Fertilizers used frequently in each zone, according to *Márgenes Agropecuarios* magazine (2008).

*[5] Distance calculated using *Guía YPF* (www.guiaypf.com.ar), from feedstock production area to Port complex at Pto. San Lorenzo/Pto. Gral. San Martín (Prov. of Santa Fe).

*[6a] Electricity consumption 1 Kwh/T estimated by de Dios, Carlos, *Grains drying and dryers*; Hemisferio Sur, 2000, pp. 244. Diego de la Torre quotes values for 0,6 in seven districts of Argentina.

*[6b] Estimated energy consumption for grain drying at the agricultural stage according to de la Torre & Bartosik (2008). (25 % is dried at storage and 75 % at the industry with 3 and 2 points of drying respectively over a total of 40,4 million tones. http://www.inta.gov.ar/balcarce/info/indices/tematica/agric/posco/gral.htm . Diego de la Torre personal communication quotes efficiencies in Argentine dryers between 982 to 2046 Kcal/kg of water and taking a reference value of 1900 Kcal/kg of water in the calculation which is conservative for Argentina reality.
*[7] Energy consumption for grain drying at the agricultural stage estimated according to de la Torre & Bartosik(2008). (8 % a gasoil over a total of and 92 % a gas GLP y GN.
*[8] IIR-BC-INF-03-09 *Energy Balances of Argentine Biodiesel Production*, with local industrial data I Huerga; J.A.Hilbert; L.Donato 2009.
*[9] 1,45 kg steam/tons of oil – Maximum value for the two surveyed companies: 785,7 kcal/kg of steam – average consumption value in Argentina Raúl Bernardi UnitecBio personal communication.
*[10] Corresponding to 981 Kcal/kg of hexane and to 24 MJ/T of oil. IIR-BC-INF-03-09.
*[11] Corresponding to the average value registered on the survey of biodiesel production companies in Argentina 0,121 T crude glycerine moist base/T biodiesel IIR-BC-INF-03-09.
*[12] Corresponding to the average value registered on the survey of biodiesel production companies in Argentina 34,79 Kwh/T biodiesel given the high dispersion of results IIR-BC-INF-03-09.
*[13] Corresponding to the average value registered on the survey of four biodiesel production companies in Argentina 0,456 T.vapor/Tbiodiesel IIR-BC-INF-03-09. This results in a value of 1499 MJ/T of oil.
*[14] Distance calculated from the Port complex Pto. San Lorenzo/Pto. Gral. San Martín (Prov. of Santa Fe) to the Port of Rotterdam, Holland (Ciani *et al*., 2007, Panichelli, 2005)L.
*[15] Argentine production companies for export are located near the ports and biodiesel transport is performed through pipes from the plants to the terminal ports. Smaller production plants are located not far than 30 km away.

Results obtained by the use of the calculating tool:

The following results obtained are detailed and commented upon for each of the production scenarios stated for Argentina and input of the values detailed in Table 1 into the system.

Energy consumption and GHG emissions for the different scenarios.
TABLE III

	Energy consumption (per km)			GHG emissions (Kg/km)		
Reference zone	**MJ per km**	**% of the reference *[16]**	**% of reductions*[16]**	**Kg CO_2-eq**	**% of the reference *[16]**	**% of reductions*[16]**
South Eastern Buenos Aires. (Tandil)	0,6450	26,8	73,2	0,047	24,5	75,5
Southern Santa Fe (Venado Tuerto)	0,5715	23,8	76,2	0,0385	21,1	78,9
Northern Buenos. Aires./Southern Santa Fe (Pergamino)	0,5435	22,6	77,4	0,0342	18,7	81,3
Western Buenos. Aires (Pehuajo)	0,5745	23,9	76,9	0,0344	19,9	80,1
Southern Córdoba (Río Cuarto)	0,5648	23,5	76,5	0,0341	18,7	81,3
Salta (Las Lajitas)	0,6419	26,7	73,3	0,0394	21,6	78,4

Table 3 *16 In comparison to conventional diesel, of fossil origin, expressed in MJ/km having as reference for gasoil 2,08 MJ/km

Energy consumption and GHG emissions for the different agriculture, transport (feedstock and biodiesel transportation) and industrial (drying and storage, crushing and estherification) stages for the different scenarios.

Table IV

Reference zone	Stage	Energy consumption (MJ/km)	GHG emissions (g CO_2-eq/km)	Total emissions per stage (g CO_2-eq/MJ fuel LHV)*[17]	Annual saving in CO_2 Emissions (ton CO_2/ha/year)
South Eastern Bs. As. (Tandil)	Agriculture	0,1037	12,2	21.5	1,3
	Industrial	0,4627	27		
	Transport*[18]	0,0787	5,4		
	Total	**0,6450**	**44,7**		
Southern Sta. Fe (Venado Tuerto)	Agriculture	0,0745	9,1	18,5	2,1
	Industrial	0,4624	27		
	Transport	0,0343	2,4		
	Total	**0,5715**	**38,5**		
Northern Bs. As./Southern Sta. Fe (Pergamino)	Agriculture	0,0518	5,2	16,4	1,8
	Industrial	0,4627	27		
	Transport	0,0290	2		
	Total	**0,5435**	**34,2**		
Western Bs. A.s (Pehuajo)	Agriculture	0,0518	5,2	17,5	1,7
	Industrial	0,4627	27		
	Transport	0,0600	4,1		
	Total	**0,5745**	**36,4**		
Southern Córdoba (Río Cuarto)	Agriculture	0,0464	3,2	16,4	1,4
	Industrial	0,4627	27		
	Transport	0,0557	3,9		
	Total	**0,5648**	**34,9**		
Salta (Las Lajitas)	Agriculture	0,0464	3,2	18,9	1,3
	Industrial	0,4627	27		
	Transport	0,1328	9,2		
	Total	**0,6419**	**39,4**		

*[17] LHV: Lower Heating Value: difference in enthalpy of a fuel at 25 °C and the products of its combustion at 150 °C
*[18] The relative impact of sea transportation is very low.

In this comparative study there are variations in: **energy consumption** (No Till vs. Conventional tillage in different areas of reference of Argentina), **quantity of fertilizers used per hectare** (idem), **distance to the location where the feedstock** -soybean- **is processed** (according to each reference zone), **energy consumption for grain drying.** On the other hand, **energy consumption for the industrial stage** is kept constant for all different scenarios, **according to surveys done in Argentina.**

Based on these comparisons, it was possible to obtain results with respect to total and specific (by stage or step) energy consumption; and with respect to total and specific (by stage or step) GHG emissions.

Therefore, taking into account the software's assumptions (see Materials and Methods, as regards **total energy consumption** (MJ/km), it could be said that:

- The **highest energy consumption** occurs in **SE Buenos Aires** (0,6450 MJ/km). Compared to conventional diesel, **savings of energy consumption** are **73.2 %.** If we fix a relative scale, according to which the lowest energy consumption scenario (Northern Bs. As./Southern Sta. Fe) represents 100% of the energy consumption, its **percentage difference with the relative highest energy consumption scenario** (SE Bs.As.) is of: $\Delta_{SEBs.As.-\ NBUE\ S\ Sta.\ Fe./NBUE\ S\ Sta.\ Fe}$ = **17.3 %.** In spite of the fact that several of the assumptions from the software are fulfilled (yields between each scenario vary in 200%, the use of fertilizers between 100 and 11,5% and the distance to the location for processing the feedstock in 463%) these differences are considered **not significative**.

- The **lowest energy consumption** occurs in **Northern Bs. As./Southern Sta. Fe** (0,5435 MJ/km). Compared to conventional diesel, **savings in energy consumption** are of a **77,4 %**.

At a **specific level**, and with respect to **energy consumption** (MJ/km) for the **Agricultural Stage**:

- The **highest energy consumption for the Agricultural Stage** occurs in **South Eastern Bs. As** (0,1037 MJ/km). If we arbitrarily fix a relative scale, according to which the scenario for the lowest energy consumption for the agricultural stage (Southern Cordoba 0,0464 MJ/km) represents 100% of the energy consumption, its **percentage difference with the scenario with the relative highest energy consumption for the agricultural stage** (South Eastern Bs. As.) is of: $\Delta_{\text{SouthEast of Bs. As-South of Córdoba.}}$ = **125,4 %**. Being fulfilled the assumptions of the software (yields between each scenario vary in 4,0%, the energy consumption varies in 57% and use of fertilizers in 100%) these differences are considered **significant**.
- The **lowest energy consumption for the Agricultural Stage** occurs in the **Southern Córdoba.** (0,0464 MJ/km).

At a **specific level**, and with respect to the **energy consumption** (MJ/km) for the **Transport Stage**:

- The **highest energy consumption for the Transport Stage** occurs in **Salta** (0,1328 MJ/km). If we arbitrarily fix a relative scale, according to which the scenario of the lowest energy consumption for the Transport Stage (Northern Bs. As./Southern Sta. Fe) represents 100% of the energy consumption, its **percentage difference with the scenario with the relative highest energy consumption for the Transport Stage** (South Western Bs. As.) is of: $\Delta_{\text{Salta-Norte de Bs. As./Sur de Sta. Fe}}$ = **355,5 %**. Being fulfilled the assumptions of the software (distance between the different scenarios and the location where the feedstock is processed varies in 491%), theses differences are considered **significant**.
- The **lowest energy consumption for the Transport Stage** occurs in the **Northern Bs. As./Southern Sta. Fe** (0,0290 MJ/km).

With respect to **total GHG emissions** (Kg CO_2 eq/km), it could be said that:

- The highest **GHG emissions** occur in **South Eastern Bs.As.** (0,047 Kg CO_2 eq/km). Comparatively and as a **percentage** of conventional diesel, the **GHG emissions** in this area are **24,5%** and its **savings** in **GHG emissions** are of **75,5 %**.
- The lowest **GHG emissions** occur in **Southern Córdoba** (0,0341 Kg CO_2 eq/km). Comparatively and as a **percentage** of conventional diesel, the **GHG emissions** in this area are 18,7**%** and its **savings in GHG emissions** are of **78,4%**.
- There is an important **annual saving of CO_2 emissions** (ton CO_2/ha/year) in **Northern Bs.As./Southern Sta. Fe** (1,8 ton CO_2/ha/year) and in **Western Bs. As.** (1,8 ton CO_2/ha/year).

Impact of sea transportation from Argentina

Sea transportation's impact, in spite of the significant distance (measured in km) between the port of origin and the final destination of the product in Europe, is relatively low. An exercise was performed by lowering the amount of kilometers of transportation of the product to zero, in order to evaluate its impact over the final results for the best and worst scenarios. In the case of Northern Buenos Aires, the reduction in energy consumption of MJ/km increased from 77,4 to 77,9% and the savings in GHG emissions (Kg/km), from 81,3 to 81,8 %.

At a **specific level**, and with respect to **GHG emissions** (g CO_2 eq/km) for the **Agricultural Stage** it can be observed that:

- The scenario that shows **more GHG emissions for the Agricultural Stage** is **South Eastern Bs.As.** (12,2 g CO_2 eq/km). If we fix arbitrarily a relative scale, according to which the scenario of less GHG emissions for the Agricultural Stage (Southern Córdoba and Salta) represent 100% of the GHG emissions, its **percentage difference with the scenario with relatively more GHG emissions** (Southern Santa Fe) is of: $\Delta_{\text{S of S.Fe.-West of Bs.As.}}$ = **284%.** Being fulfilled the assumptions of the software (yields between each scenario vary in 103% and the use of fertilizers varies in 100%) these differences are considered **significant**.
- The scenarios that show **less GHG emissions** are **Western Bs.As.** and **Salta, with** 3,2 g CO_2 eq/km.

At a **specific level**, and with respect to **GHG emissions** (g CO_2 eq/km) for the **Transport Stage** it can be observed that:

- The scenario that shows **more GHG emissions for the Transport Stage** is **Salta** (9,2 g CO_2 eq/km). If we fix arbitrarily a relative scale, according to which the scenario with less GHG emissions for the Transport Stage (Northern Bs. As./Southern Sta. Fe) represents 100% of GHG emissions, its **percentage difference with the scenario with relatively more GHG emissions** (Salta) is of: $\Delta_{\text{Salta. –North of Bs. As./South of Sta. Fe}}$ = **360%.** Being fulfilled the assumptions of the software (distance between the different scenarios and the location where the feedstock is processed varies in 463%) these differences are considered **significant**.
- The scenario that shows **less GHG emissions for the Transport Stage** is **Northern Bs. As./Southern Sta. Fe** (2 g CO_2 eq/km).

Conclusions

- ✓ The general trend indicates that the **Industrial Stage**, in the first place, together with the **Agricultural Stage**, in the second place, are the **stages that jointly generate higher energy consumption**.

- ✓ Among possible domestic scenarios, in **South Eastern Bs.As.** (Tandil) a **higher energy consumption** (with reductions in the order of 73,2% of energy consumption compared to conventional diesel) was observed. In **Northern Bs. As./Southern Sta. Fe** (Pergamino), the **lower energy consumption** (with a reduction of 77,4% in energy consumption) was observed.

- ✓ Among possible domestic scenarios, in **South Eastern Bs. As.** (Tandil) the maximum **energy consumption for the Agricultural Stage** (0,1037 MJ/km) was observed. In **Southern Córdoba** (Rio Cuarto), the **minimum energy consumption for the Agricultural Stage** (0,0464 MJ/km) was observed. The differences between both scenarios seem to stem from the fact that in South Eastern Bs. As. –Tandil- a conventional agriculture system is used, resulting in a higher energy consumption per hectare (1.575 MJ/ha/year) than in No-Till (998 MJ/ha/year).

- ✓ It does not seem to exist a **direct relation between a higher consumption of fertilizers per hectare in the Agricultural Stage** (although this does not necessarily mean an increase in yield per hectare), and a **lower energy consumption efficiency** in that same stage (Western Bs. As.-Pehuajo-). The **efficiency in energy consumption** seems to be related to **high yields** and **low energy consumption** per hectare (No-Till vs. Conventional tillage).

- ✓ **Greater distance** between the feedstock (soybean) production location and the processing location results in an **increase in the impact of the Transport Stage on the total energy consumption** (Examples: Northern Bs. As. – Pergamino – and Salta).

- ✓ Among possible domestic scenarios, in **Salta** (Las Lajitas) the **highest energy consumption for the Transport Stage** (0,1328 MJ/km) was observed. In **Northern Bs. As./Southern Sta. Fe** (Pergamino), the **lowest energy consumption for the Transport Stage** (0,0290 MJ/km) was observed. This is due to the **larger distance** that separates Salta from the processing location (Port complex of Puerto San Lorenzo/Pto. Gral. San Martín, Prov. of Santa Fe).

- ✓ In general lines, the **Industrial Stage** in the first place, together with the **Agricultural Stage**, in the second place, are the stages that jointly generate **more GHG emissions.**

- ✓ Among possible domestic scenarios, both in **Southern Córdoba** (Rio Cuarto) and in **Northern Bs. As.** (Pergamino), the **highest reduction in GHG emissions** (with savings of 81,3% in GHG emissions compared to conventional diesel) was observed. It was in **South Eastern Bs.As.** (Tandil) where the **lowest reduction of GHG emissions** (with savings of 75,5% in GHG emissions) was observed.

- ✓ Among possible domestic scenarios, **South Eastern Bs.As.** (Tandil) was specifically the context where the **highest GHG emissions for the Agricultural Stage** (12,2 g CO_2 eq/km) was observed. The scenarios of **Southern Córdoba and Salta** (Rio Cuarto and Las Lajitas) were specifically the contexts where the **lowest GHG emissions for the Agricultural Stage** (3,2 g CO_2 eq/km) were observed. It is highly probably that the differences observed are due to the differences in types of farming and in the **use of fertilizers** among the regions.

- ✓ At a **larger distance** between the production and the processing location, **the impact of the Transport Stage on global GHG emissions increases** (Example: Salta).

- ✓ Among possible domestic scenarios, in **Salta** (Las Lajitas) the **highest GHG emissions for the Transport Stage** (9,2 g CO_2 eq/km) were observed. In **Northern Bs. As./Southern Sta. Fe** (Pergamino), the **lowest GHG emissions for the Transport Stage** (2 g CO_2 eq/km) were observed. The difference between both scenarios lies on the **larger distance** between the production and the processing location (Example: From Salta –Las Lajitas- to the processing location: 1130 km).

Comparative analysis with JRC tables:

- ✓ On the basis of the comparison of the result of the present study with the values proposed by the European Commission Joint Research Centre (JRC) on its calculation template Biofuels pathway RED method as of 14/11/2008, for soybean with values included for Brazil, the following comments can be made:

- The average yield value considered by JRC is 2798 kg/ha at 15% of water content, while in Argentina, depending on the studied production regions, yields range between 2750 and 4500 kg/ha
- The Nitrogen N(ha/year) fertilizer value taken into account by JRC is 8 kg/ha, while in Argentina's production regions studied, values range between 0 and 14 kg/ha
- The Potasium K_2O(ha/year) fertilizer value taken into account by JRC is 62 kg/ha, while according to the present study, this type of fertilizer is not used in the production regions in Argentina.
- The Phosphate P_2O_5(ha/year) fertilizer value taken into account by JRC is 66 kg/ha, while in Argentina, values range between 0 and 78 kg/ha, according to the region studied.
- The methodology used in the present study does not allow for the incorporation of other agrochemicals to the calculation, but their energetic impact is peripheral compared to other inputs.
- Transport distances by truck are calculated by JRC on a basis of 700 km. Although in Argentina, distances range between 191 and 1130 km more than 80 % of the production is coming from a distance of 300 km or less.This is an additional advantage since the processing plants and biodiesel facilities are placed in the center. On this issue it has to be taken into account that most of Argentina´s production is made in areas close to processing and shipment centers, which is an additional advantage on this issue.
- Shipping freight distance considered by the JRC is 10186 km, while the value considered in the present study on the Argentine case is 12091 km.
- Hexane values considered by the JRC are of 0,7 kg/Ton of grain, while in the present study on the Argentine case, the average value considered is 0,76.
- Oil yield value considered by the JRC is of 188 kg/Ton of grain, while the average value considered in the case of Argentina's big production plants is 193 kg/Ton grain.
- The amount of steam considered by the JRC is 1000 MJ/Ton of grain for the extraction stage and 296 MJ/Ton of grain for the refining stage, while in two Argentine plants, the average value for both processes combined is 1952 MJ/Ton.
- Electricity consumption considered by the JRC is 60 kWh/Ton of grain for the refining stage, while in two Argentine plants, the average value for both processes combined is 34,3kWh/Ton of grain.
- Electricity consumption per ton of biodiesel calculated both by JRC and by the Argentine study is the same, 30 kWh/t biodiesel.
- Phosphoric acid is not considered on the calculation methodology used by the present study; average values used by JRC as tally values for Argentina are 1,74 kg/Ton of biodiesel.
- Hydrochloric acid is not considered, according to the calculation methodology used in the present study; average values used in Argentina are around 10,41kg/Ton bio at 32%, while JRC considers a reference value of 20 kg/Ton of biodiesel. Differences on this issue are important, therefore the data provided by biodiesel industry in Argentina were esthekiometrically corroborated in the lab, in order to verify their consistency.
- Methanol considered by the JRC is of 109 kg/Ton biodiesel. In Argentina, the average obtained from surveyed plants and used as a reference for the calculations is 99 kg/Ton biodiesel.

- Sodium hydroxide is not considered, according to the calculation methodology used in this study; the average values in Argentina are 4,9 kg/Ton bio at 32% while JRC considers a reference value of 6,72 kg/Ton of biodiesel.
- The energy needed for steam generation, according to the JRC, is 1545 MJ/Ton of biodiesel, while the average value of Argentina used in this study is 1183 MJ/tn of biodiesel. It should be clarified that in the present study, the highest value of steam consumption from all the companies surveyed was taken into account.
- Among the transformation values, the JRC considers 1111 MJ/MJ of steam, while and the amount considered in the present study is 1276 MJ/MJ steam.
- Values taken into account by the JRC in every step of the process result in 47,5 g CO_2 eq/MJbiodiesel, in a range between maximum values of 55,9 and minimum values of 39,7. According to the calculations made by the present study for different Argentine scenarios, the resulting range was between 16,4 and 21,5 g CO_2 eq/Mjbiodiesel.

Recommendations

Since most soybean production comes from the central agricultural areas in Argentina, like Buenos Aires and Santa Fe Province, as it was shown in figure 1 where the results have been more favorable as regards GHG emissions savings, if a single value needs to be chosen for the whole soybean biodiesel produced in Argentina, it should be close to the results obtained in Northern Bs. As./Southern Sta. Fe (Pergamino).

According to those calculations, it is possible to identify the main characteristic of soybean production in Argentina in relation to GHG saving emissions and to compare it with other agricultural-industry systems worldwide with the aim to establish typical/default values for biofuels intended to export to EU.

Therefore, the present study confirm that there is a need to modify the tables prepared by the JRC for soybean biodiesel (according to which the typical value is 40% and the default value of GHG emission savings is 31%) and to assess that GHG emission savings in soybean biodiesel produced in Argentina in no till system reach to 77,4% as typical value[3].

The data provided and the calculations has proven, as it has been stated in the previous two INTA reports, that DG TREN should proceed to introduce the appropriate amendments to the Annex V of Directive 2009/35/EC by the comitology process before the entry into force of such Directive in order to avoid trade disruption.

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[3] The study is refers to "real data" at field, processing and transport level, so INTA considers reasonable to request a typical value following Directive 2009/28/EC.

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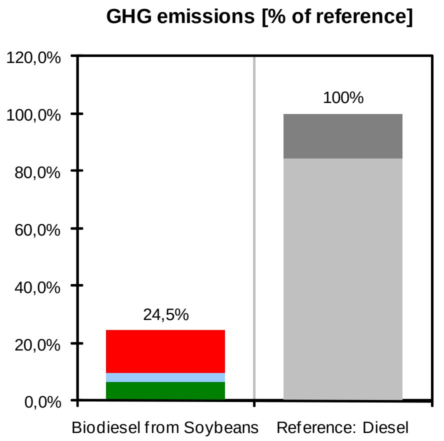
ANNEXS

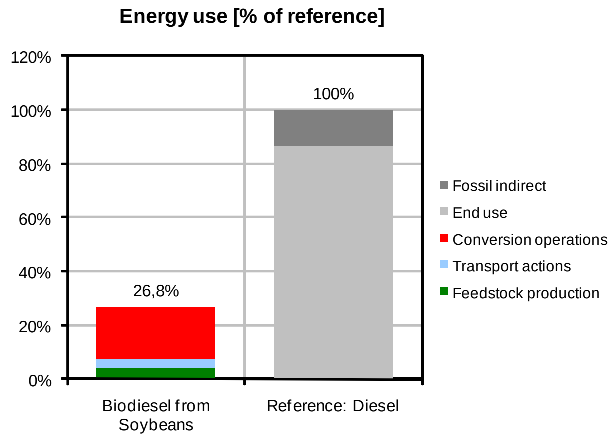
Results for South Eastern Bs.As. (Tandil) with Conventional Farming

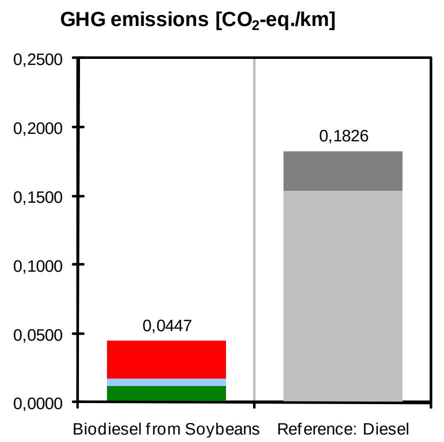
Summary Input		**Summary output**	Biodiesel from Soybeans				Reference: Diesel			
			Energy use (per km)		GHG emissions (kg/km)		Energy use (per km)		GHG emissions (kg/km)	
			(MJ)	(% of ref.)	(kg CO2-eq.)	(% of ref.)	(MJ)	(%)	(kg CO2-eq.)	(%)
Biofuel	Biodiesel	Feedstock production	0,1037	4%	0,0122	7%				
Feedstock	Soybeans	Transport actions	0,0787	3%	0,0054	3%				
Reference	Diesel	Conversion operations	0,4627	19%	0,0270	15%				
Print summary results		End use					2,0800	87%	0,1541	84%
Show detailed results		Fossil indirect					0,3224	13%	0,0285	16%
		Total	0,6450	26,8%	0,0447	24,5%	2,4024	100%	0,1826	100%
Return to input		**% Reduction**		**73,2%**		**75,5%**				**0%**
		GHG emission (kg CO2-eq/MJ LHV fuel)			**0,0215**				**0,0878**	
		Avoided emission (tonne CO_2/ha/yr)			**1,3**					

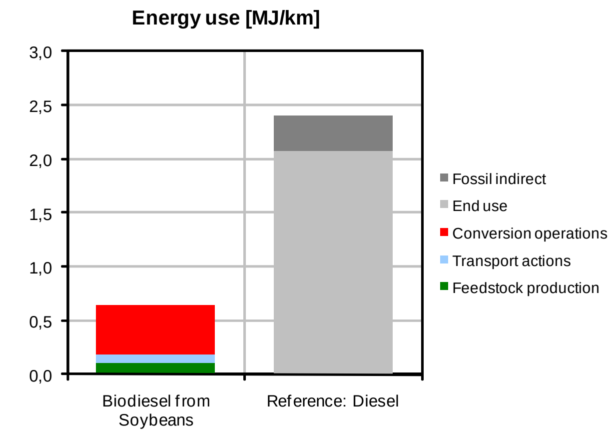
Biofuels greenhouse gas calculator
Developed by Ecofys Netherlands and CE Delft / Commissioned by SenterNovem

ECOFYS SenterNovem







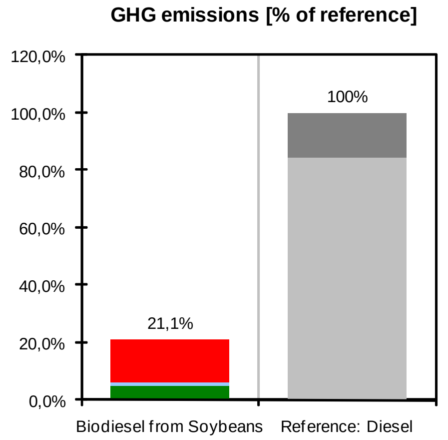


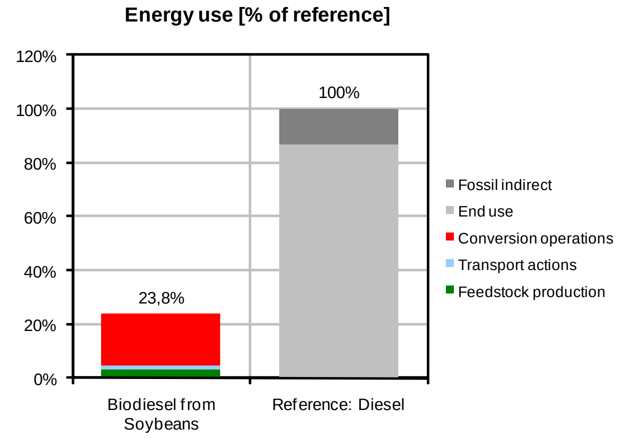
Results for Southern Santa Fe, Venado Tuerto – No Till

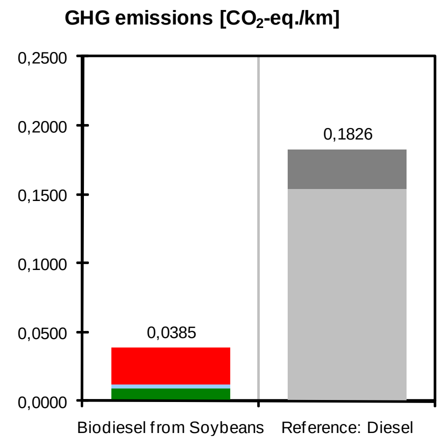
Summary Input		Summary output	Biodiesel from Soybeans				Reference: Diesel			
			Energy use (per km)		GHG emissions (kg/km)		Energy use (per km)		GHG emissions (kg/km)	
			(MJ)	(% of ref.)	(kg CO2-eq.)	(% of ref.)	(MJ)	(%)	(kg CO2-eq.)	(%)
Biofuel	Biodiesel	Feedstock production	0,0745	3%	0,0091	5%				
Feedstock	Soybeans	Transport actions	0,0343	1%	0,0024	1%				
Reference	Diesel	Conversion operations	0,4627	19%	0,0270	15%				
Print summary results		End use					2,0800	87%	0,1541	84%
Show detailed results		Fossil indirect					0,3224	13%	0,0285	16%
		Total	0,5715	23,8%	0,0385	21,1%	2,4024	100%	0,1826	100%
Return to input		**% Reduction**		**76,2%**		**78,9%**				**0%**
		GHG emission (kg CO2-eq/MJ LHV fuel)			**0,0185**				**0,0878**	
		Avoided emission (tonne CO_2/ha/yr)			**2,1**					

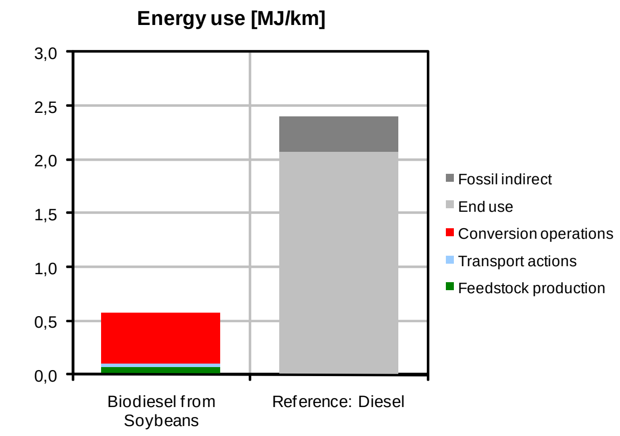
Biofuels greenhouse gas calculator

Developed by Ecofys Netherlands and CE Delft / Commissioned by SenterNovem









Results for Northern Bs.As./Santa Fe, Pergamino – No Till

Summary Input		**Summary output**	Biodiesel from Soybeans				Reference: Diesel			
			Energy use (per km)		GHG emissions (kg/km)		Energy use (per km)		GHG emissions (kg/km)	
			(MJ)	(% of ref.)	(kg CO2-eq.)	(% of ref.)	(MJ)	(%)	(kg CO2-eq.)	(%)
Biofuel	Biodiesel	Feedstock production	0,0518	2%	0,0052	3%				
Feedstock	Soybeans	Transport actions	0,0290	1%	0,0020	1%				
Reference	Diesel	Conversion operations	0,4627	19%	0,0270	15%				
Print summary results										
		End use					2,0800	87%	0,1541	84%
Show detailed results		Fossil indirect					0,3224	13%	0,0285	16%
		Total	0,5435	22,6%	0,0342	18,7%	2,4024	100%	0,1826	100%
Return to input		**% Reduction**		**77,4%**		**81,3%**				**0%**
		GHG emission (kg CO2-eq/MJ LHV fuel)			**0,0164**				**0,0878**	
		Avoided emission (tonne CO_2/ha/yr)			**1,8**					

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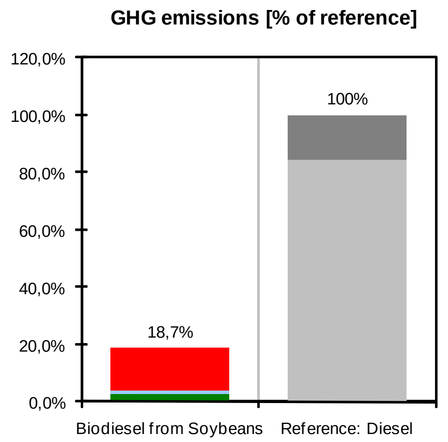
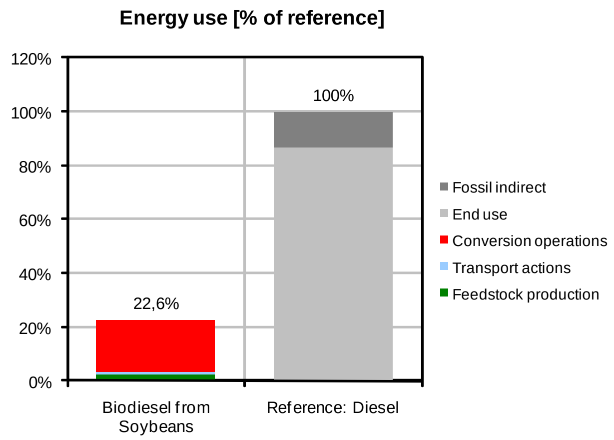
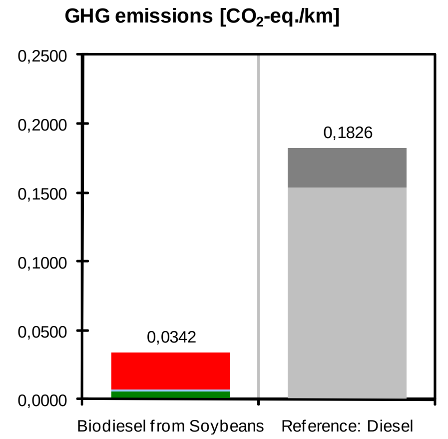
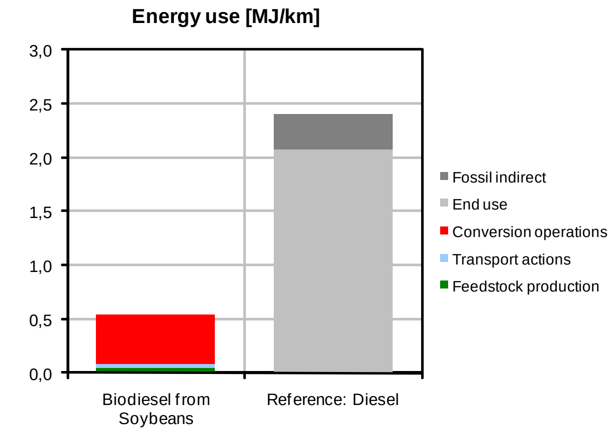
ECOFYS SenterNovem





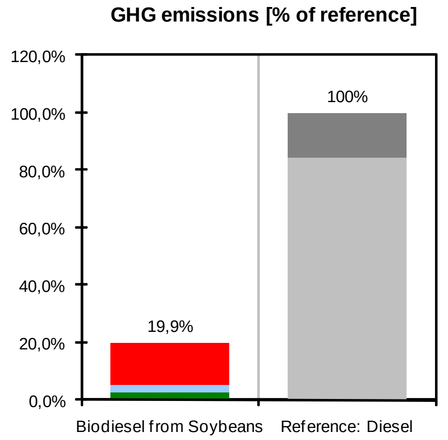


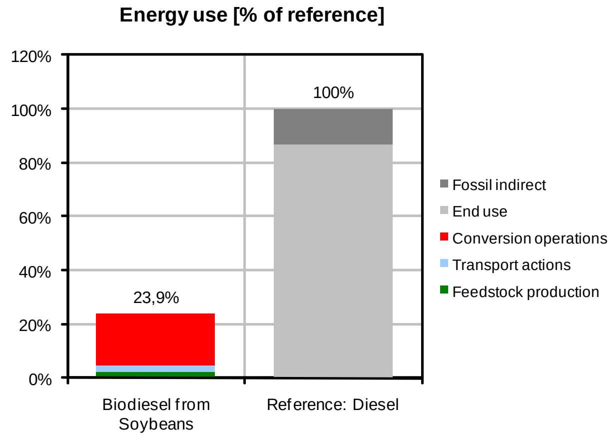


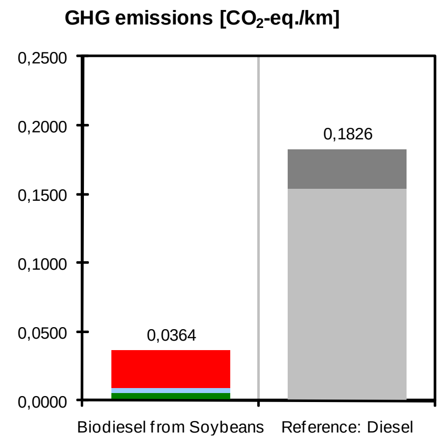
Results for Western Buenos Aires, Pehuajó – No Till

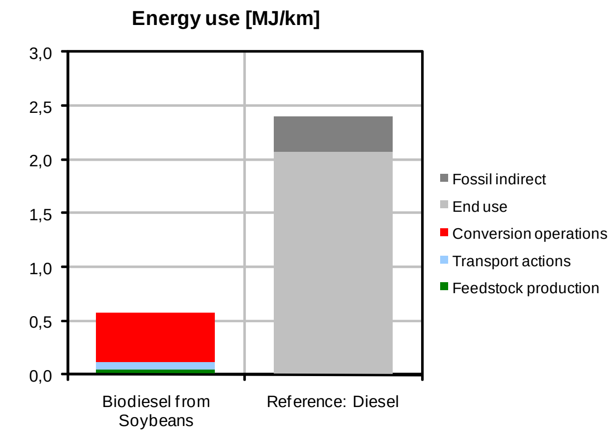
Summary Input		**Summary output**	Biodiesel from Soybeans				Reference: Diesel			
			Energy use (per km)		GHG emissions (kg/km)		Energy use (per km)		GHG emissions (kg/km)	
			(MJ)	(% of ref.)	(kg CO2-eq.)	(% of ref.)	(MJ)	(%)	(kg CO2-eq.)	(%)
Biofuel	Biodiesel	Feedstock production	0,0518	2%	0,0052	3%				
Feedstock	Soybeans	Transport actions	0,0600	2%	0,0041	2%				
Reference	Diesel	Conversion operations	0,4627	19%	0,0270	15%				
Print summary results		End use					2,0800	87%	0,1541	84%
Show detailed results		Fossil indirect					0,3224	13%	0,0285	16%
		Total	0,5745	23,9%	0,0364	19,9%	2,4024	100%	0,1826	100%
Return to input		**% Reduction**		**76,1%**		**80,1%**				**0%**
GHG emission (kg CO2-eq/MJ LHV fuel)					**0,0175**				**0,0878**	
Avoided emission (tonne CO_2/ha/yr)					**1,7**					

Biofuels greenhouse gas calculator
Developed by Ecofys Netherlands and CE Delft / Commissioned by SenterNovem









Results obtained for Salta (Las Lajitas) – No Till

Summary Input		**Summary output**	Biodiesel from Soybeans				Reference: Diesel			
			Energy use (per km) (MJ)	(% of ref.)	GHG emissions (kg/km) (kg CO2-eq.)	(% of ref.)	Energy use (per km) (MJ)	(%)	GHG emissions (kg/km) (kg CO2-eq.)	(%)
Biofuel	Biodiesel	Feedstock production	0,0464	2%	0,0032	2%				
Feedstock	Soybeans	Transport actions	0,1328	6%	0,0092	5%				
Reference	Diesel	Conversion operations	0,4627	19%	0,0270	15%				
Print summary results		End use					2,0800	87%	0,1541	84%
Show detailed results		Fossil indirect					0,3224	13%	0,0285	16%
		Total	0,6419	26,7%	0,0394	21,6%	2,4024	100%	0,1826	100%
Return to input		**% Reduction**		**73,3%**		**78,4%**				**0%**
GHG emission (kg CO2-eq/MJ LHV fuel)					**0,0189**				**0,0878**	
Avoided emission (tonne CO_2/ha/yr)					**1,3**					

Biofuels greenhouse gas calculator
Developed by Ecofys Netherlands and CE Delft / Commissioned by SenterNovem