EKONERG Institute, Ltd.

IEA Bioenergy
Task 38 Case Study

Title:

Assesment of the GHG reduction potentional through biodiesel in Croatia in the context of JI

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NTL of IEA Bioenery Task 38

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1. BACKGROUND AND OBJECTIVES

The Republic of Croatia became a party to the United Nations Framework Convention on Climate Change (UNFCCC) in 1996, by parliamentary Decree on Ratification (Official Gazette # 55/1996). Pursuant to that Decree, the Republic of Croatia has under Article 22 of the Convention undertaken the commitments outlined in Annex I as a country undergoing the transitional process to a market economy. Croatia has thus committed itself to maintain emissions of greenhouse gases at their 1990 levels.

The Republic of Croatia is also a signatory of the Kyoto Protocol. Upon its entering into force and its ratification by Parliament, Croatia shall commit to reduce its emissions of greenhouse gases by 5 percent in relation to the reference year, over the commitment period from 2008 to 2012 [4].

Baseline Year (1990)
In 1990, the total emissions of GHG in Croatia were 31,608,900 t CO_2-eq (the net emissions – sources and sinks were 25,103,700 t CO_2-eq). The contribution share of individual GHG to the total emissions in 1990 are: CO_2 contributed with 72.7 percent to the aggregate greenhouse gas emissions, N_2O with 12.3 percent, CH_4 with 12.0 percent and synthetic gases with 3.0 percent. [2]

In the total 1990 emissions, the energy sector contributed with 71.0 percent (emission from fossil fuels in traffic sector are about 12 percent), industrial processes with 12.3 percent agriculture with 13.7 percent and waste management with 3.0 percent.

Specific Croatian Circumstances under Article 4.6 of Convention
According to Article 4.6 of the Convention, countries with economies in transition have a certain degree of flexibility in meeting their commitments to the Convention, including the selection of base year emission.

Croatia has a low level of per capita emissions of GHG, practically the lowest amongst developed countries in transition. In 1990 year per capita emissions in Croatia were 6.6 t CO_2 eq. Croatia submitted a request to the UNFCCC to take into account specific situation with determining the base year for the Convention and Kyoto Protocol [4]. A request has also bee submitted for the increase of the limit of country specific value of removal by sinks which is adopted on COP9 in Milan, Italy. The negotiation regarding energy sector is still ongoing. Final request of Croatia is to increase base year for 4.46 million of tons of CO_2 above standard approach for defining base year emission) (Figure 1.1.) [4]. If the negotiations will end successfully result would be ratification of the Kyoto protocol in Croatian parliament.

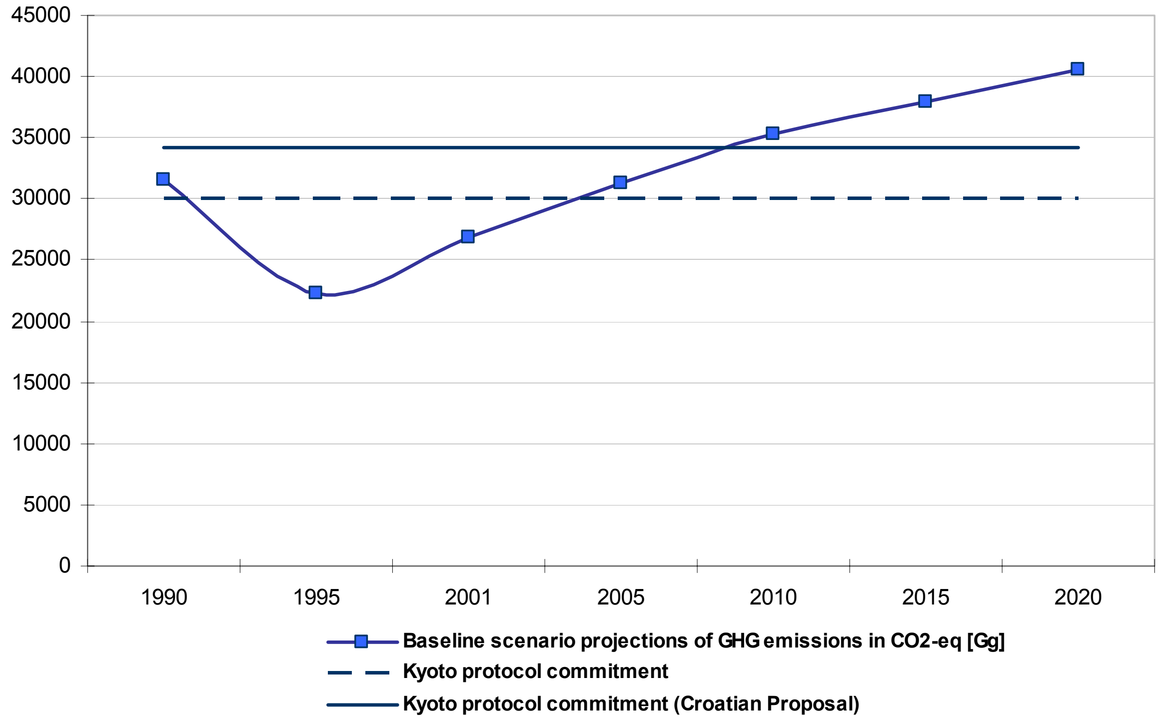


Figure 1.1: Kyoto commitments and baseline GHG emission projections [3]

The possibilities and implications of meeting the Convention and the Kyoto Protocol have been analysed in the First National Communication and during the development of Second National Communication [4],[3]. A total of 39 measures have been identified for the reductions in all emission sectors. The utilisation of biomass has the greatest potential among renewable energy sources – in the electricity, household, services and industrial sectors. One of the most promising options with respect to liquid biofuels is the production of biodiesel which could play a significant role in reducing greenhouse gas emissions in Croatia.

Bioenergy position in Croatia

The policies encouraging renewable energy use in the Republic of Croatia are based on the National energy programmes launched in 1997 by the Government of Croatia. *BIOEN* is the National energy programme for utilisation of biomass and waste for energy production. Its objective is that by 2030 at least 15% of Croatian total energy consumption will be covered from biomass and waste [4].

The national strategy of Croatia recommends adopting an integrated approach to the development in the different sectors: agriculture, energy, environment, tourism, etc. In that regard and as part of the BIOEN programme, the project *Introduction of biodiesel in the Republic of Croatia* was launched in the year 2000 [5] . This introduction is considered as a means to:

- increase the security of energy supply since Croatia is heavily dependent on imported oil and gas;
- use degraded or less fertile land, and to increase agricultural productivity;
- meet Croatian commitment to reducing greenhouse gas emission;
- enhance the tourism industry by emphasizing environmentally conscious approaches;
- increase the sectoral productivity and employment rate;

- protect the environment by recycling waste, especially edible waste oils.

Objectives of the study
The objectives of the study are:

- analyse the life cycle GHG emissions for biodiesel for this project and for wider use of biodiesel in Croatia
- emission avoidance compared to a baseline scenario without introduction of this renewable fuel
- benefits related to the energy balance of biodiesel
- to analyse the possibilities of producing biodiesel in the framework of Joint Implementation including costs of GHG mitigation through use of biodiesel.

2. APPROACH AND PREDEFINITIONS

A life cycle analysis of passenger cars/tractors with internal combustion engine and urban (city) busses with liquid bio-fuel (biodiesel) and fossil fuels is made to compare the overall greenhouse gas emissions of both systems for transportations on national scale (Figure 2.1.). [11] Only one bioenergy system to supply biofuels like biodiesel from rapeseed is analysed for the Croatian situation in 2005., 2010. and 2020. For one transportation fossil fuel based on oil like diesel, the same approach is taken such that the emissions and costs can be compared. According to National Biodiesel project **rapeseed** (*Brassica napus L.sspp.oleifera*) is preferred crop to be used for biodiesel production.

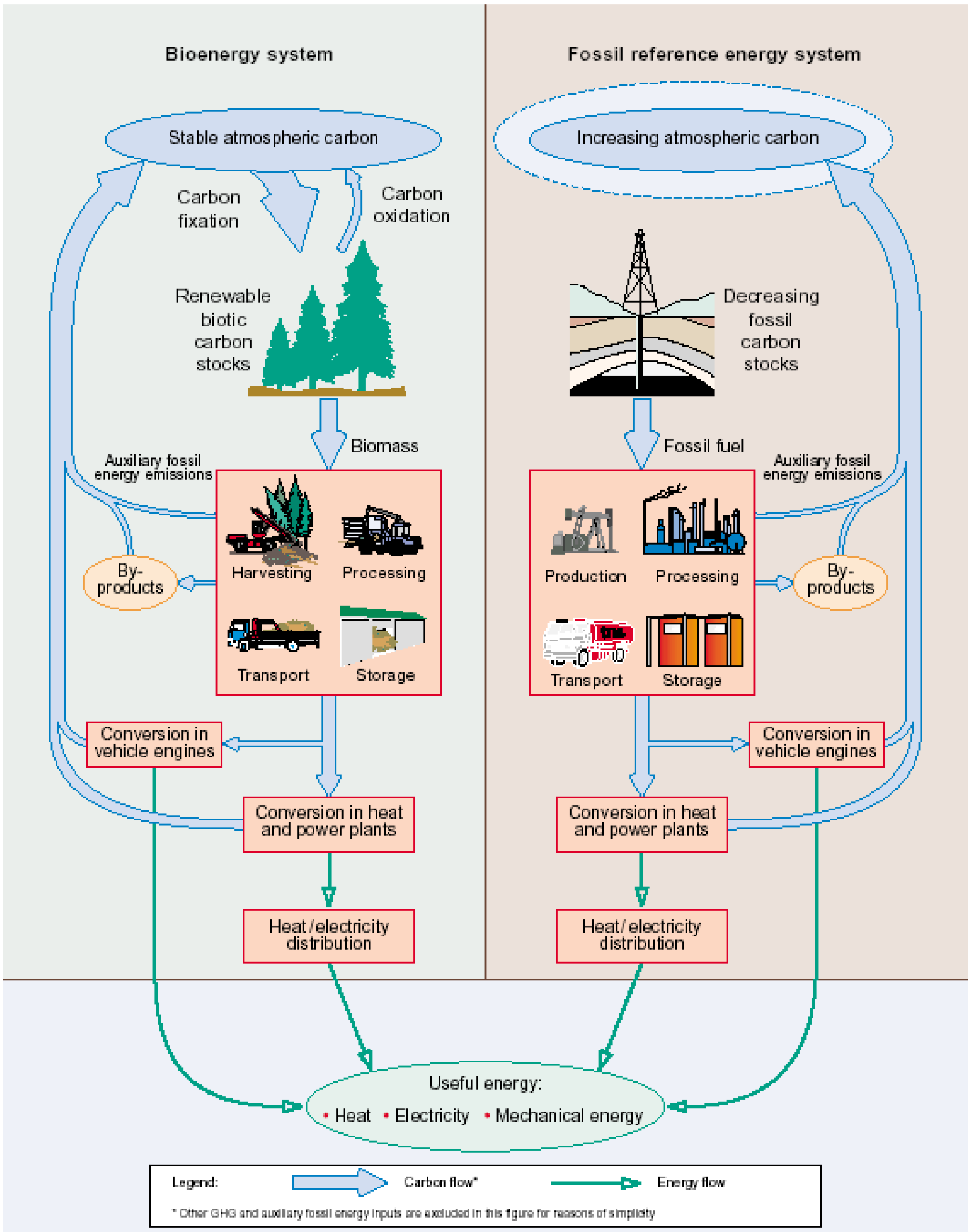


Figure 2.1: General standard methodology for calculation of GHG balance [11]

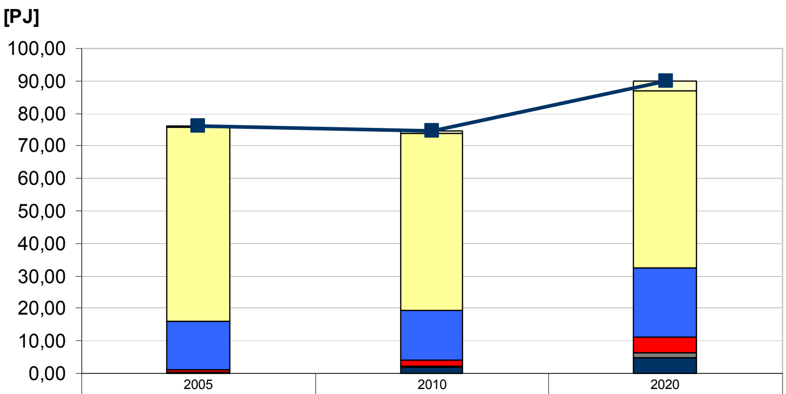
2.1. SCENARIOS

<u>Baseline Scenario</u>

In this case study, which involves the assessment of biodiesel use on national level, it seemed most appropriate to look at the scenarios established by the Energy sector development strategy [4]. On the basis of so called “S1 scenario” from the national Energy strategy, the national team of experts made the so called “With measures” scenario within the study for the purposes of “Second National Report of Republic of Croatia to the UNFCC”. [1] This scenario was chosen as a baseline scenario Croatian negotiations process and for this case study.

The scenario is based on the presumption of moderate introduction of new technologies into the business and relatively slow introduction of reforms and restructuring in energy sector on national level. Nevertheless, this scenario does not represent a completely frozen future situation in respect to the last decade. It also includes certain improvements to the present situation in terms of renewable energy resources penetration and efficiency increase. In favour of that stands the fact that The Energy Sector Development Strategy is an adopted policy document and there are approximately 30 regulatory documents which support its implementation, of which five will regulate use of renewable energy and energy efficiency.[4]

In the study for “Second National Report of Republic of Croatia to the UNFCC” the scenario taken as a baseline here is widely described and consists of many information and data about energy consumption projections and GHG emissions from all possible sectors in Croatia. The data taken from the scenario for the purposes of this study refers to biodiesel energy demand projections in year 2005, 2010 and 2020. Figure 2.1., presents renewable energy resource structure, according to the baseline scenario, including the projections for biodiesel.



	2005	2010	2020
Biodiesel	0,35	0,69	2,97
Hydro pow er	59,80	54,27	54,34
Biomass	14,67	15,48	21,22
Solar energy	0,77	1,78	4,82
Wind Energy	0,15	0,50	1,55
Geothermal energy	0,34	1,75	4,90
Total	76,08	74,47	89,80

Figure 2.1: Renewable energy resource structure [3]

As it can be seen on the figure, baseline scenario predicts introduction of biodiesel in Croatia in 2005 followed by moderate increase of biodiesel consumption in next fifteen years. The mineral based motor fuels production is going to grow acccording to projections from 77.35 PJ in 2005, through 90.1 PJ in 2010 and up to 117.93 PJ in 2020. [3] The quantities of motor fuels and biodiesel production in transport sector according to baseline scenario are given in the Table 2.1.

According to projections, the majority of produced biodiesel is going to be consumed in transport sector, so the share of biodiesel in transport sector consumption would increase up to 2.22% in year 2020 as it can be seen from Table 2.2.

Table 2.1: Quantities of biodiesel and motor fuels production in transport sector

Year	2005	2010	2020
Production of biodiesel in transport sector [t]	7547	15364	72237
Production of motor fuels in transport sector [t]	1771223	2063182	2700456

Table 2.2: Share of biodiesel in transport sector according to baseline scenario

Year	2005	2010	2020
Share of biodiesel in transport sector	0,36%	0,63%	2,22%

Scenario "With additional measures"

This scenario consists of the biodiesel production projections also taken from the one of the scenarios developed for the purposes of "Second National Report of Republic of Croatia to the UNFCC". It assumes that the climate change and sustainable development concept shall cause significant change in orientation of the overall Croatian industry and economy. As its name tells, this scenario takes into account potential additional measures for GHG emissions reduction. Most important measures are following :

- Construction of 300 MW of installed power in power plants on renewable energy sources (wind farms, small hydro, CHP on biomass)
- Increase of efficiency in electricity distribution
- Increase of efficiency of heat production and introduction of CHP in industrial sector
- Change of structure of transport sector including increase of public transport on account of cars and increase of railway on account of road traffic. From the perspective of energy demand, increase of share of electricity, and biodiesel on account of mineral based motor fuels
- Increase of use of solar and geothermal energy as well as CHP in the services sector, including also increase in the insulation of the buildings.
- Moderate increase of gas consumption in the households sector with simultaneous increase in use of new technologies (solar collectors, biomass combustion, small CHP) and better heat insulation.

Considerable effects of these measures are expected beyond the year 2010. More intensive development in use of bio fuels, particularly biodiesel, is recognised as one of the most important measures in transport sector. According to this scenario, the increase in use of biodiesel is going to happen after 2005 with a faster rate of introduction of biodiesel fuel than in the case of baseline scenario. The quantities of biodiesel and motor fuels production in transport sector according to this scenario are given on Table 2.3.

Table 2.3: Quantities of biodiesel and motor fuels production in transport sector

Year	2005	2010	2020
Production of biodiesel in transport sector [t]	7547	37197	175741
Production of motor fuels in transport sector [t]	1771223	2044634	2393841

The production of biodiesel as well as production of biodiesel and motor fuels in transport sector expressed in energy units according to this scenario is presented on the Table 2.4.

Table 2.4: Production of biodiesel and share of biodiesel in transport sector according to "With measures" scenario

Year	2005	2010	2020
Production of Biodiesel [PJ]	0,35	1,50	6,81
Production of Biodiesel in transport sector [PJ]	0,28	1,38	6,52
Production of motor fuels in transport sector [PJ]	77,35	89,29	104,54
Share of biodiesel in transport sector	0,36%	1,52%	5,87%

Maximum potential scenario

According to biodiesel project within the framework of National Energy Program (BIOEN) maximal land use for cultivation of oil rape in Croatia is estimated to approximately 400 000 ha. [5] This was the starting point in determination of the Maximum potential scenario.

It has to be noted that the surface of 400 000 ha is an only a potential which cannot be reached in a short period of time. In that sense, scenario used in this case study assumes gradual introduction of oil rape cultivation for the needs of biodiesel production. It also assumes that the maximal potential is going to be reached in 2020. Comparison with the baseline scenario and "With additional measures" scenario is given in the Table 2.5.

Table 2.5: Land used for cultivation of oil rape

Year	2005	2010	2020
Maximal potential scenario [ha]	10000	100000	400000
Scenario "With additional measures" [ha]	8717	37358	169608
Baseline scenario [ha]	8717	17185	73970

Given the values of specific land use per tonne of biodiesel produced and lower heating value of biodiesel, it is possible to calculate the quantity of biodiesel produced expressed in energy units:

Specific land use per tonne of biodiesel	0,924	$ha/t_{biodiesel}$ [6]
Lower heating value of biodiesel	37,1	$MJ/kg_{biodiesel}$

	2005	2010	2020
Production of biodiesel [PJ]	0,40	4,02	16,06

According to that, the motor fuels production given in baseline scenario would decrease in case of maximum potential scenario as presented in Table 2.6.

Table 2.6: Production of biodiesel and share of biodiesel in transport sector according to maximum potential scenario

Year	**2005**	**2010**	**2020**
Production of Biodiesel [PJ]	0,40	4,02	16,06
Production of Biodiesel in transport sector [PJ]	0,33	3,90	15,77
Production of motor fuels in transport sector [PJ]	77,30	86,77	95,29
Share of biodiesel in transport sector	0,43%	4,30%	14,12%

The quantities of biodiesel and motor fuels production in transport sector according to the maximal potential scenario are given on Table 2.7.

Table 2.7: Quantities of biodiesel and motor fuels production in transport sector

Year	**2005**	**2010**	**2020**
Production of biodiesel in transport sector [t]	8895	105121	425067
Production of motor fuels in transport sector [t]	1770078	1986929	2182027

It was assumed that additional biodiesel produced according to both “with additional measures” and maximal potential scenario would replace the same quantity of mineral based diesel in transport sector.

Figure 2.2., presents the comparison between production (consumption) of biodiesel in case of “Baseline”, “With additional measures” and “Maximal potential” scenario expressed in energy units.

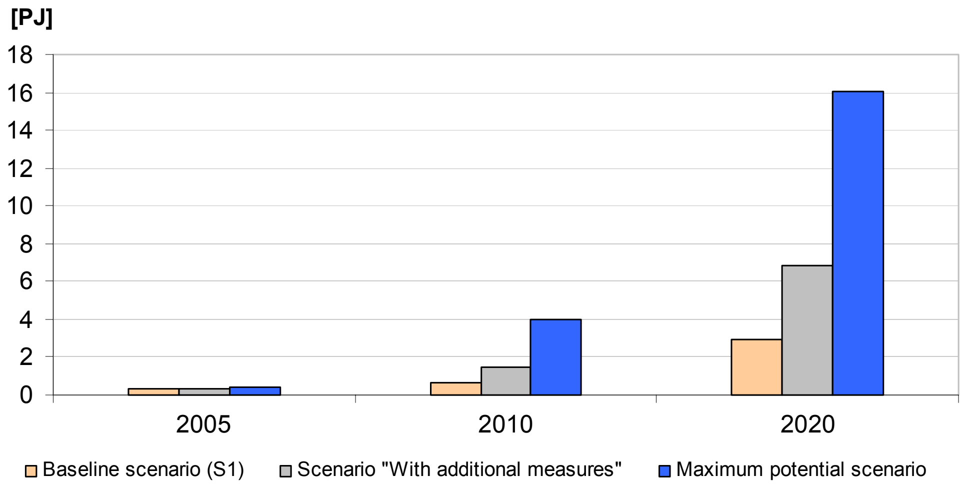


Figure 2.2: Production of biodiesel expressed in energy units

The quantities of biodiesel produced according to all three scenarios are presented on Table 2.8.

Table 2.8: Production of biodiesel according to baseline scenario, “with additional measures scenario” and maximum potential scenario

Year	2005	2010	2020
Baseline scenario [t]	9434,0	18598,4	80053,9
Scenario "With additional measures" [t]	9434,0	40431,3	183558,0
Maximal potential scenario [t]	10822,5	108225,1	432900,4

According to Table 2.8., the same quantity of biodiesel produced would replace mineral based diesel.

3. METHODOLOGY AND RESULTS

3.1. GHG EMISSIONS BALANCE FOR BIOENERGY AND FOSSIL REFERENCE SYSTEM

Biodiesel is used as a motor fuel in vehicles and machines with internal combustion engines which normally use a mineral based diesel.

According to IPCC, when calculating the GHG emissions in transport sector, the main assumption is that the emissions from the systems using biomass are equal to zero. [7] Namely, carbon which is absorbed from the atmosphere in the process of photosynthesis equals the amount of CO_2 emitted during the conversion in the vehicles. However, the lifecycle of biodiesel is not completely free of GHG emissions. Cultivation of rape, transport and biodiesel production require additional energy from fossil fuels that has to be included in the overall emissions balance within the lifecycle. During the biodiesel production process some by-products are created: cake in the process of pressing and glycerol in the process of esterification. Overall emissions depend on their final use and have to be included in the lifecycle emissions assessment.

The total emissions of greenhouse gases (CO2, N2O, CH4) over entire life cycle are calculated. The Global Warming Potential for 100 years:

- 1 CO_2 =1 CO_2
- 1 CH_4 = 23 CH_4
- 1 N_20 = 296 N_20

was used. The costs were analysed based on economic comparison of the total transportation costs with biodiesel and diesel. The methodology used is recommended and was developed by IEA Bioenergy Task 38. The methodology allows a complete comparison of the GHG and economics between current and future transportation systems based on fuels from biomass and from oil or other fossil fuels.

For the purposes of this study it was assumed that the biodiesel produced in Croatia will be used in different sectors (agriculture, energy). It is presumed that for agriculture sector biodisel will be widely used by tractors, forestry machinery etc. Regarding energy sector, biodiesel will be used by busses in public transport and passenger cars with internal combustion engines. The GHG emissions balance assessment was done by using the GEMIS model (**G**lobal **E**mission **M**odel of **I**ntegrated **S**ystems) developed in Öko-Institut in Darmstadt, Germany. [10] Its main advantage is that it can calculate the specific emissions by taking into consideration the whole lifecycle of the examined system, in this case use of biodiesel in busses, cars and/or tractors. Estimations for cars and tractors are the same, and in the following text there is no difference between them. For the purpose of this study an extensive Austrian data base of different processes which occur in industry, agriculture, transport, power generation etc. as well as products of these processes is used due to insufficient national data. These processes can be combined in to a large number of different scenarios each of them representing the system which is going to be investigated in terms of GHG and other air emissions. These scenarios, or systems, than can be compared. In that respect, two scenarios on national scale were made; one to compare reference fossil systems and bioenergy system in case of biodiesel use in busses and one to compare reference fossil system and bioenergy system in case of biodiesel use in cars/tractors. Each of the scenarios consisted of three chains.

Chains in the scenario considering biodiesel use in busses:

- Bus diesel (Bus/DI)
- Bus biodiesel, energy use of by-products (Bus/ME/RA/EU)
- Bus biodiesel, material use of by-products (Bus/ME/RA/MB)

Chains in the scenario considering biodiesel use in cars/tractors:

- Cars/tractors (Car/DI)
- Cars/tractors, energy use of by-products (Car/ME/RA/EU)
- Cars/tractors, material use of by-products (Car/ME/RA/EU)

The lifecycle of biodiesel use includes:

- Cultivation of oil rape
- Transport, drying and storage
- Pressing
- Transestering (production of metilester ME – biodiesel)
- Transport of biodiesel to the filling station and filling the biodiesel into the vehicles
- Combustion of biodiesel in vehicles.

Following data were used from Croatian data base:

- Area of cultivation
- Electricity mix
- Amount of fertilizer used for the cultivation
- Production of oil
- Transportation distances
- Type of vehicle

The results of the calculation within the GEMIS model are expressed in kilograms of CO_2 equivalent referring to 1km driven. Figure 3.1., presents the GHG emissions life cycle of the fossil fuel system and biodiesel system in CO_2 equivalent in the case of biodiesel use in public transport busses in Croatia.

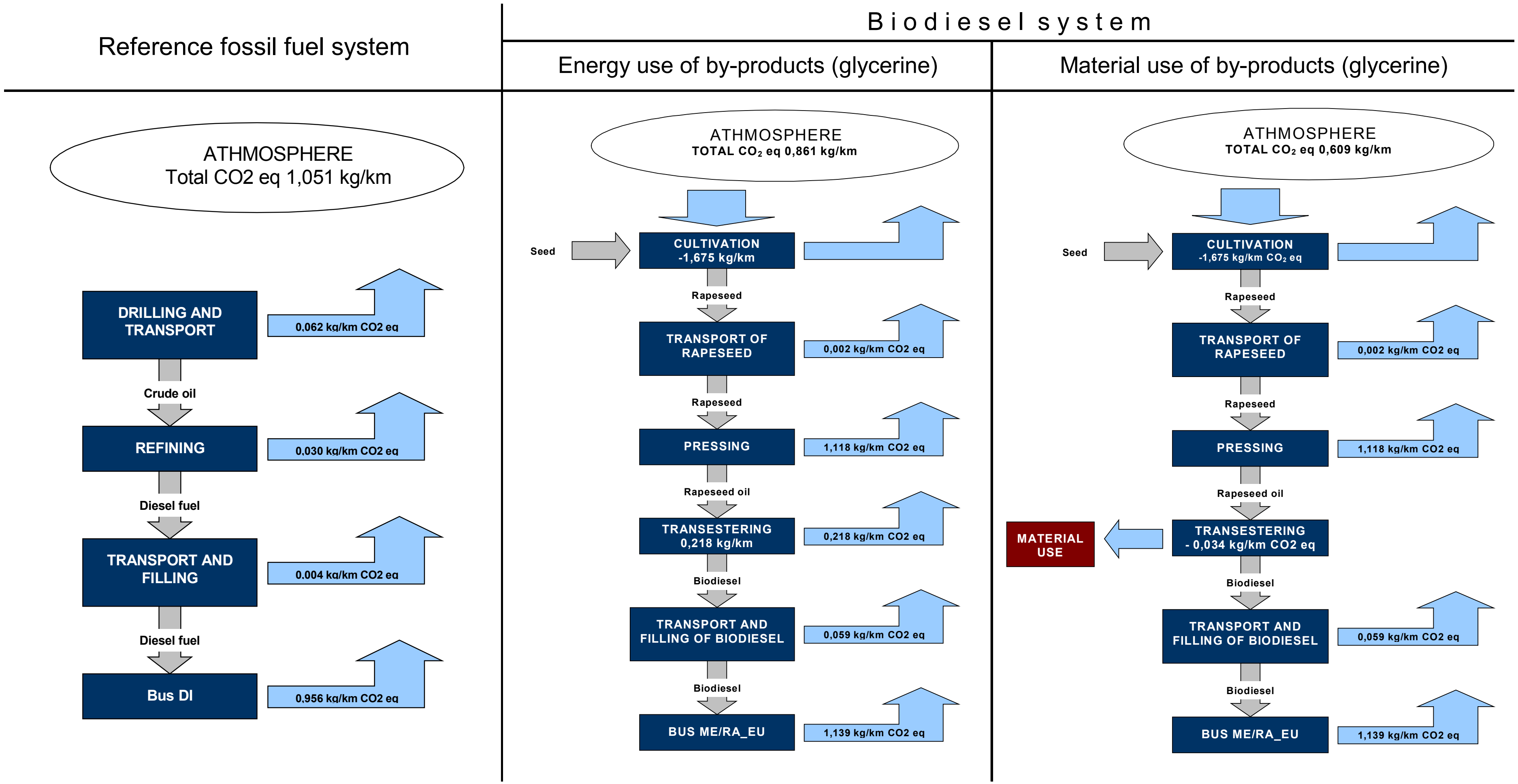


Figure 3.1: Reference system and biodiesel system flowcharts in terms of GHG emissions for the biodiesel use in busses

Overall balance of GHG gases in case of diesel and biodiesel use in city busses and in passenger cars/tractors is given on the Table 3.1.

Table 3.1: Overall balance of GHG gases for Bioenergy system and Fossil Fuel system

Bioenergy system		**Fossil Fuel System**	
Option	Emissions CO_2-eq [kg/km]	Option	Emissions CO_2-eq [kg/km]
Bus metil ester, glycerol-energy use	0,861	Bus diesel	1,051
Bus metil ester, glycerol-material use	0,609		
Car metil ester, glycerol-energy use	0,171	Car diesel	0,205
Car metil ester, glycerol-material use	0,125		
Option	Emissions CH_4 [kg/km]	Option	Emissions CH_4 [kg/km]
Bus metil ester, glycerol-energy use	9,586E-04	Bus diesel	1,234E-03
Bus metil ester, glycerol-material use	4,892E-04		
Car metil ester, glycerol-energy use	2,132E-04	Car diesel	2,608E-04
Car metil ester, glycerol-material use	1,274E-04		
Option	Emissions N_2O [kg/km]	Option	Emissions N_2O [kg/km]
Bus metil ester, glycerol-energy use	1,034E-03	Bus diesel	3,051E-05
Bus metil ester, glycerol-material use	1,028E-03		
Car metil ester, glycerol-energy use	1,956E-04	Car diesel	1,234E-05
Car metil ester, glycerol-material use	1,946E-04		

The comparison of greenhouse gas emissions of cars/tractors with internal combustion engines for biodiesel and fossil fuels are shown in Figure 3.2., referring to 1km driven. The shares of CO2, CH4, and N2O on the total CO2 equivalent emissions are shown. The same comparison is given for busses in Figure 3.3.

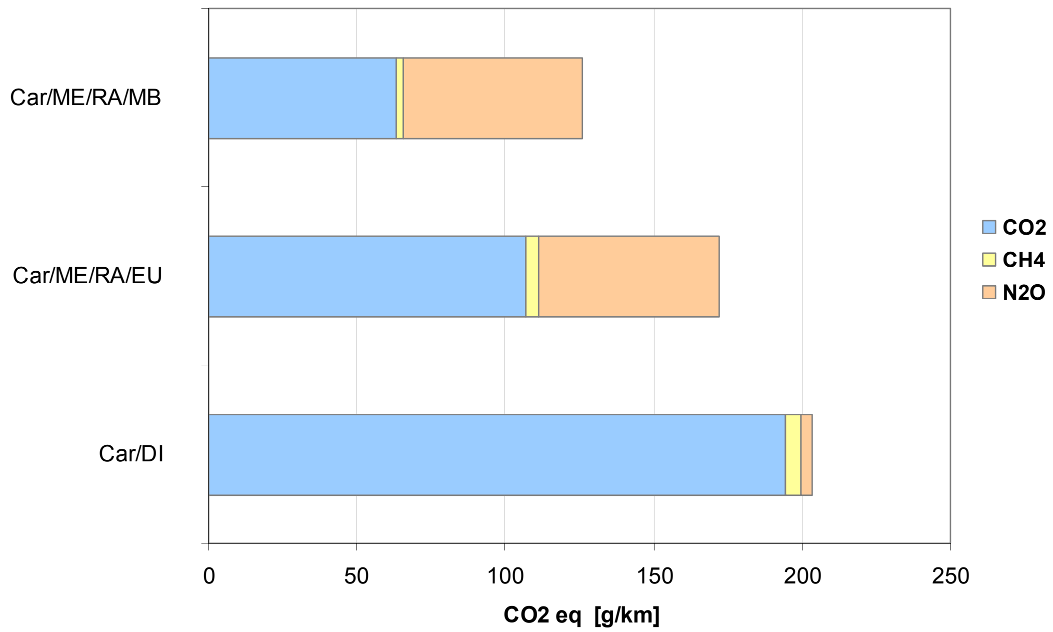


Figure 3.2: Comparison of GHG emissions of cars/tractors with internal combustion engine driven with biodiesel and fossil fuels

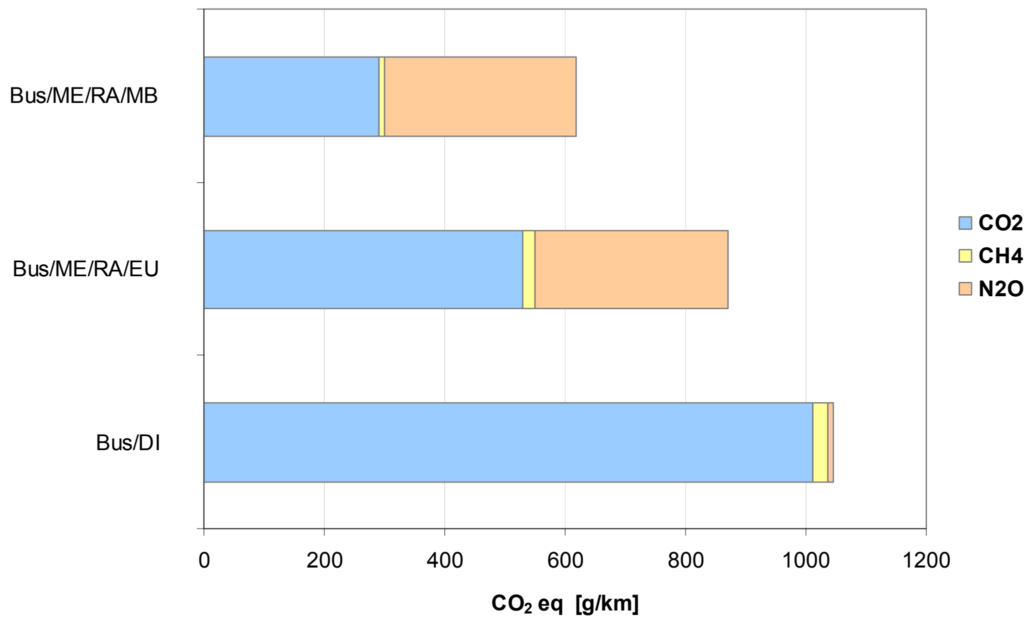


Figure 3.3: Comparison of GHG emissions of city busses with internal combustion engine driven with biodiesel and fossil fuels

The comparison of greenhouse gas emissions demonstrate that vehicles using biodiesel have lower or even much lower greenhouse gas emissions than fossil transportation fuel.

3.2. OVERALL GHG EMISSIONS AVOIDANCE FOR THE DEFINED SCENARIOS

The projections of future biodiesel production in Croatia were given in the three before described scenarios. The lifecycle analysis carried out in the GEMIS model provided the information about the specific GHG emissions of vehicles that would use biodiesel or diesel as a fuel. Knowing that information it is possible to calculate the potential GHG reductions, in other words GHG avoidance in case of using biodiesel as a fuel according to the aforementioned scenarios.

The Lower heating value of biodiesel was set as 14.5 percent lower than the lower heating value of mineral based diesel. Also, the fuel consumption of vehicles using biodiesel was assumed as 14 percent higher than the consumption when using mineral based diesel fuel (Table 3.2). These assumptions were also taken into consideration when the GEMIS model analysis was carried out.

Table 3.2: Properties of biodiesel and fossil diesel

	Biodiesel	**Diesel**
Lower heating value [MJ/kg]	37,10	42,50
Specific fuel consumption - buses [MJ/km]	13,56	11,90
Specific fuel consumption - cars [MJ/km]	2,48	2,17

Apart from the assumptions related to the fuel consumption, some additional assumptions were made. Concerning the share of the cars /(tractors) and busses in overall biodiesel consumption, the shares were set in a way that the 50 percent of biodiesel production would be used in busses and the rest 50 percent of biodiesel production would be used in cars/tractors.

As it can be seen from the Figure 3.1., the biodiesel lifecycle, and hence the emissions it created, differ in case of different by-products use. As the official projections about by-product treatment within the process of biodiesel production do not exist within any of the scenarios defined, it was assumed that 50 percent of biodiesel will be produced in the process with the energy use of glycerol and 50 percent of biodiesel will be produced in the process with the material use of glycerol. Regarding cake it was assumed that all cake will be used as animal food.

In order to calculate the potential for GHG emissions reductions it was necessary to calculate the emissions for the two cases, diesel and biodiesel use, in all three scenarios. Basically, the methodology was to calculate the distance that would busses and cars potentially cover with the amount of fuel produced according to the projections in the scenarios. After that followed the multiplication of the distance with the specific GHG emissions calculated with the help of GEMIS for the particular system (bus-diesel, bus-biodiesel, car/tractor-diesel, car/tractor-biodiesel). The result is the amount of GHG emissions expressed in CO_2 equivalent for each of the scenarios, as presented in the Table 3.3.

Table 3.3: GHG emissions in CO2 eq for each of scenarios for both systems

Emissions of GHG in CO_2 equivalent [kt]			
Year	2005	2010	2020
Baseline scenario - Diesel use	36,59	72,13	310,47
Baseline scenario - Biodiesel use	19,90	39,23	168,84
"With additional measures" scenario - Diesel use	36,59	156,80	711,89
"With additional measures" scenario - Biodiesel use	19,90	85,27	387,14
Maximal potential scenario scenario - Diesel use	41,97	419,73	1678,92
Maximal potential scenario scenario - Biodiesel use	22,83	228,26	913,04

The lifecycle analysis carried out in GEMIS showed that the use of biodiesel clearly results in lower specific GHG emissions than the use of mineral based diesel. This also means that the use of biodiesel results in potential GHG emissions reduction regardless of the scenario considered. The baseline scenario assumes the lowest biodiesel production, hence the lowest GHG reductions if the produced biodiesel substitutes mineral based diesel. The two other scenarios assume higher biodiesel production and thus higher GHG reductions. (Table 3.4.).

Table 3.4: Emission reduction potential CO2 eq

Emission reduction potential in CO_2 equivalent [kt]			
Year	2005	2010	2020
Scenario "With additional measures"	0,00	38,63	183,12
Maximal potential scenario	2,46	158,57	624,25

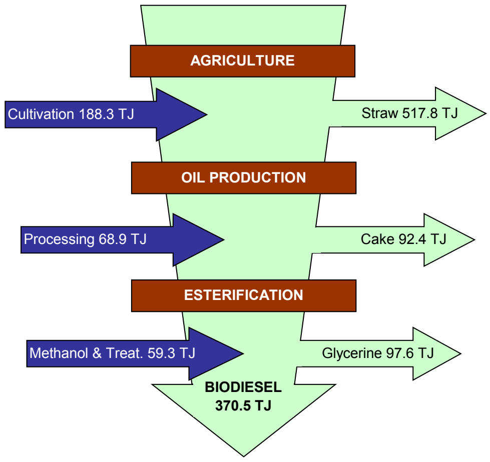
3.3. ENERGY AND MASS BALANCES

In this study we track several types of energy and mass flows through all three scenarios. Energy and mass balances are calculated according data from study *Introducing the biodiesel fuel production in Republic of Croatia* [5].

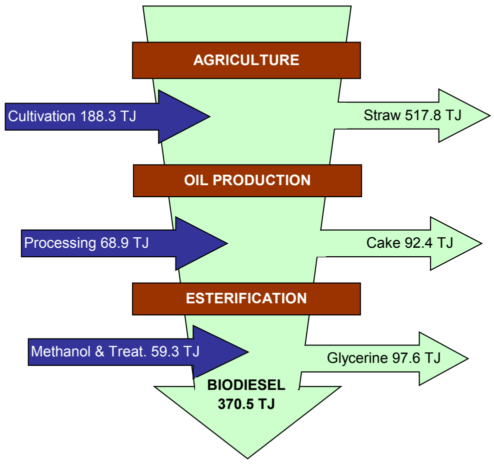
<u>Energy balance of biodiesel production</u>

Energy balance of biodiesel production shows that the energy output is approximately 3.4 times higher than energy input. Namely, on 36.3 GJ of energy input per a hectare of cultivated land surface, the energy output is 123.7 GJ per hectare, which includes all by-products: biodiesel, straw, cake and glycerol. If energy balance only includes biodiesel as a final product, without energy use of by-products, the energy output would be 42,5 GJ which is around 17 percent higher than overall energy input [5], [8].

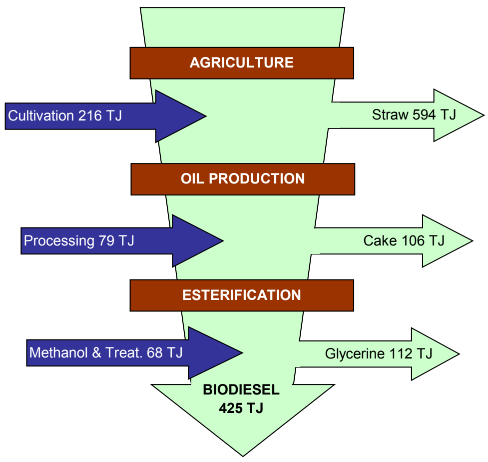
Energy balance for defined scenario options (year 2005)



baseline scenario

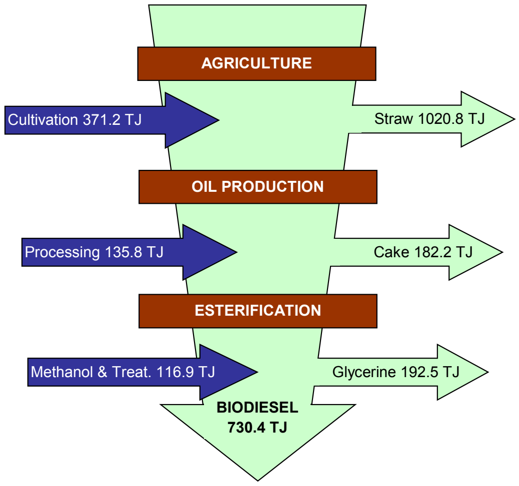


with additional measures

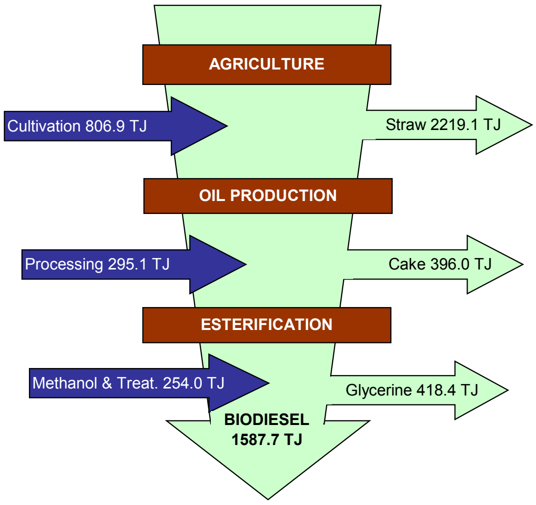


maximum potential scenario

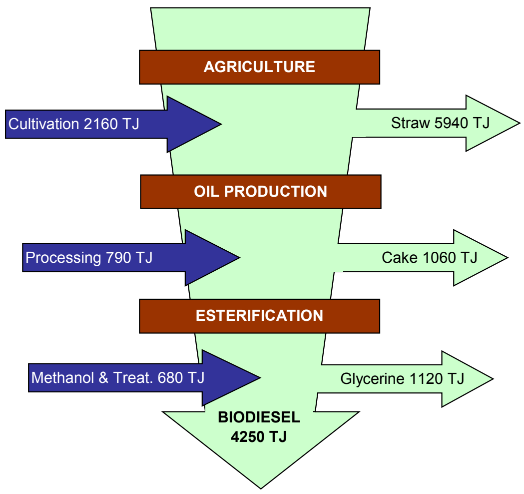
Energy balance for defined scenario options (year 2010)



baseline scenario

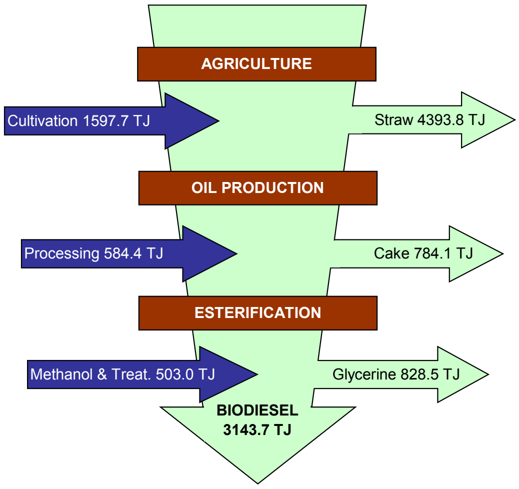


with additional measures

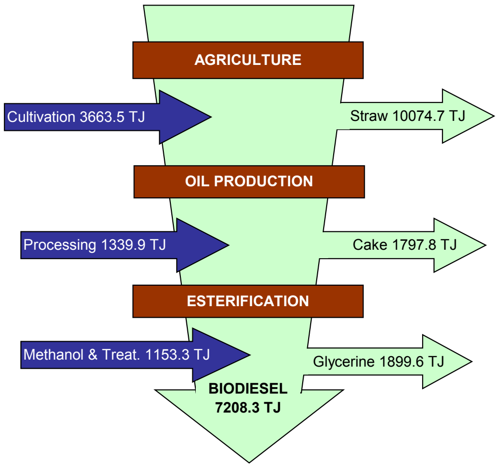


maximum potential scenario

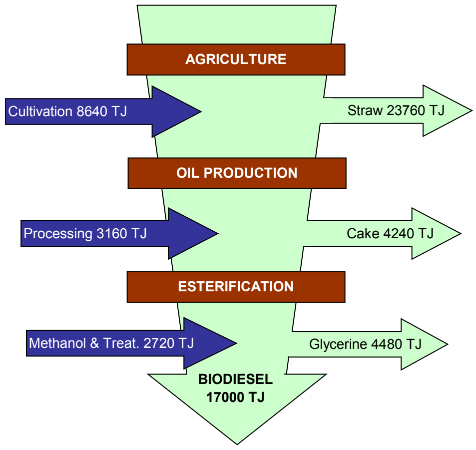
Energy balance for defined scenario options (year 2020)



baseline scenario



with additional measures

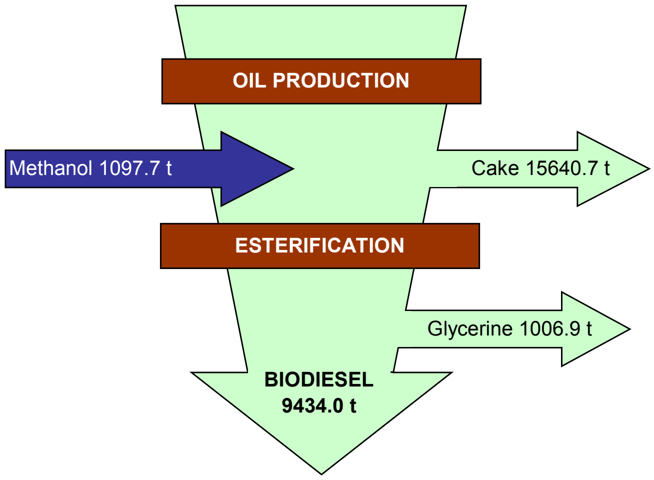


maximum potential scenario

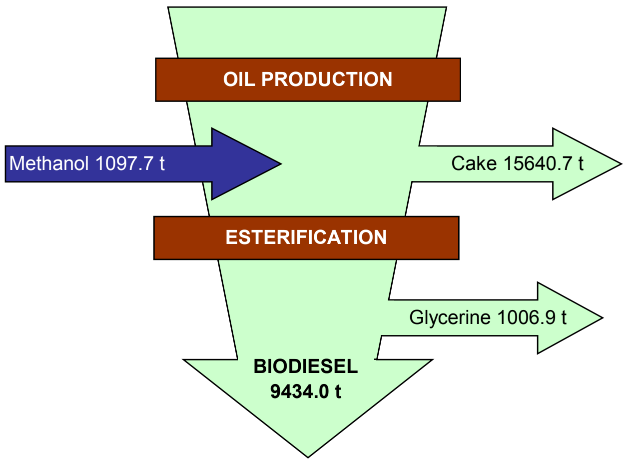
<u>Mass balance of biodiesel production</u>

Mass balance of biodiesel production shows that there is much more mass output than input. This is mainly because of the rape cultivation process and its characteristics (relatively small mass of seeds grows into manifold bigger mass of rape crops). The only significant mass input is methanol needed in the proces of esterification (transestering) with 0.116kg per 1kg of biodiesel produced. [5]

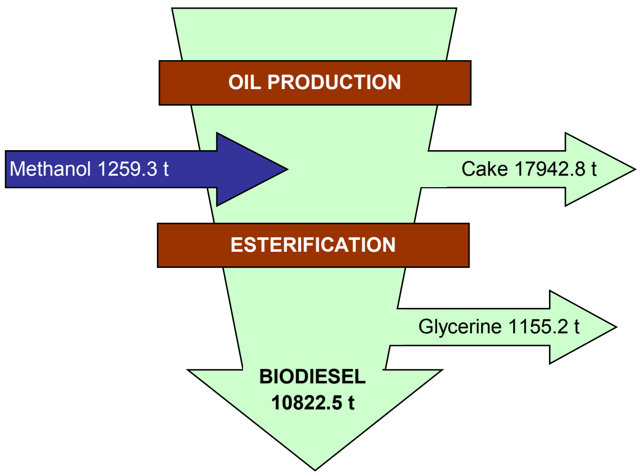
Mass balance for defined scenario options (year 2005)



baseline scenario

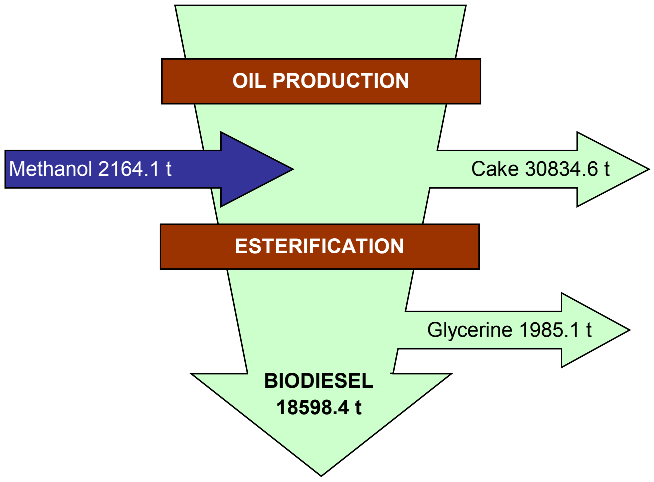


with additional measures

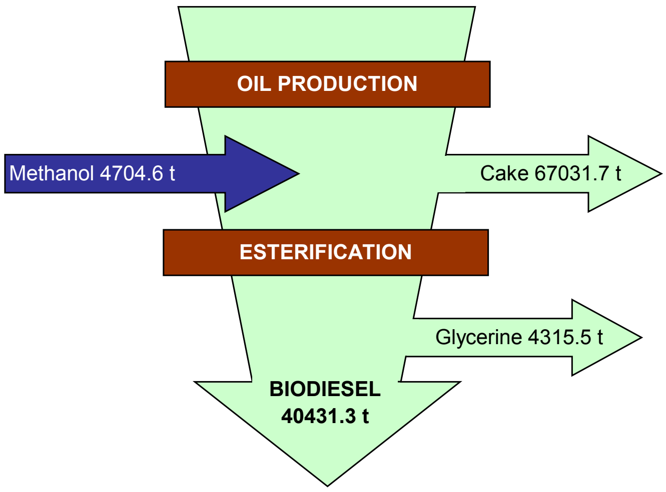


maximum potential scenario

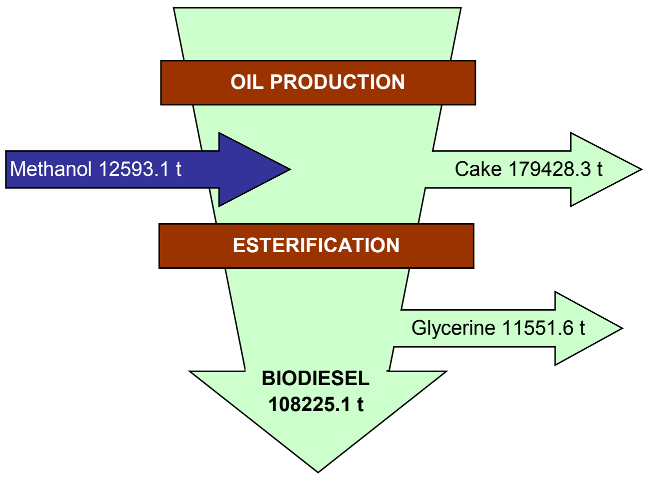
Mass balance for defined scenario options (year 2010)



baseline scenario

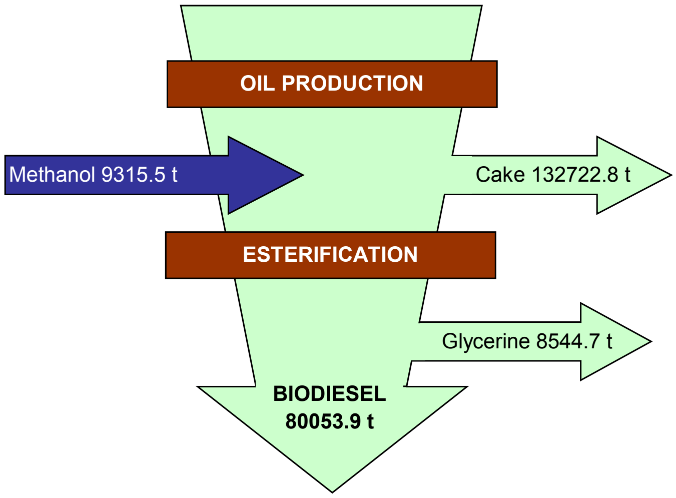


with additional measures

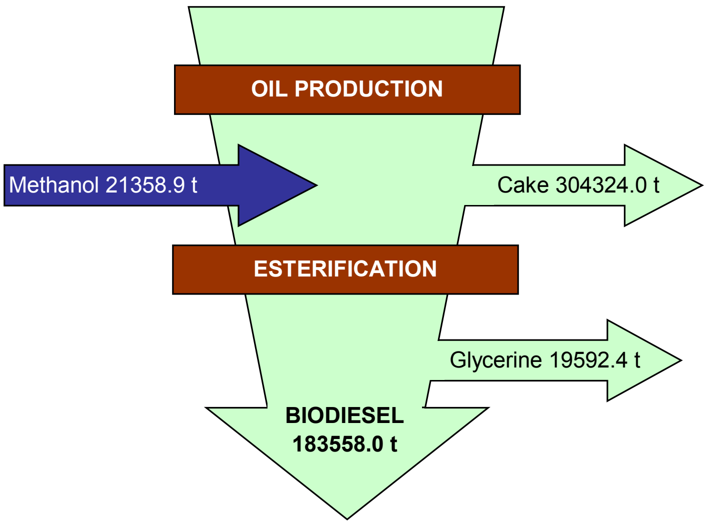


maximum potential scenario

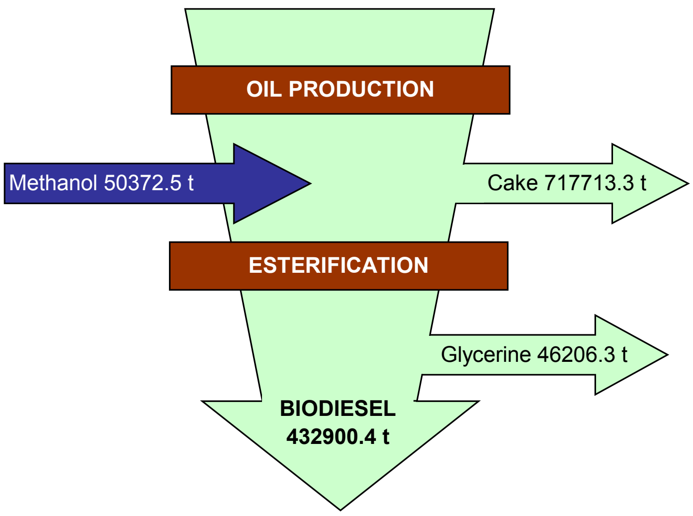
Mass balance for defined scenario options (year 2020)



baseline scenario



with additional measures



maximum potential scenario

3.4. POSSIBILITIES OF PRODUCING BIODIESEL IN THE FRAMEWORK OF JI

Basic idea of the introducing a Joint Implementation mechanism was a possibility of more cost effective and flexible way to comply with the Kyoto protocol commitments because of the differences in emission reduction costs in particular countries. Joint implementation projects result in *emission reduction units* (ERUs) which can then be used by investing Annex I parties to help meet their emission targets.

The Republic of Croatia, as a party included in the Annex I to the Convention, has the possibility to participate in the greenhouse gas emission reduction projects by the Joint Implementation mechanism. At this moment, the main barrier in implementation of the emission reduction projects by Joint Implementation mechanism is the unresolved issue of the base year for Croatia. Namely, the strategy for the implementation of the Kyoto mechanisms in the Republic of Croatia depends on how the base year issue will be resolved under the Convention. For the moment The Republic of Croatia has signed a Memorandum of Understanding (MoU) on co-operation only with the Kingdom of the Netherlands. These two countries intend to co-operate in reducing emission of greenhouse gases under Article 6 of the Kyoto Protocol (REF JI). [9]

List of companies/local authority bodies interested in implementing CO_2 emission reduction measures through biodiesel use is given on Table 3.5. [9]

Table 3.5: List of companies/local authority bodies interested in implementing CO_2 emission reduction measures

Measure	Company/local authority interested
Use of biodiesel	Grad Zagreb - City of Zagreb
	Grad Osijek - City of Osijek
	Polet d.d. Vinkovci - Transport company
	Županijska komora Vukovar - Croatian Chamber of Economy, subsidiary Vukovar

On the basis of emission reduction potential for Scenario «with additional measures» and maximum potential scenario, emission reduction potential for Kyoto commitment period (2008 - 2012) is calculated. (Table 3.6)

Table 3.6: Emission reduction potential for Kyoto comitment period in CO_2 equivalent [kt]

Emission reduction potential for Kyoto comitment period in CO_2 equivalent [kt]						
Year	2008	2009	2010	2011	2012	Total
Scenario "With additional measures"	13,91	24,37	38,57	47,22	57,00	181,08
Maximal potential scenario	67,95	107,69	158,52	188,50	221,73	744,38

From the results of this study it can be concluded that there is a potential for implementation of GHG emission reduction through biodiesel projects in Croatia by the Joint Implementation mechanism. Before implementation there are few issues to be resolved:

- the base year issue
- ratify the Kyoto Protocol
- establish the legislative framework
- establish institutional and organisational framework
- create emission allocation plan.

3.5. COSTS OF GHG MITIGATION THROUGH THE USE OF BIODIESEL

The costs were analysed based on economic comparison of the total transportation costs with biodiesel and diesel.

According to feasibility study *Introducing the biodiesel fuel production in Republic of Croatia* production cost of biodiesel from raps without subsidiaries from Government would be between 0,86 -1,0€/l. In the Republic of Croatia there is still no production of biodiesel and consequently biodiesel is not available at filling station. Production costs for diesel are about 0, 69€/l and is influenced by exchange rate of € to kuna. All the calculation were made according to exchange rate 1€ = 7,54 kuna.

The comparison of the fuel production costs for biodiesel and diesel in the case that biodiesel is available at the filling station is shown in Figure 3.7. Because of high uncertainty regarding production costs of biodiesel in Croatia , two options are taken in consideration:

- Option I – production cost of biodiesel = 0,86€/l
- Option II - production cost of biodiesel = 0,93€/l

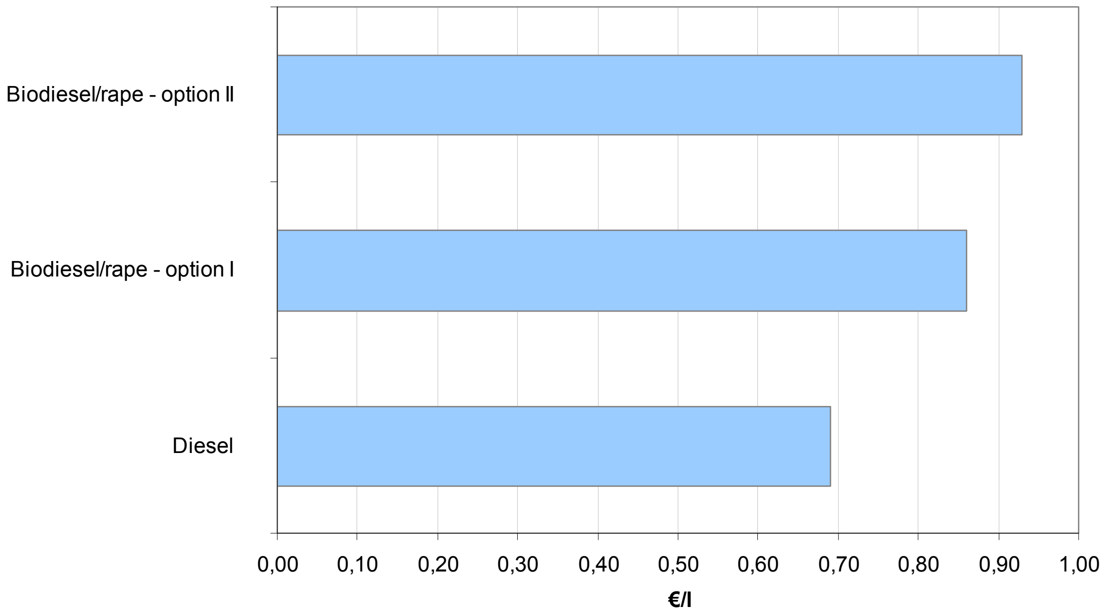


Figure 3.7: Comparison of production costs for biodiesel and diesel

The combination of GHG emissions and transportation cost result in the mitigation costs for greenhouse gas reduction, given in € per avoided tonne of CO_2-equivqlent. The mitigation costs of replacing diesel by biodiesel are shown in Table 3.7.

Table 3.7: Mitigation costs for greenhouse gas reduction with biodiesel in the transportation sector

	€/tCO2 equivalent avoided	Substituted fossil system (Diesel)
Biofuel system	Biodiesel/rape - option I	243
	Biodiesel/rape - option II	327

The mitigation costs per avoided greenhouse gas unit for two different price options of production of biodiesel in Croatia are little bit higher what is to be in industrialised countries.

4. CONCLUSIONS

This study provides information on the life cycle greenhouse gas emissions and costs of use biodiesel in Croatia in the context of Joint Implementation.

The Republic of Croatia is a signatory of the Kyoto Protocol. Upon its entering into force and its ratification by Parliament, Croatia shall commit to reduce its emissions of greenhouse gases by 5 percent in relation to the reference year, over the commitment period from 2008 to 2012. The implementation of the Convention's and Kyoto Protocol's commitments will be an extremely difficult task for Croatia, perhaps even beyond its capacities. A total of 39 measures have been identified for the reductions in all emission sectors. The utilisation of biomass has the greatest potential among renewable energy sources – in the electricity, household, services and industrial sectors. One of the most promising options with respect to liquid biofuels is the production of biodiesel which could play a significant role in reducing greenhouse gas emissions in Croatia.

The results of this study demonstrate, that use of biodiesel in transportation sector in Croatia have much lower greenhouse gas emissions than use of fossil fuels made from oil, and that enhanced use of biodiesel in transportation sector can contribute to meet Croatia's greenhouse gas reduction goal. The mitigation costs of replacing diesel by biodiesel are in the range from 243-327€ per avoided tonne of CO_2-equivqlent. The results of the study also demonstrate that there is a potential for implementation of GHG emission reduction through biodiesel project in Croatia by the Joint Implementation mechanism. The main barrier in implementation of this project in the context of Joint Implementation mechanism is the unresolved issue of the Croatian base year.

The results of this study may help policy makers for the greenhouse relevant evaluation of biodiesel project in Croatia and the compilation of reduction scenarios in the connection with the Kyoto Protocol.

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