Tomislav Kurevija

ISSN 0350-350X
GOMABN 46, 2, 103-127
Pregledni rad / Review
UDK 665.334.9.094.942 : 665.353.4.094.942.003.1.001.6 : (100)

NEGATIVNI EKOLOŠKI UČINCI GLOBALNE PROIZVODNJE BIODIZELSKOG GORIVA

Sažetak

Količina fosilnog goriva koje čovječanstvo danas utroši tijekom jedne godine sačinjena je od organske materije koja je sadržavala 44×10^{15}kg ugljika, što je 400 puta veća količina u odnosu na trenutačnu biološku godišnju proizvodnu kvotu organske materije našega planeta. Ovako velika potrošnja fosilnih goriva dovela je do uvođenja biogoriva kao jednog od alternativnih izvora energije, koje je nužno za smanjenje ovisnosti o fosilnim ugljikovodicima i emisije ugljičnog dioksida u atmosferu. Stoga je Europska unija odredila cilj o povećanju udjela biogoriva na 5,75 % u transportnom sektoru do 2010. godine. Biodizel se često naziva čistim, ekološkim i obnovljivim gorivom ali ako se cijela situacija promatra globalno, biodizel bi se također mogao nazvati i jednim od najopasnijih izvora energije za Zemljin ekosustav. Glavna opasnost od znatnog povećanja korištenja biogoriva dolazi zbog krčenja šuma kako bi se osiguralo neophodno tlo za uzgoj različitih usjeva. Svake godine velike površine tropskih prašuma Jugoistočne Azije i Južne Amerike nepovratno su izgubljene zbog potražnje transportnog sektora za biogorivom. Milijuni hektara šuma zadnjih su godina pretvoreni u plantaže palmi i šećerne trske, ugrožavajući tako ekosustav i opstanak mnogih životinjskih i biljnih vrsta. Krčenje šuma najčešće se provodi izazivanjem požara i isušivanjem prašumskih tresetnih močvara. Izgaranje drveta i oksidacija treseta tijekom sušenja uzrokuje oslobađanje ogromnih količina ugljičnog dioksida u atmosferu, što je u suprotnosti s nazivom biodizela kao "CO_2 uravnoteženog goriva". Stoga, svaki energetski proces i alternativno gorivo prije globalne uporabe mora biti promatrano i valorizirano kroz 4E princip: ekološki, energetski, ekonomski i edukacijski.

1. Uvod

Uporaba biodizela u dizelovim motornim vozilima odvija se već dulji niz godina, ali ozbiljnija implementacija i promocija u EU razvija se značajnije tek u zadnjih pet do deset godina. Razlog tomu je djelomično i politika EU glede smanjenja CO_2 emisija sukladno Kyoto protokolu, te shvaćanju da iskorištavanje biodizela ne emitira dodatne količine CO_2 (zbog uravnoteženja emitiranog CO_2 rastom uljarica) osim prilikom procesa transporta i proizvodnje biomase te gotovog proizvoda. Različite studije pokazale su da uporaba 1 kg biodizela dovodi do smanjenja otprilike 3 kg CO_2 emisija u odnosu na fosilni dizel, ako se promatra cjelokupni proces [11]. U sklopu Kyoto protokola, zemlje članice EU obvezale su se na smanjenje CO_2 emisija za 8 % do 2010., u odnosu na referentnu 1990. godinu. Također, EU Direktiva 2003/30/EC obvezuje zemlje članice EU da postignu volumni udjel biogoriva od 2 % u ukupnom gorivu plasiranom na tržište do 31. prosinca 2005. Ovaj postotak mora se povećavati godišnje za 0,75 % do zadanog cilja od 5,75 % u 2010. godini [7]. Prije Kyoto protokola, porast korištenja energije predviđen je sa 1,366 Mtoe u 1995. godini na 1,583 Mtoe u 2010. (Europska komisija, 1998). Ovakav porast potražnje za energijom predviđa se opskrbiti posve obnovljivim izvorima energije, povećavajući njihov udjel s 8,1 % u 1995. na 14,6 % u 2010. [2]. Stoga, znatno povećanje korištenja biogoriva zahtijeva pažljivo razmatranje svih ekoloških utjecaja.

Tablica 1: Smjernice implementacije uporabe alternativnih goriva u EU prema Europskoj komisiji u 2001. [2]

Godina	Biogoriva	Prirodni plin	Vodik	Ukupno
2005.	2%			2%
2010.	6%	2%		8%
2015.	7%	5%	2%	14%
2020.	8%	10%	5%	23%

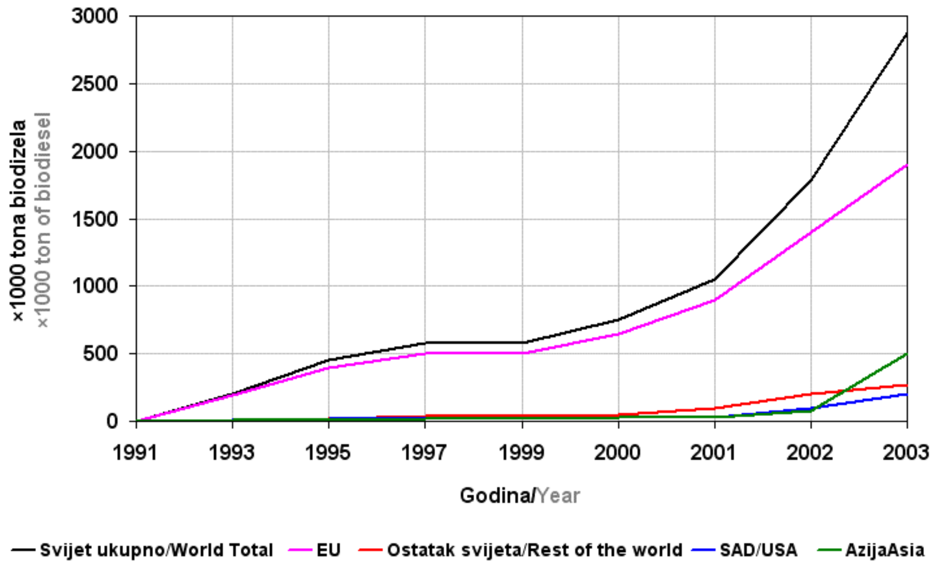
Dok su pozitivne strane biodizelskog goriva kao što su smanjenje CO_2 emisije u fazi izgaranja goriva evidentne, negativni indirektni učinci prilikom proizvodnje biodizela kao što su krčenje šuma, opasnost od smanjenja biodiverziteta, zagađenja zemlje i vode nitratima, fosfatima i pesticidima mnogo su kompleksniji te također imaju globalni utjecaj na ekosustav.

2. Proizvodnja i uvoz biodizelskog goriva u EU

Trenutačno zemlje proizvođači biogoriva u EU imaju malen udio u odnosu na globalnu proizvodnju biogoriva, otprilike nešto manje od 6 %, a većina proizvodnje biogoriva sastoji se od proizvodnje etanola (SAD i Brazil). Međutim, EU je najvažniji proizvođač biodizela na globalnom tržištu. Od 1993. godine, proizvodnja biodizela se u EU povećala gotovo deset puta, sa 80 000 proizvedenih tona do 780 000 tona u 2001., pa sve do 3 184 000 tona u 2005. (tablica 2) [2]. Njemačka je vodeća EU zemlja u proizvodnji biodizela, zatim slijede Francuska, Italija i Češka. Diljem EU biodizel se upotrebljava u automobilima sa dizelskim motorom u mješavinama različitih omjera s fosilnim dizelom, a u Njemačkoj, Austriji i Švedskoj također se upotrebljava i u čistoj formi u prilagođenim vozilima javnog prijevoza.

Proizvodnja biodizela u EU trenutačno zauzima oko 1,4 milijuna hektara obradive površine te postoji otprilike 40 postrojenja za preradu koja godišnje proizvedu oko 3184000 tona. Oko 12 %, od ukupno na tržište plasiranog biodizela, uvozi se iz jugoistočne Azije (Malezija i Indonezija) u obliku sirovine palminog ulja.

Slika 1: Svjetska proizvodnja biodizelskog goriva od 1991. do 2003. [6]



3. Nacionalni programi i ciljevi zemalja članica EU glede proizvodnje biodizelskog goriva

Iako je važnost implementacije biogoriva u transportnom sektoru istaknuta u dokumentima EU pod nazivom *White Paper on Renewable Sources of Energy* (1997) i Green Paper: Towards a European strategy for the security of energy supply (2000), u mnogim zemljama članicama EU nije došlo do kreiranja i pokretanja nacionalnih programa. U Njemačkoj je, na primjer, biogorivo izuzeto od plaćanja poreza te oslobođeno ekoloških taksi. Prvi nacrt Direktive 2003/30/EC obvezuje zemlje članice EU na prodaju biodizela na domaćim tržištima u utvrđenim postocima u razdoblju od 2005.-2010., dok je drugim nacrtom Direktive dana smjernica za oslobađanje poreza biogoriva, kako bi se snizila jedinična prodajna cijena i biodizel učinio kompetitivnijim u odnosu na fosilni.

Zbog različitih problema kao što su limitirani nacionalni potencijali za proizvodnju uljarica, gubitak državnih potpora, preusmjeravanje poticaja u druge svrhe ili visokog troška proizvodnje, više od polovice zemalja EU nije ispunilo zadani cilj u 2005. od 2,0 % volumnog udjela biodizela u ukupnom tržištu fosilnog dizela.

Tablica 2: Proizvodnja i uvoz biodizelskog goriva u EU tijekom 2005. [6] [11]

Zemlja Country	**Proizvodnja biodizela u 2005. Production of biodiesel in 2005 (×1000 tona)**	**Proizvodni kapacitet u 2005. Production capacity in 2005 (×1000 tona)**	**Udio biodizela u ukupnoj potrošnji dizela Share of biodiesel in diesel consumption in 2005 (%)**
Njemačka/Germany	1669	2681	2,00
Francuska/France	492	775	2,00
Italija/Italy	396	857	2,00
Češka/Czech Republic	133	203	3,03
Poljska/Poland	100	150	-
Austrija/Austria	85	134	2,50
Slovačka/Slovakia	78	89	2,00
Španjolska/Spain	73	224	2,00
Danska/Denmark	71	81	0,00
Ujedinjeno Kraljevstvo/UK	51	445	0,30
Slovenija/Slovenia	8	17	
Estonija/Estonia	7	20	0,00
Litva/Lithuania	7	10	2,00
Latvija/Latvia	5	8	2,00
Ostale EU zemlje Other EU MemberStates	9	375	-
UKUPNO / TOTAL	3184	6069	1,50
Uvoz palminog ulja iz JI Azije Imports of palm oil from South East Asia	≈ 500	-	-

Tablica 3: Pregled nacionalnih ciljeva pojedinih zemalja članica EU za 2005. [6]

Zemlja Country	Udio biodizela na tržištu Biodiesel market share		
	2003. (%)	2004. (%)	2005. (%)
Austrija/Austria	-	-	2,50
Cipar/Cyprus	0	-	-
Češka/Czech Republic	2,10	2,20	3,03
Danska/Denmark	0	0	0
Estonija/Estonia	0	0	0
Finska/Finland	0,10	-	0,10
Francuska/France	-	1,60	2,0
Njemačka/Germany	1,40	-	2,0
Grčka/Greece	0	-	-
Mađarska/Hungary	-	-	0,5
Irska/Ireland	-	-	0,06
Latvija/Latvia	0,30	1,25	2,0
Litva/Lithuania	-	-	2,0
Malta	0,02	-	-
Nizozemska/Netherlands	0	0	-
Portugal	0	-	1,0
Slovačka/Slovakia	0,24	0,50	2,0
Španjolska/Spain	1,09	-	2,0
Švedska/Sweden	1,80	2,0	3,0
Ujedinjeno Kraljevstvo/United Kingdom	-	-	0,30

4. Globalni ekološki problem masovne proizvodnje biodizelskog goriva iz palminog ulja

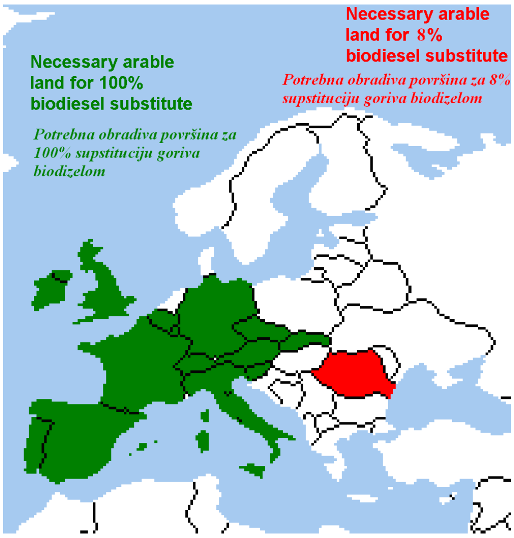
Korištenje biogoriva stvara dilemu u pogledu stvarne ekološke koristi kada se sustav proizvodnje i korištenja promatra globalno. Povećanje potražnje za biogorivom u odnosu na fosilni dizel korisno je u pogledu smanjenja emisije stakleničkih plinova poradi izgaranja samog goriva, ali poradi trenutačnog modela pretvorbe velikih površina u plantaže za proizvodnju uljarica posebice u JI Aziji, kako bi se zadovoljila svjetska potražnja, neizbježno je krčenje šumskih prostora. Europska unija trenutačno je u deficitu potrebne količine biodizela kako bi se zadovoljio utvrđeni cilj, s obzirom da više od polovice zemalja nije investiralo pravodobno u izgradnju rafinerija i povećanje proizvodnje uljarica. Problem je također u intenzivnom porastu potrošnje dizelskog goriva u odnosu na motorni benzin zbog politički nestabilne situacije u svijetu i rasta cijena naftnih derivata u zadnjih 5 godina. Stoga je procijenjeno da će biodizel proizveden iz palminog ulja u sljedećih nekoliko godina doseći udio u ukupnoj potrošnji biodizela od čak 25 % na tržištu EU, što će uzrokovati uništavanje jednog od najdragocjenijih predjela tropskih prašuma u svijetu. Razlog povećanja udjela biodizela proizvedenog iz palminog ulja je u većem prinosu po jedinici površine u usporedbi s tradicionalnim uljaricama kao što su uljana repica i soja (tablica 4), kao i u znatno nižim troškovima proizvodnje, što utječe na finalnu cijenu produkta.

Tablica 4: Prinos biodizelskog goriva za različite kulture [11]

Uljarica Oil-bearing plant		Soja Soybean	Uljana repica Rapeseed	Jatropha Curcas	Palma Palm
Prinos biogoriva Yield of biofuel	m³/km²/y	35 - 45	100 - 130	160	580
	bbl/acres/y	0,90 - 1,15	2,55 - 3,30	4,10	14,80
	GJ/km²/y	1 165 - 1 500	3 330 – 4 330	5 330	19 315

Uljana repica još je uvijek dominantna kultura za proizvodnju biodizela na području EU sa udjelom od oko 80 %, ali kompetitivnost energetskog i prehrambenog sektora uzrokovala je porast cijene ulja na 600 €/t u 2005. Istodobno, cijena palminog ulja bila je za oko 33 % jeftinija i iznosila je 400 €/t.

Slika 2: Potrebna obradiva površina za 8% udjela biodizelskog goriva u EU u usporedbi sa 100 %-tnim udjelom u ukupnoj potrošnji dizelskog goriva, prema nasadima uljane repice...



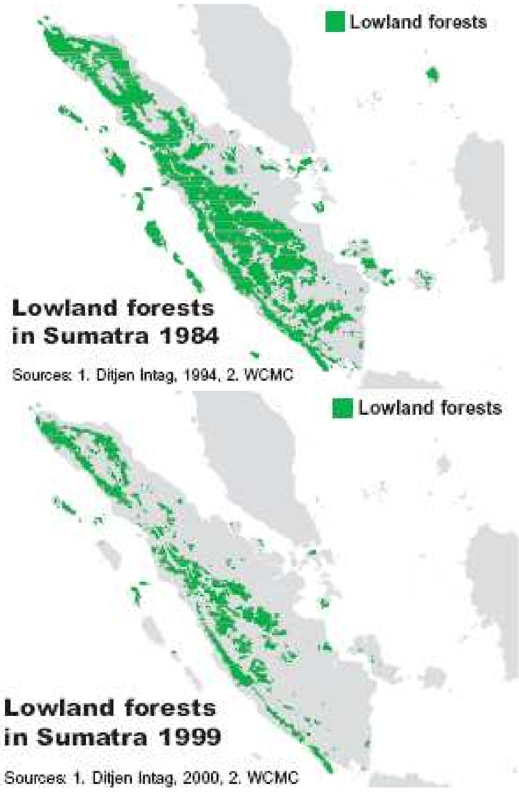
Prikaz veličine površine koja bi bila potrebna kako bi se ostvario cilj supstitucije dijela fosilnog dizela biodizelom prikazan je na slici 2, ako se uzme u obzir tipični prinos uljane repice i trenutačna potrošnja fosilnog dizela u EU. Za cilj od 8 %

supstitucije dizela biodizelom, potrebna bi bila ogromna površina veličinom jednaka Rumunjskoj za uzgoj uljane repice i proizvodnju goriva. Primjera radi, kada bi se supstituirala cjelokupna količina dizela biodizelom više od polovice površine EU bilo bi prekriveno nasadima uljane repice. Ovakve činjenice upućuju na potrebu uvoza sirovine za proizvodnju biodizela iz drugih dijelova svijeta.

4.1. Krčenje šuma u JI Aziji uzrokovano kultivacijom palmi za proizvodnju i izvoz biodizel sirovine u EU

Između 1989. i 2000. površine za uzgoj palmi u Indoneziji utrostručile su se, što je usko povezano sa svjetskim rastom proizvodnje palminog ulja za to razdoblje. U 2003. godini, 75 % od ukupnih 5,2 milijuna hektara palminih plantaža bilo je smješteno na Sumatri te 18 % na Kalimantanu [4]. Sukladno povećanju potražnje za biodizelskim gorivom očekuje se povećanje površine palminih plantaža za četiri puta do 2020. godine, na otprilike 20 milijuna hektara obradive površine u Indoneziji te 10 milijuna hektara u Maleziji.

Slika 3: Prikaz uništavanja indonezijskih prašuma zbog proizvodnje palminog ulja [12]



U razdoblju između 1985.-2000., razvoj palminih plantaža bio je odgovoran za 87 % ukupne iskrčene površine tropskih šuma u Maleziji, dok je ta brojka u Indoneziji iznosila 66 %. Samo u 2004. ukupna površina palminih plantaža dosegnula je 6,5 milijuna hektara, od čega je 4 milijuna hektara nastalo izravnim krčenjem tropske prašume. Trenutačno trend potražnje u svijetu za biodizel gorivom uzrokuje godišnji gubitak od otprilike 2 milijuna hektara tropskih prašuma u Indoneziji, s prenamjenom u plantaže palmi, što je površina ekvivalentna površini Slovenije.

Poslovanje vezano uz proizvodnju palminog ulja često u JI Aziji propagiraju države i tvrtke kao važan ekonomski faktor rasta. Međutim, analize su često jednostrane i najčešće ne uzimaju u obzir značajne ekološke utjecaje kao što su, na primjer, dugoročne posljedice uklanjanja tropskih šuma, najčešće izazivanjem požara, zagađenje zraka i vode te prijetnja opstanku različitih životinjskih i biljnih vrsta. Također, učestala je pojava da veličina iskrčene površine tropske prašume na kraju ne odgovara realnoj zasađenoj površini, ili se plantaže uopće ne zasade, zbog sumnjivih radnji tvrtki povezanih s proizvodnjom ulja iz palmi. Procijenjeno je da bi ukupna površina iskrčenih tropskih šuma u zadnjem desetljeću, zbog prijavljenog poslovanja vezanog uz plantaže palmi, neovisno o tome da li je na kraju doista plantaža zasađena ili ne, mogla premašiti 10 milijuna hektara [12]. Oko 40 % legalne opskrbe drvne industrije potječe izravno od krčenja tropskih šuma zbog nasada palmi. Ako preostala količina drva nije ekonomski isplativa za distribuciju na tržište, izazivanjem šumskih požara nastoji se iskrčiti šumsko prostranstvo. Šumski požari 1997./98. izazvani direktno radi plantaži palmi bili su odgovorni za devastaciju 5 milijuna hektara tropskih šuma i zagađenje zraka diljem Indonezije i Malezije što je dovelo i do napetosti među dvjema državama zbog kvalitete zraka [9].

Tablica 5: Ukupna površina iskrčenih tropskih šuma i buduće aktivnosti (u milijunima hektara)[12]

Zemlja Country	**Površina palminih plantaža 2001. Palm plantation area**	**Iskrčena šuma zbog nasada palmi 2002. Forest area cleared for palm oil**	**Ciljana površina nasada u 2003. Targeted oil palm area**	**Dodatna površina u planu iza 2004. Additional area to be established**
Malezija/Malaysia	3,67	1,21	3,74	0,09
Indonesia/Indonezija	3,10	2,05	9,13	10,01
Ukupno/Total	6,77	3,26	12,87	10,10

Tresetno-močvarne tropske šume kao što su Tripa, Singkil i Kluet na Sumatri te Sebangau, Mawas i Tanjung Puting na Borneu, imaju značajnu ulogu u prirodnoj sekvestraciji ugljika i biodiverzitetu. Ovaj tip tropskih šuma poznat je kao sekvestracijski prirodni taložnik ugljika i korišten je u međunarodnim sporazumima i trgovanjima glede emisija ugljičnog dioksida, dok je istodobno biodizel proizveden iz palminog ulja promoviran kao gorivo kojim se smanjuje emisija stakleničkih plinova u atmosferu. Međutim, tresetne močvarne tropske šume sve češće postaju ciljem za smještaj palminih plantaža unatoč regulativama koje zabranjuju komercijalni razvoj ovih područja, te činjenici slabijeg uroda na ovakvim područjima u usporedbi s drugim vrstama tla. Zbog sprječavanja daljnjih emisija ugljičnog dioksida ključno je zaustaviti širenje palminih plantaža na područjima tropskih šuma, a posebno tresetnih močvara. Zbog močvarnog tla teško je kultivirati palmine nasade na isušenom tresetnom tlu debljine manje od jednog metra, a trošak formiranja palminih nasada na ovakvom tipu močvarnog tla je i do 40 % veći. Unatoč tome, brojne tvrtke prijavljuju se za dobivanje dozvola za pretvaranje tresetnih močvara u palmine nasade.

4.2. Emisija ugljičnog dioksida prilikom krčenja šume izazivanjem šumskih požara i isušivanja tresetnih močvara

Emisije ugljičnog dioksida, kao i ukupnih emisija stakleničkih plinova (GHG) prikazanih kao CO_2 ekvivalent, prikazane su u tablici 6 za biodizel i fosilno dizel gorivo.

Tablica 6: Emisije ugljičnog dioksida za biodizel i fosilni dizel [11]

Karakteristike goriva / Fuel characteristics	Biodizel Biodiesel	Fosilni dizel Fossil Diesel
Donja ogrjevna vrijednost, MJ/kg (MJ/l) Lower calorific value	*37,8 (33,3)*	*42,7(35,44)*
CO_2 emisija prilikom izgaranja goriva, kg/kg (kg/MJ) CO_2 emission due to combustion process	*0**	*3,15(0,074)*
CO_2 emisija prilikom proizvodnje goriva, kg/kg (kg/MJ) CO_2 emission due to production process	*0,92 (0,024)*	*0,56(0,013)*
Ukupna CO_2 emisija, kg/kg (kg/MJ) Total fuel life cycle CO_2 emission	*0,92 (0,024)*	*3,71(0,087)*
Ukupna emisija stakleničkih plinova (GHG) prikazana kao CO_2 ekvivalent, kg/kg (kg/MJ) Total emission of greenhouse gases (GHG) shown as CO_2 equivalent	*1,55 (0,040)*	*4,06(0,095)*
Energija potrebna za proizvodnju goriva, MJ/MJ(MJ/kg) Energy needed for fuel production	*0,45 (17,01)*	*1,26(53,80)*

**Biodizel je CO_2 neutralno gorivo jer ukupnu emisiju CO_2 prilikom izgaranja apsorbiraju uljarice prilikom svoga rasta*

4.2.1. Emisija CO_2 prilikom šumskog požara kao metode čišćenja terena za kultivaciju palminih nasada

Promatrajući kultiviranje palminih nasada u području tropskih prašume JI Azije moguće je izračunati količinu CO_2 koja se emitira prilikom izazvanog šumskog požara. Emisijski faktor za CO_2 prilikom izgaranja biomase tropske šume (EF_F) iznosi otprilike [1]: $EF_{F\,CO2}$ = 1,580 kg/kg gorive biomase

Ukupni emisijski faktor stakleničkih plinova (GHG) prikazan kao CO_2 ekvivalent bit će [1]: $EF_{F\,GHG} \approx 1{,}600$ kg/kg gorive biomase.

Količina suhe tvari odnosno biomase za tipičnu tropsku šumu Indonezije i Malezije prema literaturi [3] [5] iznosi: $M \approx 200$ t/ha ≈ 20 000 t/km^2.

Prilikom krčenja tropske šume izazivanjem šumskih požara za potrebe nasada palmi, moguće je izračunati ukupni emisijski faktor stakleničkih plinova (ε_F) prilikom izgaranja biomase, uzevši u obzir efikasnost izgaranja biomase prilikom požara (η_F) od otprilike 25 % [8] [5]:

$\varepsilon_F = EF_{F\,GHG} \times M \times \eta_F$

$\varepsilon_F = 1{,}600 \times 20\,000 \times 0{,}25$

$\varepsilon_F = 8\,000$ t/km^2 = 8 000 000 kg$_{GHG}$/km^2

Iz tablice 4 vidljivo je da se prinosom palminog ulja može dobiti otprilike 580 000 l/km^2 biodizela. Kako bi se izrazila ušteda u GHG emisiji prilikom izgaranja u motornim vozilima ove količine biodizela proizvedene na 1 km^2 plantaže, u odnosu na fosilni dizel, neophodno je pretvoriti volumne jedinice biodizela u energetske jedinice raspoložive energije zbog različitih gustoća i kaloričnih vrijednosti biodizela i fosilnog dizela.

Raspoloživa energija iz biodizela pridobivenog sa 1 km^2 plantaže (E_b), uzevši u obzir srednju ogrjevnu moć biodizela od 33,3 MJ/l iznosi:

$E_b = 580\,000 \times 33{,}3 = 19\,314$ GJ/km^2.

Kako emisija stakleničkih plinova izražena kao CO_2 ekvivalent GHG_{CO2eq} za 1 MJ energije iskorištene iz biodizela iznosi 0,040kg$_{GHG}$/MJ (Table 6), ukupna godišnja emisija stakleničkih plinova ($\varepsilon_{biodiesel}$) u cjelokupnom procesu proizvodnje, transporta i izgaranja biodizela, za prinos s 1 km^2 plantaže, bit će:

$\varepsilon_{biodiesel} = 0{,}040 \times 19\,314 \cdot 10^3 = 772\,560$ kg$_{GHG}$/km^2/god

Emisija stakleničkih plinova prilikom izgaranja fosilnog dizela jednake energetske vrijednosti, uzevši u obzir GHG emisiju za fosilni dizel tijekom cjelokupnog ciklusa proizvodnje, transporta i izgaranja od 0,095kg$_{GHG}$/MJ (tablica 6), iznosit će:

$\varepsilon_{diesel} = 0{,}095 \times 19\,314 \cdot 10^3 = 1\,834\,830$ kg$_{GHG}$/km^2/god

Korištenjem biodizela u motornim vozilima ušteda u ukupnim GHG emisijama, na godišnjoj osnovi, u odnosu na fosilni dizel te za 1 km^2 prinosa biodizela s plantaže palme, iznosi:

$\Delta\varepsilon = \varepsilon_{diesel} - \varepsilon_{biodiesel} = 1\,834\,830 – 772\,560 = 1\,062\,270$ kg$_{GHG}$/km^2/god

Međutim, vidljivo je da metodom uklanjanja tropske šume izazivanjem požara, kako bi se kultivirala palma, biodizel postaje “CO_2 neutralno gorivo” tek kada se GHG emisije nastale iz šumskog požara kompenziraju uštedom u GHG emisijama koju biodizel ima u odnosu na fosilni dizel. Za 1 km^2 palmine plantaže ovo vrijeme uravnoteženja (t_F) iznosit će:

$t = \varepsilon_F / \Delta\varepsilon = 8\ 000\ 000/1\ 062\ 270 = 7{,}5$ godina

4.2.2. Emisije CO_2 prilikom šumskog požara i isušivanja tresetnih močvara tropskih prašuma kao metode čišćenja terena za kultivaciju palminih nasada

Ako se plantaža palmi planira na području tresetnih močvara tropskih prašuma, koje su promovirane kao veliki prirodni taložnik ugljika, pojam biodizela kao "CO_2 neutralnog goriva" postaje još gori. Prema literaturi [10], isušivanje tresetnih močvara u području JI Azije oslobodit će oko 50-100 tona/ha/god ugljičnog dioksida. Procijenjeno je da se trenutačno odvija proces isušivanja tresetnih močvara u području JI Azije na površini od 7 milijuna hektara, najvećim dijelom zbog uzgoja nasada palmi. Ovakav proces isušivanja tresetnih močvara bogatih ugljikom uzrokuje godišnju emisiju CO_2 od 0,35 - 0,70 gigatona što je otprilike 5 -10 % trenutačnih godišnjih svjetskih emisija [10].

Uzimajući u obzir 1 km^2 površine na kojoj se odvija proces isušenja tresetne močvare radi kultiviranja palminih nasada, godišnja emisija stakleničkih plinova (ε_{PS}) bit će tada otprilike: $\varepsilon_{PS} \approx 75$ tona/ha $\approx 7\ 500\ 000\ kg_{GHG}/km^2/god$

Kako uzgoj palmi zahtijeva dreniranu dubinu tla od najmanje 70 cm ispod površine, proces isušivanja može potrajati i do nekoliko godina (tablica 7).

Tablica 7: Ukupna isušena dubina za 10, 20 i 40 godina nakon krčenja tresetne močvare tropske šume [10]

Kultura Crop	Početna kompaktnost tresetnog tla Initial mechanical peat soil compaction	Ukupna isušena dubina nakon 10 godina Total subsidence after 10 years	Ukupna isušena dubina nakon 20 godina Total subsidence after 20 years	Ukupna isušena dubina nakon 40 godina Total subsidence after 40 years
Palma (min. 70 cm) Oil Palm (min. 70cm)	40 cm	120 cm	200 cm	350 cm

Pretpostavljajući da će ukupan proces drenaže močvarnog tla potrajati i do 5 godina prije negoli je moguće zasaditi nasade palmi na kompaktno i drenirano tlo (tablica 7), emisija stakleničkih plinova za vrijeme tog razdoblja iznosit će:

$\varepsilon_{PS} \approx 7\ 500\ 000 \times 5 \approx 37\ 500\ 000\ kg_{GHG}/km^2/god$

Kao i u slučaju računice balansiranja emisija stakleničkih plinova prilikom izazivanja šumskih požara, korištenje biodizela s ovakvih plantaža palmi na tresetnim močvarama JI Azije uravnotežit će emisiju stakleničkih plinova u odnosu na korištenje fosilnog dizela za: $t = \varepsilon_F / \Delta\varepsilon$ = 37 500 000/1 062 270 = 35 godina.

Ovako izračunati podaci ukazuju na činjenicu da biodizel uvezen iz JI Azije nije "CO_2 uravnoteženo gorivo", već krajnje opasno gorivo za globalni svjetski ekosustav, uzevši u obzir povećanje izvoza u zemlje EU iz godine u godinu.

7. Zaključak

Današnja percepcija biodizela kao kvalitetnog djelomičnog supstituta fosilnim gorivima, te kao krajnje ekološki pogodnog izvora energije, vrlo je upitna. Uljana repica, europska tradicionalna kultura za proizvodnju biodizela, zbog kompetitivnosti energetskog i prehrambenog sektora oko obradive zemlje te skupe radne snage i nižeg prinosa, ne može konkurirati palminom ulju iz JI Azije u pogledu cijene po toni sirovine. Zbog limitiranih područja u EU za nove plantaže uljane repice, kako bi se uspio zadovoljiti cilj Europske komisije o implementaciji biogoriva u transportni sektor, logično je zaključiti da će se uvoz palminog ulja iz JI Azije iz godinu u godinu sve više povećavati. Ovakav razvoj događaja može dovesti do potpune devastacije iznimno ekološki vrijednih prostranstava azijskih tropskih prašuma, kako bi se zadovoljila svjetska potražnja za biodizelom, te izumiranje i gubitak staništa mnogih životinjskih vrsta, kao, na primjer, orangutana.

Parlament EU bi trebao razmotriti je li ekološki opravdano na temelju smanjenja emisija u skladu s Kyoto protokolom na drugom kraju svijeta izazivati nepopravljivu devastaciju tropskih prašuma ili zabraniti uvoz palminog ulja kao ekološki rizičnog goriva. Dok vodik kao gorivo u obliku gorivnih članaka neće biti ekonomski spreman nadomjestiti fosilne ugljikovodike u transportnom sektoru, biodizel nije najbolje globalno rješenje. Prvenstveno bi ga trebalo koristiti u javnom prijevozu, ali samo iz domaćih resursa i proizvodnih kapaciteta, nikako daljnjim uvozom iz JI Azije, što je ekološki potpuno neprihvatljivo. Goriva koja mogu nadomjestiti biodizel uvezen iz Azije su stlačeni prirodni plin i ukapljeni naftni plin koji također smanjuju emisije stakleničkih plinova u odnosu na dizelska i benzinska goriva. Nadalje, tehnologija ugradnje plinskih sustava u automobile je ekonomski opravdana i u vrlo visokom stadiju tehnološkog razvitka.

Literatura:

[1] ANDREAE, M. O.; MERLET, P.: *Emission of trace gases and aerosols from biomass burning*, Global Biogeochemical cycles, Vol. 15, No. 4, p. 955–966, December 2001

[2] BENDZ, K.: *EU-25 Oilseeds and Products Biofuels situation in the European Union 2005*, USDA Foreign Agricultural Service, Global Agriculture Information Network- GAIN Report - E35058, pp.11, www.useu.be/agri

[3] BROWN, S: *Estimating Biomass and Biomass Change of Tropical Forests: a Primer*, Department of Natural Resources and Environmental Sciences, University of Illinois, A Forest Resources Assessment publication – 134 ISBN 92-5-103955-0, USA, 1997.

[4] BUCKLAND, H.: *The oil for ape scandal*: *How palm oil is threatening orang-utan survival*, Research report for Friends of the Earth Society, London, September 2005., pp.50, http://www.foe.co.uk/resource/reports/oil_for_ape_full.pdf

[5] CARVALHO JR. J. A.; HIGUCHI N.; ARAÚJO T.M.; SANTOS J.C.: *Combustion completeness in a rainforest clearing experiment in Manaus, Brazil*, Journal of Geophysical Research, Volume 103, 1998, Issue D11, p. 13195-13200

[6] Internet source: *Chapter 2 - Analysis of biofuel policies in a selection of EU memeber states*, pp.44, www.klimaat.be/pdfs/Biofuels_2.pdf

[7] Schnepf R.: *European Union Biofuels Policy and Agriculture: An Overview*, CRS Report for Congress, EC, "An EU Strategy for Biofuels," Com(2006) 34, Annex V., pp.6

[8] STEININGER, M.K.: *Net carbon fluxes from forest clearance and regrowth in Amazon*, Ecological Applications, 14(4) Supplement, 2004, p. S313–S322, Ecological Society of America

[9] UNEP (1999). Levine, J.S.; Bobbe, T.; Ray, N.; Singh, A.; Witt R.G.: *Wildland Fires and the Environment: a Global Synthesis*, UNEP/DEIAEW/TR.99-1, Division of Environmental Information, Assessment and Early Warning (DEIA&EW) United Nations Environment Programme (UNEP), pp.52

[10] VAN DEN EELAART, A.: *Ombrogenous Peat Swamps and Recommended Uses in Tropical Areas*, A Web site by Adriaan van den Eelaart in support of ISDP (Integrated Swamp Development Project) IBRD Loan 3755-IND, http://www.eelaart.com/, pp.8

[11] VAN THUIJL, E.; ROOS, C.J.; L W.M. BEURSKENS: *An overview of biofuel technologies, markets and policies in Europe*, Energy Research Centre of the Netherlands, Project no. ECN 7.7449.02.01., January 2003., pp. 64

[12] WAKKER, E.: *Greasy Palms: The social and ecological impacts of large-scale oil palm plantation development in Southeast Asia*, Research for Friends of the Earth Society, March 2004., London, pp.49 www.foe.co.uk/resource/reports/greasy_palms_impacts.pdf,

UDK	ključne riječi	key words
665.334.9.094.942	biodizelsko gorivo, metilni ester repičinog ulja	biodiesel fuel, rapeseed oil methyl esther (RME)
665.353.4.094.942	biodiselsko gorivo, metilni ester palminog ulja	biodiesel fuel, palm oil methyl ester (PME)
.003.1	gledište ekonomske ekologije	economic ecology viewpoint
.001.6	gledište održivog razvoja	sustainable development viewpoint
(100)	svijet	world

Autor:

Tomislav Kurevija, dipl.ing.

Rudarsko-geološko-naftni fakultet, Sveučilište u Zagrebu, Pierottijeva 6, Zagreb

Primljeno:

26.2.2007.

Tomislav Kurevija

ISSN 0350-350X
GOMABN 46, 2, 103-127
Pregledni rad / Review
UDK 665.334.9.094.942 : 665.353.4.094.942.003.1.001.6 : (100)

NEGATIVE ENVIRONMENTAL IMPACTS DUE TO GLOBAL BIODIESEL PRODUCTION

Abstract

Fossil fuels that mankind burns today in a single year were made from organic matter containing 44×10^{15}*kg of carbon, which is 400 times the net primary productivity of the planet's current biota. Such large consumption of fossil fuels introduced biodiesel as one of the alternative sources of energy that is needed for decrease of dependence on fossil hydrocarbons and lowering of* CO_2 *emissions into the atmosphere. Therefore, EU goal is to achieve biodiesel share of 5,75% in transportation sector until 2010. Biodiesel is often called clean, ecological and renewable alternative fuel. If whole situation is viewed globally, biodiesel could easily be named as one of the most dangerous sources of energy for Earth's ecosystem. Main threat from large scale biofuel utilization comes from deforestation of land needed for cultivation of crops. Every year large areas of rainforests in South East Asia and South America are irretrievably lost due to world biofuel demand. Millions of hectares are turned into large palm and sugarcane plantation endangering ecosystem and survival of many species. Furthermore, large scale deforestation is often being conducted with forest fires and drying swamp areas of rainforests. Combustion of wood and oxidation of peat during drying process emits enormous quantities of* CO_2 *into the atmosphere which is contrary to biodiesel appellation as "*CO_2 *balanced fuel". Every energetic process and alternative fuel before utilize globally must be viewed through complete production cycle and 4E principle: ecology, efficiency, economy and education.*

1. Introduction

The use of biodiesel in vehicle engines has been known for a long time, but in Europe the production and utilization of these fuels has been developing more seriously only in the past five to ten years. This is partly due to European and national environmental policies aiming at the reduction of CO_2 emissions. Target is to decrease emissions from transport sector, as biodiesel does not lead to any additional CO_2 emissions released to the air, apart from the emissions due to production and transport of the biomass and biofuels. Various studies have estimated that the use of 1 kg of biodiesel leads to the reduction of some 3 kg of CO_2 [11].

In the Kyoto protocol, the European Union member countries have committed to a reduction of their CO_2 emissions by 8% relative to 1990 levels by the year 2010. Furthermore, EU with Directive 2003/30/EC obligates the Member States to establish a minimum percentage of 2% by 31. December 2005, by volume of biofuels to be sold in their respective national markets. This amount is to increase every year by 0.75% to 5.75% in the year 2010. [7] Prior to the Kyoto commitment, energy consumption was predicted to increase from 1,366 Mtoe (million tons of oil equivalent) in the year 1995 to 1,583 Mtoe in the year 2010 (European Commission, 1998). The increased energy consumption was predicted to be supplied entirely by renewable energy sources, increasing their share from 8.1% in 1995 to 14.6% in 2010 [2]. The increased use of biofuels requires careful consideration of all environmental impacts.

Table 1: Rough guidelines of alternative fuels consumption share in EU, according to European Commission in 2001 [2]

Year	Biofuels	Natural gas	Hydrogen	Total
2005.	2%			2%
2010.	6%	2%		8%
2015.	7%	5%	2%	14%
2020.	8%	10%	5%	23%

While positive impacts such as reduction in fossil CO_2 emissions in the combustion stage are evident, the indirect impacts of biofuels production such are deforestation, danger of reducing biodiversity, contamination of land and water with nitrates, phosphates and pesticides are more complex and have global impact on environment as well.

2. Production and imports of biodiesel in EU

Presently, the biofuels producing countries in the European Union only have a small share in global production, namely a little less than 6%. Most of the global biofuels production consists of ethanol and the main ethanol producers are USA and Brazil, whereas the share of Europe is rather small. However, Europe is the most important producer of biodiesel on the global market. As from the year 1993, the European production level of biodiesel increased by almost ten times, from 80 000 tons in 1993 to 780 000 tons in 2001 and further to 3 184 000 tons in 2005. (Table 2) [2].

Figure 1: World production of biodiesel from 1991 till 2003 [6]

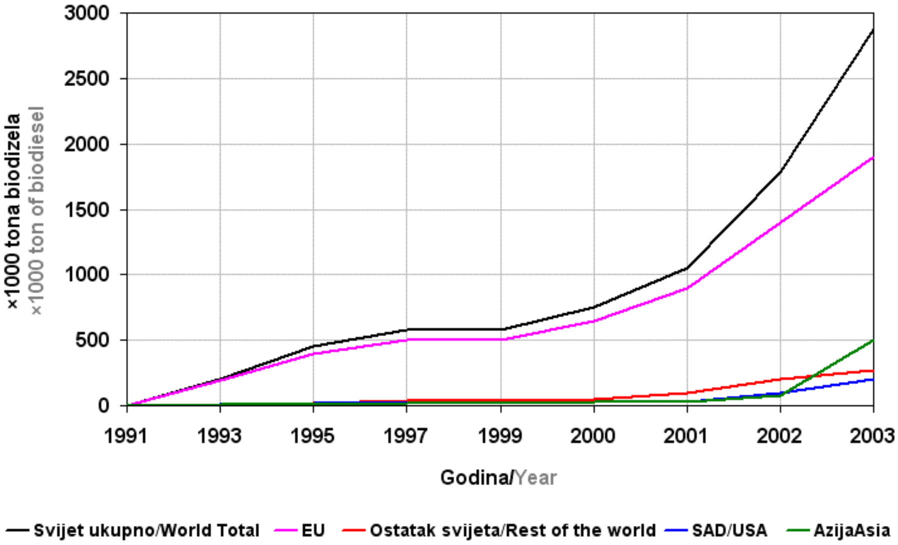


Table 2: EU biodiesel production and imports in 2005. [6] [11]

Country	Production of biodiesel in 2005 (x1000 ton)	Production capacity in 2005 (x1000 ton)	Share of biodiesel in diesel consumption in 2005 (%)
Germany	1669	2681	2,00
France	492	775	2,00
Italy	396	857	2,00
Czech Republic	133	203	3,03
Poland	100	150	-
Austria	85	134	2,50
Slovakia	78	89	2,00
Spain	73	224	2,00
Denmark	71	81	0,00
UK	51	445	0,30
Slovenia	8	17	
Estonia	7	20	0,00
Lithuania	7	10	2,00
Latvia	5	8	2,00
Other EU countries	9	375	-
TOTAL	3184	6069	1,50
Palm oil imports from SE Asia	**≈ 500**	**-**	**-**

Germany is the leading European producer, followed by France, Italy and Czech Republic. Throughout the European Union, biodiesel is applied in vehicle engines in various blends with regular diesel. In Germany, Austria and Sweden, it is used in pure form in adapted captive fleet vehicles.

Somewhat 12% of total biodiesel volume is imported from East Asia (Malaysia and Indonesia) in form of crude palm oil. Biodiesel production currently uses around 1,4 million hectares of arable land in the EU. Today, there are approximately 40 plants in the EU producing up to 3 184 000 tonnes of biodiesel annually.

3. National indicative targets of eu member states concerning production of biodiesel

Although the importance of biofuels utilization in transport sector has already been point out in the EU White paper on renewable sources of energy (1997) and the Green paper on a European strategy for the security of energy supply (2000), this has not led to the development of specific biofuels national policies in many EU Member States.

Table 3: Overview of submitted national indicative targets of EU countries for 2005. [6]

Country	Biodiesel market share		
	2003 (%)	2004 (%)	2005 (%)
Austria	-	-	2,50
Cyprus	0	-	-
Czech Republic	2,10	2,20	3,03
Denmark	0	0	0
Estonia	0	0	0
Finland	0,10	-	0,10
France	-	1,60	2,0
Germany	1,40	-	2,0
Greece	0	-	-
Hungary	-	-	0,5
Ireland	-	-	0,06
Latvia	0,30	1,25	2,0
Lithuania	-	-	2,0
Malta	0,02	-	-
Netherlands	0	0	-
Portugal	0	-	1,0
Slovakia	0,24	0,50	2,0
Spain	1,09	-	2,0
Sweden	1,80	2,0	3,0
United Kingdom	-	-	0,30

Some countries support biofuels utilization by exempting them from excise duties or environmental taxes. However, in June 2001, the discussion on biofuels did result in two EU Directive proposals on the promotion of biofuels. The first draft of Directive 2003/30/EC obliges the EU Member States to sell a certain amount of biofuels on their national markets in the period 2005 - 2010. In order to support this, the second draft of Directive 2003/30/EC provides the opportunity to the Member States to adjust their national excise duty systems for automotive fuels in favour of biofuels.

4. Global environmental issues concerning production of biodiesel from palm oil

The usage of biofuels creates a dilemma in terms of net environmental benefits of using lowcarbon fuels. Increased demand for this kind of fuel over standard fossil diesel is beneficial in terms of carbon emissions due to fuel combustion, but under current land conversion patterns, increased production in South-East Asia to meet higher global demand (especially EU) would inevitably involve extensive forest clearance. European Union is currently in short of biodiesel, as some Member States have underinvested in refinery production in recent decades while vehicle producing companies are increasingly switching to diesel instead of gasoline. It is estimated that the share of palm oil biodiesel in a few years could account for 20% of Europe's automotive consumption and cause the destruction of some of the most valuable forests of the world. Reason of increased share of palm oil, in total EU biodiesel consumption, lies in greater yield per hectare for palm plantation (Table 4), as well as in lower costs of production, which influences final purchase price.

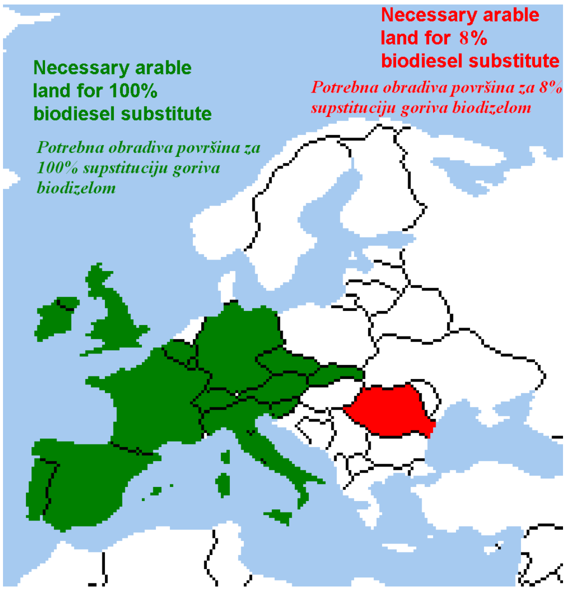
Table 4: Yield of biofuel for different crop cultures [11]

Oil-bearing plant		Soybean	Rapeseed	Jatropha Curcas	Palm
Yield of biofuel	$m^3/km^2/y$	35 - 45	100 - 130	160	580
	bbl/acres/y	0,90 - 1,15	2,55 - 3,30	4,10	14,80
	$GJ/km^2/y$	1 165 - 1 500	3 330 – 4 330	5 330	19 315

Until today, rapeseed is still dominant source for biodiesel in EU with share of some 80% but competition with food sector has driven its price to somewhat 600€ per tonne in 2005. At the same time, price of crude palm-oil was around 33% cheaper, making it about 400€ per tonne.

Conception of how much arable land is needed to substitute fossil diesel with biodiesel is shown on Figure 2, if typical crop yield for rapeseed is considered and current fossil diesel consumption in EU. For EU target of 8% biodiesel share, enormous area as closed as Romania would be needed to grow rapeseed and produce biodiesel. If entire fossil diesel is replaced with pure biodiesel, for the sake of example, more than half of the EU area should be covered with rapeseed fields. These facts indicate that import of raw oil for production of biodiesel is more than necessary.

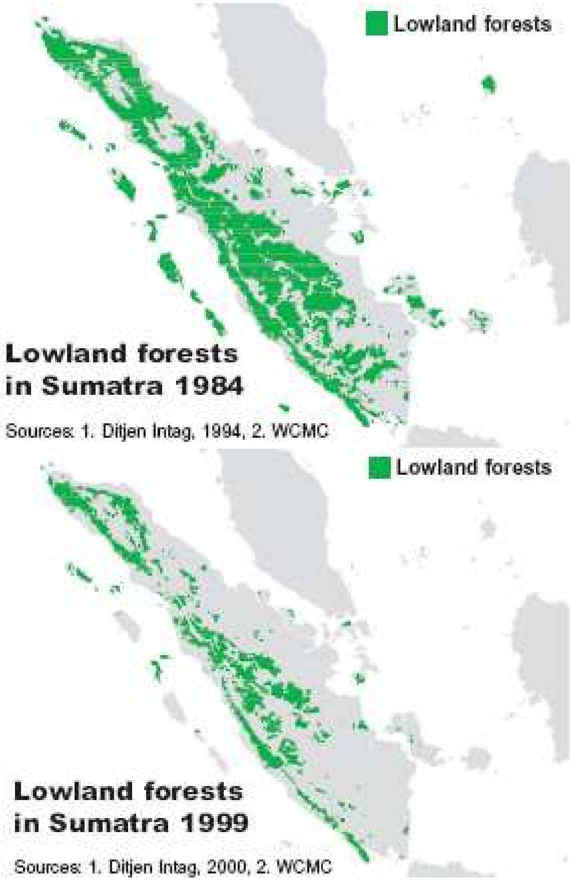
Figure 2: Necessary total arable area for EU goal of 8% biodiesel share, in comparison to 100% biodiesel share in total diesel consumption, according to rapeseed yield and fossil diesel consumption in EU



4.1. Deforestation in South Asia caused by cultivation of palm oil needed for biodiesel production and export to EU

Between 1989 and 2000, the area of oil palm harvested in Indonesia more than tripled, with an inevitable associated rise in the total production of palm oil. In 2003, 75% of Indonesia's 5,2 million hectares of palm oil plantations were located in Sumatra, with a further 18% located in Kalimantan [4]. It is expected that this area will more than triple, to approximately 20 million hectares in Indonesia and 10 million hectares in Malaysia by 2020. Between 1985 and 2000 the development of palm oil plantations was responsible for estimated 87% of deforestation in Malaysia, and an estimated 66% of Indonesia's plantations have involved forest conversion. By the beginning of 2004, there were 6,5 million hectares of palm oil plantations across Sumatra and Borneo. Of this total area, almost 4 million hectares had previously been forested. Currently, every year about 2 million hectares of Indonesian virgin forest, a total area equivalent to Slovenia, are turned over to palm oil production.

Figure3: Example of Indonesia's rainforest destruction due to palm oil production [12]



The palm oil business is often advertised by governments and companies as making an important economic contribution to development. However, this analysis is often one sided, and fails to take into account the substantial social and environmental costs. These include the ecological price of removing rainforest such, as well as pollution to water and air that are rarely taken into account. Furthermore, the area released for conversion does not necessarily reflect the real area planted, and the palm oil industry is habitually associated with deforestation beyond establishing palm oil estates on previously forested land. The amount of forest removed under the auspices of plantation development, regardless of whether palms have ever been planted, may be as much as 10 million hectares. Around 40% of Indonesia's legal timber supply results from land clearance for conversion to plantations. In the past, if the remaining timber stands are not commercially valuable, burning has been a widely used method of land clearance. The forest fires of 1997/98 were responsible for the devastation of over 5 million hectares decreasing air quality which led to tensions between Indonesia and Malaysia [9].

Table 5: Plantation area and estimated forest area cleared based on industry estimates [12] (Mha.)

Country	Palm plantation area (2001)	Forest area cleared for palm oil (2002)	Targeted oil palm area in 2003	Additional area to be established after 2004
Malaysia	3,67	1,21	3,74	0,09
Indonesia	3,10	2,05	9,13	10,01
Total	6,77	3,26	12,87	10,10

Peat-swamp forests, including those in Tripa, Singkil, and Kluet in Sumatra, and Sebangau, Mawas, and Tanjung Puting in Borneo, play a major role in carbon sequestration and biodiversity. This forest type is being promoted as a carbon sink and used in international carbon offset agreements, while palm oil is concurrently publicised as a carbon emission reducing fuel. Peat swamp forests, however, are increasingly becoming prime targets for palm oil expansion, despite regulations against the development of deep peats and lower productivity relative to other soils. It is crucial that the expansion of palm oil plantations does not lead to the clearance of forests and, in particular, peat forests. It is difficult to cultivate oil palms on peat land thicker than 1 metre [10], and the costs of establishing a plantation on this type of soil tend to be 40 % higher than on dry land but. Nevertheless, numerous companies continue to apply for licences to allow the conversion of deep peat land.

4.2. Carbon-dioxide emissions from deforestation and peat-swamps drying

Emissions of CO_2, as well as total greenhouse gases GHG emissions, presented as CO_2 equivalent, are shown in Table 6 for three transportation fuels: biodiesel, fossil diesel and natural gas.

Table 6: CO_2 emissions for various transport fuels [11]

Fuel characteristics	Biodiesel	Fossil Diesel
Lower calorific value, MJ/kg (MJ/l)	*37,8 (33,3)*	*42,7(35,44)*
CO_2 emission due to combustion process, kg/kg (kg/MJ)	*0**	*3,15(0,074)*
CO_2 emission due to production process, kg/kg (kg/MJ)	*0,92 (0,024)*	*0,56(0,013)*
Total fuel life cycle CO_2 emission, kg/kg (kg/MJ)	*0,92 (0,024)*	*3,71(0,087)*
Total emission of greenhouse gases (GHG) shown as CO_2 equivalent, kg/kg (kg/MJ)	*1,55 (0,040)*	*4,06(0,095)*
Energy needed for fuel production, MJ/MJ(MJ/kg)	*0,45 (17,01)*	*1,26(53,80)*

**Biodiesel is CO_2 neutral fuel because whole emission of CO_2 from combustion process is absorbed by crop during it's growth.*

4.2.1. Emission of CO_2 due to forest fires as method of land clearing

Considering South Asia case of deforestation for palm oil cultivation purposes, it is possible to derive amount of CO_2 that is emitted during forest fire. Carbon-dioxide emission factor for tropical rainforest biomass (EF_F) burning is approximately [1]:

$EF_{F\ CO2}$ = 1,580 kg per kilogram of dry matter burnt

Total emission factor of GHG shown as CO_2 equivalent would be [1]:

$EF_{F\ GHG}$ ≈ 1,600 kg per kilogram of dry matter burnt

Determined quantity of biomass dry matter in typical tropical rainforest (M) in tropical forests of Malaysia and Indonesia according to [3] [5] is approximately:

$M \approx 200$ t/ha ≈ 20 000 t/km^2

Now, it is possible to derive total GHG emission during forest fire (ε_F) that is carried out for land clearance and beginning of palm cultivation, taking into account assumed combustion efficiency of tropical forest fire (η_F) [8] [5] of approximately 25%:

$\varepsilon_F = EF_{F\ GHG} \times M \times \eta_F$

$\varepsilon_F = 1{,}600 \times 20\ 000 \times 0{,}25$

$\varepsilon_F = 8\ 000$ t/km^2 = 8 000 000 kg$_{GHG}$/km^2

From Table 4 it could be seen that yield of palm oil plantation is somewhat 580 000 l/km^2 of biodiesel. To calculate savings in GHG emissions from this amount of biodiesel produced from 1 km^2 of palm plantation, oppose to fossil diesel, it is necessary to convert volume units into available fuel energy, because of different densities and calorific values of biodiesel and fossil diesel.

Consequently, gained fuel energy (E_b) from 1 km^2 of palm oil plantation in form of biodiesel, taking into account calorific value of biodiesel of 33,3 MJ/l, is:

$E_b = 580\ 000 \times 33{,}3 = 19\ 314$ GJ/km^2

Since emissions of GHG_{CO2eq} for 1 MJ energy used from biodiesel fuel is 0,040kg$_{GHG}$/MJ (Table 6), total annual emission of GHG (ε_{bio}) through production, transportation and combustion stage, for 1 km^2 yield of palm oil plantation, is:

$\varepsilon_{biodiesel} = 0{,}040 \times 19\ 314 \cdot 10^3 = 772\ 560$ kg$_{GHG}$/km^2/annually

Hence, emission of GHG from equivalent amount of energy used from fossil diesel, taking into account GHG emission of 0,095kg$_{GHG}$/MJ (Table 6), would be:

$\varepsilon_{diesel} = 0{,}095 \times 19\ 314 \cdot 10^3 = 1\ 834\ 830$ kg$_{GHG}$/km^2/annually

This means that with biodiesel utilization, savings in GHG emission on annual basis, for 1 km^2 of palm oil plantation yield would be:

$\Delta\varepsilon = \varepsilon_{diesel} - \varepsilon_{biodiesel} = 1\ 834\ 830 - 772\ 560 = 1\ 062\ 270$ kg$_{GHG}$/km^2/annually

However, with tropical forest clearance to cultivate palm oil crop for biodiesel production it is seen that biodiesel becomes "CO_2 balanced fuel" only then when emissions from large forest fires are compensated with emissions savings that biodiesel offers oppose to fossil diesel utilization. For 1 km^2 yield of palm oil plantation this period (t_F) would be:

$t = \varepsilon_F / \Delta\varepsilon = 8\ 000\ 000/1\ 062\ 270 = 7{,}5$ years

4.2.2. Emissions of CO_2 due to forest fire and drying of peat swamp as a method of land clearing

If the palm oil plantation is planned on peat swamp tropical forest, which is promoted as large carbon sink, situation for biodiesel as CO_2 balanced fuel gets even worse. According to [10], drained peat-swamp land will release about 50-100 tons/ha/year of GHG emissions, mostly CO_2. It is estimated that in the whole of SE Asia about 7 million ha of peat lands are drained now, mainly for palm oil cultivation purposes. In that case the drained peat lands used for agriculture in SE Asia will contribute to about 0.35-0.7 gigaton CO_2/year, or about 5 - 10% of the total yearly worldwide CO_2 emissions [10].

Considering 1 km^2 of drained peat-swamp and supposed cultivation of palm-oil, emissions of GHG (ε_{PS}) would be: $\varepsilon_{PS} \approx 75$ t/ha $\approx 7\,500\,000$ kg_{GHG}/km^2/year.

Since palm oil cultivation require drainage depth below surface of at least 70 cm, the process could last for a couple of years. (Table 7)

Table 7: Total groundwater depths for 10 , 20 and 40 years after reclamation [10]

Crop	Initial mechanical peat soil compaction	Total subsidence and groundwater depth after 10 years	Total subsidence and groundwater depth after 20 years	Total subsidence and groundwater depth after 40 years
Oil Palm (min. 70cm)	40 cm	120 cm	200 cm	350 cm

Assuming that the complete process of drainage would last for as much as five years for complete soil compaction and ability to plant palm oil crop, emitted GHG in that period would be:

$\varepsilon_{PS} \approx 7\,500\,000 \times 5 \approx 37\,500\,000$ kg_{GHG}/km^2

This means, likewise as forest fires GHG emission calculation method in previous section, that utilization of biodiesel from SE Asia would equilize emitted GHG, oppose to utilization of fossil diesel, after:

$t = \varepsilon_F / \Delta\varepsilon = 37\,500\,000/1\,062\,270 = 35$ years

These calculated data show that biodiesel imported from SE Asia is not "CO_2 balanced fuel", but extremely environmentally aggressive fuel.

7. Conclusion

Today's perception of biodiesel as valuable partial substitution of fossil fuels and ecologically acceptable source of energy is very doubtful. Rapeseed, European traditional crop for biodiesel production, because of competition with food sector for land area, expensive labour and lower yield, can not compete with SE Asia palm oil in aspect of cost per tonne of oil. Due to limited land area in Europe for further development of rapeseed plantation, it is logical to conclude that the import of palm oil from SE Asia will increase with every upcoming year. This could lead to total devastation of most valuable rainforests in the world and distinction of some species like orangutan. European Union Parliament should consider if it is acceptable to continuously destruct Asia rainforests to satisfy biofuel needs, or the import of palm oil will be banned. Until the hydrogen would be economically ready to substitute oil derivates in transportation sector, biodiesel is not the best global solution. It could be promoted in public transportation but only from domestic resources and capacities, not from SE Asia which is ecologically intolerable. The fuel that could replace this imported palm oil could easily be compressed natural gas, which also has CO_2 decrement ability in comparison with fossil diesel. Furthermore, vehicle upgrade technology is economically justifiable and in high stage of technological development.

References:

[1] ANDREAE, M. O.; MERLET, P.: *Emission of trace gases and aerosols from biomass burning*, Global Biogeochemical cycles, Vol. 15, No. 4, p. 955–966, December 2001

[2] BENDZ, K.: *EU-25 Oilseeds and Products Biofuels situation in the European Union 2005*, USDA Foreign Agricultural Service, Global Agriculture Information Network- GAIN Report - E35058, pp.11, www.useu.be/agri

[3] BROWN, S: *Estimating Biomass and Biomass Change of Tropical Forests: a Primer*, Department of Natural Resources and Environmental Sciences, University of Illinois, A Forest Resources Assessment publication – 134 ISBN 92-5-103955-0, USA, 1997.

[4] BUCKLAND, H.: *The oil for ape scandal*: *How palm oil is threatening orang-utan survival*, Research report for Friends of the Earth Society, London, September 2005., pp.50, http://www.foe.co.uk/resource/reports/oil_for_ape_full.pdf

[5] CARVALHO JR. J. A.; HIGUCHI N.; ARAÚJO T.M.; SANTOS J.C.: *Combustion completeness in a rainforest clearing experiment in Manaus, Brazil*, Journal of Geophysical Research, Volume 103, 1998, Issue D11, p. 13195-13200

[6] Internet source: *Chapter 2 - Analysis of biofuel policies in a selection of EU memeber states*, pp.44, www.klimaat.be/pdfs/Biofuels_2.pdf

[7] Schnepf R.: *European Union Biofuels Policy and Agriculture: An Overview*, CRS Report for Congress, EC, “An EU Strategy for Biofuels,” Com(2006) 34, Annex V., pp.6

[8] STEININGER, M.K.: *Net carbon fluxes from forest clearance and regrowth in Amazon*, Ecological Applications, 14(4) Supplement, 2004, p. S313–S322, Ecological Society of America

[9] UNEP (1999). Levine, J.S.; Bobbe, T.; Ray, N.; Singh, A.; Witt R.G.: *Wildland Fires and the Environment: a Global Synthesis*, UNEP/DEIAEW/TR.99-1, Division of Environmental Information, Assessment and Early Warning (DEIA&EW) United Nations Environment Programme (UNEP), pp.52

[10] VAN DEN EELAART, A.: *Ombrogenous Peat Swamps and Recommended Uses in Tropical Areas*, A Web site by Adriaan van den Eelaart in support of ISDP (Integrated Swamp Development Project) IBRD Loan 3755-IND, http://www.eelaart.com/, pp.8

[11] VAN THUIJL, E.; ROOS, C.J.; L W.M. BEURSKENS: *An overview of biofuel technologies, markets and policies in Europe*, Energy Research Centre of the Netherlands, Project no. ECN 7.7449.02.01., January 2003., pp. 64

[12] WAKKER, E.: *Greasy Palms: The social and ecological impacts of large-scale oil palm plantation development in Southeast Asia*, Research for Friends of the Earth Society, March 2004., London, pp.49 www.foe.co.uk/resource/reports/greasy_palms_impacts.pdf,

UDK	ključne riječi	key words
665.334.9.094.942	biodizelsko gorivo, metilni ester repičinog ulja	biodiesel fuel, rapeseed oil methyl esther (RME)
665.353.4.094.942	biodiselsko gorivo, metilni ester palminog ulja	biodiesel fuel, palm oil methyl ester (PME)
.003.1	gledište ekonomske ekologije	economic ecology viewpoint
.001.6	gledište održivog razvoja	sustainable development viewpoint
(100)	svijet	world

Author:
B.Sc. Tomislav Kurevija, e-mail: tomislav.kurevija@rgn.hr
Faculty of Mining, Geology and Petroleum Engineering, Department of Petroleum Engineering,
University of Zagreb, Pierottijeva 6, Zagreb

Received:
26.2.2007.