COLOFON

Projectnummer : 356598/1010

Samenvatting

In deze evaluatie wordt aangetoond dat de (technisch) mogelijke bijdrage van bio-energie aan

Summary

This evaluation shows that the (technical) potential contribution of bio-energy to the future world's energy supply could be very large. In theory, energyMsminerg

In the long run much more knowledge and information is required about which regions would be most suited for a sustainable production and trade in biomass energy. It will be necessary to develop and introduce a ‘FSC’ type mark for biomass-based energy carriers.

There are still a number of crucial research questions in areas such as: economic drivers of land use, competition of biomass with other land uses, and competition with other sources of energy and materials. These interactions need to be studied at local/regional level,on with ot still cot st[(la)’ c

Inhoudsopgave

Inleiding

1. Achtergrond

Dit project vormt onderdeel van de Novem-programma's GAVE en EWAB. Het GAVE-programma rmcht zich op de inventarmsatie van perspectiefvolle, klimaatneutrale GAsvormige en Vloeibare Energmedragers, terwmjl EWAB zich rmcht op de EnergmeWinning uit Afval en Bmomassa. Novem voert het GAVE-programma uit in opdracht van de ministeries van

Om dit inzicht te verkrijgen zullen de volgende deelvragen beantwoord worden:

1. Wat is er vanuit diverse bronnen bekend over de mondiale productie van biomassa en het

Deelproject 3	**Aanzet tot het formuleren van duurzaamheidscriteria omtrent import van biomassa voor energietoepassingen**
Partijen	**UU-NW&S**
Uitvoerders	Faaij, Van den Broek,61urkenburg
Centrale vraag	Welke duurzaamheidscriteria kunnen een rol sale vraagg

Synthese van het project: Beschikbaarheid Biomassa voor energieopwekking

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Energieonderzoek Centrum Nederland (ECN)
Universiteit Wageningen

1. Inleiding

Deze synthese beoogt een compact en helder overzicht te geven van de inzichten die in de beschikbare literatuur bestaan ten aanzien van de potentiële toekomstige beschikbaarheid van biomassa voor energietoepassingen op mondiale schaal.
Daartoe worden samenvattingen gegeven van:

1. De potentieelstudies naar de bijdrage van biomassa aan de (toekomstige) mondiale energievoorziening.
2. Het mondiale landgebruik.
3. Verwachtingen van de toekomstige mondiale vraag naar voedsel, veevoeder en organische materialen en feedstocks.
4. Mogelijke toekomstige ontwikkelingen in de productie van voedsel en biomassa.

In dit document worden de verkregen inzichten uit de deelstudies samengevoegd tot een totaalbeeld. Dit beeld geeft inzicht in de hoeveelheden biomassa die mondiaal beschikbaar zouden kunnen komen voor energietoepassingen. Tevens geeft dit beeld inzicht in de belangrijkste factoren die de mondiale beschikbaarheid van biomassa sterk positief of negatief kunnen beïnvloeden.
Verder gaat deze paper in op de mogelijkheden, randvoorwaarden en mogelijke bedreigingen van (grootschalige) import van (energie uit) biomassa naar Nederland. Dit wordt geïllustreerd aan de hand van een case-studie van export van (energie uit) biomassa van Nicaragua naar Nederland.
Dit alles resulteert in een synthese van de inzichten betreffende de mogelijkheden, beperkingen en randvoorwaarden van import van (energie uit) biomassa.

<u>Aanpak</u>
De informatie en resultaten die in deze paper worden gerapporteerd zijn verkregen door literatuurstudie en een overkoepelende analyse van de gegevens die met name dient om gevoeligheden van de uitkomsten ten aanzien van het totale mondiale biomassapotentieel zichtbaar te maken. Dit werk moet daarom niet worden beschouwd als een nieuwe scenariostudie of analyse van het mondiale biomassapotentieel. Overigens zijn de gegevens, verkregen uit literatuurstudie, vaak gebaseerd op modelberekeningen.

2. Resultaten van review van studies: vraag en aanbod van land

2.1 Overzicht van studies naar het potentieel voor energie uit biomassa op mondiale schaal

In het hoofdproject zijn 17 studies vergeleken die allen kijken naar het mondiale aandeel van biomassa-energie in de toekomstige energiemix. Hierbij is onderscheid gemaakt tussen studies die zich richten op de aanbodkant van biomassa-energie ('Resource Focused') en studies die zich meer richten op de vraagkant ('Demand Driven'). De studies zijn vergeleken

De resultaten voor de aanbodgerichte studies liggen tussen de 47 EJ/jr (BATTJES) en 450 EJ/jr (GBP250) voor de periode 2020 -2050. Om de verschillen te verklaren is er gekeken naar de totstandkoming van de resultaten, waarna een aantal opmerkelijke resultaten nader is belicht.

2.2 Landgebruik op mondiale schaal

eel voor verschillende diëten: van 10.05
11.6 MJ/persoon*dag voor een proteïnerijk
gie
n 10340tot 14200)9.1(r)221caaanequivaendtenver persoon ,ver p]TJT*-0.00087Tc0.00097Tw[(dig)9.53(,-0.87 voor eerespectieevlijk)en veg

diaen vraa nar dvoedd vop basisvan 1de ie3.3)tb[TJT*-0.00083Tc0.00093Tw[(D)9.17ie3.35D)9.17ie3.35Dvens ioor 1(i btabl v22t). Er isvteovop ichtsvan 1devhuiig

Tabel 2.4: Berekende gemiddelde potentiële graanopbrengsten op mondiale schaal voor verschillende typen landbouwproductiesystemen

	High External Input systeem (ton droge stof graaneq./ha*jr)	Low External Input systeem (ton droge stof graaneq./ha*jr)

De genoemde conversie-efficiënties variëren met een factor 2-4 tussen de verschillende wereldregio's met (zonder uitzondering) de hoogste rendementen voor West Europa en Noord Amerika. Een belangrijke verklaring voor deze verschillen is (weer) de intensiteit van de productiesystemen. Met name extensieve veeteelt voor vleesproductie heeft een lage

[b] De productiviteit van biomassa voor de desbetreffende materiaaltoepassing varieert; voor chemicaliën kan ruwe biomassa worden gebruikt (bijvoorbeeld voor productie van synthesegas of bio-crude), maar voor bijvoorbeeld katoen i-4.9(os)-2(sl)-4.9(e)-7.5(c)-7.5(h)0.4(t-4.9(os)-2(e)-7.5(e)-7.5(n)0.4(d)-11.6(e)-7.5(e)-7.5(l)-4.9(va)-7.5(n he)-7.5(t)-

Cascadegebruik

Het is belangrijk te beseffen dat een aanzienlijk deel van deze biomassa 'bewaard' blijft en in een later stadium vrijkomt als afval (of herbruikbaar materiaal). Dit is niet zo voor het houtskoolgebruik in de staalindustrie. En bij productie van kunststoffen uit biomassa treden energieverliezen op zodat niet alle biomassa die als feedstock voor kunststof wordt gebruikt uiteindelijk beschikbaar komt als (organisch) afval. Maar in iede9(in i9t)-4.9(t is 9(os)-2 le(os)-id(t e)48.9(t i
ebruie van biomassa voor materiaatoep1.156 gn todt geie van deho(evelheid oerg)9.5ae(ishn)]TJT*-0.0102 T

(Organisch) afval
De productie van afval is afhankelijk van bevolkingsaantallen en economische groei met direct daaraan gekoppeld gebruik van materialen. Het biomassabestanddeel van afval kan worden beschouwd als hernieuwbare brandstof (zie ook paragraaf 2.4).
Afval wordt door weinig studies over het mondiale biomassapotentieel meegenomen. Fischer & Schrattenholzer komen op basis van, eenvoudige, modelberekeningen en gebruik van kentallen voor afvalproductie per capita op een aanbod van MSW (Municipal Solid

Interpretatie van de tabel

Tabel 4.1: Overzicht van het potentiële biomassa-aanbod voor een aantal belangrijke (potentiële) categorieën e en daarvoor essentiële randvoorwaarden en aannamen

Categorie biomassa	**Belangrijkste aannamen**	**Potentieel energieaanbod**

Energieteelt: De potentieel grootste bijdrage van biomassa kan komen van energieteelt op de

Belangrijke stromen zijn met name secundaire stromen die vrijkomen bij fabricage van

5. Mogelijkheden voor import van bio-energie: case Nicaragua

Om inzichtelijk te maken wat de grootschalige import van biomassa naar Nederland zou

In heslpeval van Nicarapua was de inschattinp dat dit merendeels struikachtip land zal zijn zonder economische activiteit. Watergebruik en biodiversiteit kunnen mogelijk problemen geven. Daarom wordt aanbevolen niet daar te planten waar heslprondwaterniveau erg kritisch is en tevens om natuurlijke habitats binnen de plantage te handhaven. Verder lijkt hesl noodzakelijk de plantages minstens licht te bemesten om voor de afvoer van nutriënten te compenseren. Interessant is dat oceaantransport van hout leidt tot een verslechterinp van de energiebalans, maar dat hes overall effecs nog steeds acceptabel is: de totale energie

7. Discussie en conclusies

De resultaten van dit project zijn hoofdzakelijk gebaseerd op de uitkomsten van andere studies en omvatten geen nieuwe analyse van het mondiale toekomstige biomassapotentieel.

Behalve dat dit gegeven vraagt om maatwerk voor het in detail verkennen van de

<u>Samenvattend</u> kan uit deze studie en uit de review van beschikbare literatuur worden geconcludeerd dat biomassa in potentie een zeer grote bijdrage kan leveren aan de toekomstige wereldenergievoorziening, een bijdrage die het huidige mondiale energiegebruik zelfs kan overtreffen. Deze bijdrage is echter (sterk) afhankelijk van

Wirsenius, S., Human use of lafr afr organic materials, Department of Physical Resource Theory, Chalmers University of Technology, Goteborg University, Goteborg, Sweden, 2000, Ph.D.-thesis.

J. Wolf, L.M. Vleeshouwers, M.K. van Ittersum, Exploratory study on the lafr area required for global food supply afr the potential area afr production of biomass fuel, Wageningen University, June 2000.

Bijlage 1

Hoofdproject:
Literatuuroverzicht wereldwijd potentieel
Van biomassa-energie

UU-NW&S

A review of assessments on the future global contribution of biomass energy

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Energy crops and the primary, secondary and tertiary types of residues may be defined as follows:

3. Present bioenergy consumption

Since the studies discuss the global potential contribution of bioenergy in the context of energy system transformation and climatic change mitigation, the timeframe is typically 50 to 100 years.

Table 4.1: Approach, time frame, and geographic aggregation used in the reviewed bioenergy assessments

Study	Characteristics

4.2 Bioenergy sources

Table 4.2 accounts for the bioenergy sources considered in the studies (see also figure 2.1 in section 2). As can be seen, not all studies offer complete assessments. In some cases,

In GEP, land requirements for bioenergy is roughly outlined in a post-scenario feasibility test[1] iii)

The reason for this is that the objective of the study was to evaluate the consequences of a certain supply of biomass energy (i.e. as assumed in the original LESS-BI study). Since there is no feedback between land allocation and the energy model the demand for energy crops cannot be adapted to the land availability[3].
None of the other studies treat the bioenergy sector and other land uses in an integrated manner.

With the present approaches, analysts *avoid* rather than *analyse* the competition for land between different land uses. As noted earlier, surplus cropland in industrialised regions and degraded land in developing regions are suggested as suitable for energy crop production. The rationale is that targeting such areas for bioenergy would limit the risk of competition with food production.

Yield of energy crops
Figure 4.3 below presents the global average yield levels in energy crops production, which is used in the studies[4]. Yield levels can vary between regions and over time. Details on regional yield levels –and their changes over time– are reported in appendix B. In the integrated land use/energy-economy models (LESS-BI – IMAGE, BATTJES) the yield level is a function of the model parameters determining productivity (e.g., soils, climate, agronomic practice) and the distribution of energy crops production over suitable a39.0. Other studies make assumptions about regional yield levels based on the present experiences in fiber and energy crops production.

Figure 4.3: Global average yield levels assumed in the studies. [5]

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[3] it is aimed to include a feedback in a next version of IMAGE
[4]

Table 4.5: Assumption on residue availability made in 5 studies.

Study	Type agricultural residues		Recoverability fraction
		Forest	*Crops*

5. Results

In this chapter the results are presented on a global level, distinguished between industrialised and developing regions, and distinguished for the types of biomass[6]. Furthermore the differences between the results are discussed and linked to the different assumptions made

Other high estimates are 300 EJ (HALL) 205 EJ/yr (RIGES) and 220

In 2030, this share is only 23%. However in time it increases from 64% in 2050 up to 76% in 2100. This is mainly caused by a high absolute increase of energy crops, rather than a decrease of residues in absolute terms. The energy crops were assumed to be able to increase rapidly since a doubling of the yield was assumed from 2025 up to 2100.

5.1.3 Regional differences

Since most studies aggregate over different regions, it is not possible to compare the regional contribution to the world biomass potential. Therefore a compar8son has been made between

This is some 372 Mha. in industrialised countries and 518 Mha. in developing countries (total

6. Discussion

In the previous sections the methodologies and results of various studies were described. In this section we discuss the main assumptions and relate them to other, not biomass energy related literature. We focus on the yield, land availability, residues and the required establishment rate of energy plantations.

Assumptions on the yield
Some studies, (LESS-BI, GEP "high yield", SEI/Greenpeace "double yield") have high assumptions on feasible productivity of energy plantations. Only SØRENSEN, LESS-IMAGE and BATTJES[8] used regional yield distribution. SWISHER and RIGES differentiated between industrialised and developing regions, on the basis of different management factors (RIGES furthermore includes natural conditions when assessing productivity). rature. stud8 01 Tc-Bc-0.dmpt el[(u22(o) u22r[(I)2e 6uc:)3(el Y)(I)2ieleleld soelyactove$8(o)w

The highest assumption in Figure 6.1 is from the SEI/Greenpeace high productivity case. However, this assumption was used for a post-scenario feasibility check and did not directly

7. Conclusion and recommendation

Looking at the results and the approaches from the studies on the global future contribution of bioenergy, the following conclusions can be drawn.

Results
The results of assessments of biomass energy potential vary largely.
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Approach
Many studies use comparable approaches based on the same background study. Regarding the approaches of the reviewed studies, it is concluded that many resource focused assessments are based on assumptions made by HALL. Especially the assumptions regarding residues are not based on field experiments but on literature (Hall). Furthermore, it is noteworthy that many studies do not make bottom up assumptions, but assess the total amount of biomass energy and check the feasibility of the results afterwards (GEP, SEI/Greenpeace). This type of post scenario feasibility checks is seldom based on firm data. It can be concluded that with the present approaches, analysts *avoid* rather than *analyse*

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Broek, v. d., R. (1997). Wood Energy Today for Tomorrow - TAe role of wood energy in Europe and OECD Tc0 Tw(:)Tj/ TT16Crcle of wood er 1 Tf12 0 0 12 72 715.88 Tm( )Tj15g

Appendices of the GRAIN report : A review of assessments on the future global contribution of biomass energy

Page

B1: Name: Sørensen:

(Sørensen 1999)

Timeframe: 2050

Geographical aggregation: world, aggregated into 6 regions:

Biofuels from energy crops on cropland =
AF (cropland) x PP [W/m2] x AE x HF x UF (cropland energy crops) x FE Eq B1.1

Biofuels from energy crops on rangeland =
AF (rangeland) x PP [W/m2] x HF x UF (rangeland energy crops) x IE (anim. prod) Eq B1.2

In which:
AF = Area Fraction (grid based)
PP = potential production (grid based)
AE = agricultural efficiency factor (regional based)
HF = harvest fraction (regional based)
UF = utilisation factor (regional based)
FE = conversion efficiency (constant)
IE = efficiency transforming biomass into delivered products

Forest residues

The use of forest residues was included within the decentralised mode of the renewable energy scenario. This was based on the present forestland and the calculation

B2 : Name WEC

(WEC 1994)

Timeframe: 2020

Geographical aggregation: world, aggregated into 9 regions

1. North America
2. Western Europe
3. E Europe + NIS
4. Japan + Australia
5. Latin America

Energy Crops:

Table B2.2: Biomass energy consumption assessments in 2020 by WEC (1994) for

Table B3.2a and B3.2b: Estimates of practical and maximum potential and practical potential of biomass energy from Swisher and Wilson (1993) in TWeh/yr (a) and EJ/yr (b) with efficiencies of 50% (maximum potential) and 33% (practical potential)

Table B3.2a.

Max eff 50%	Maximum potential		Practical potential	
Pract eff 33%	Residues	Energy Crops	Residues	Energy Crops
	2030	2030	2030	2030

B5: Name: AGLU
(Edmonds, Wise et al. 1996)

Timeframe: 1990-2100

Geographical aggregation: World, 11 regions

1. United States
2. Canada
3. Western Europe
4. Japan
5. Australia & New Zealand
6. Eastern Europe and Former USSR
7. China and Centrally planned Asia
8. Middle East
9. Africa
10. Latin America
11. Other South and East Asia

Background:
The study had been done by using two models of MiniCAM 2.0 which is a set of models withinn the Pacific Northwest National Laboratory Global Change Assessment Model (GCAM) system. In this study, the energy model ERB (Edmonds-Reilly-Barns) and the land use model AGLU (Agriculture-Land-Use) module were used. The AGLU is a dynamic market equilibrium model. The model employs information on supplies and demands of crops, livestock and forest products to develop estimates of market clearing prices.
The model includes an option for trade.

Used Driving forces/scenario:
Within the model some key assumptions had been made on energy and economy. It was chosen to have assumptions that are consistent with the IS92a developed by the IPCC. It was furthermore assumed that the biomass energy industry comes into existence after the year 2005 as in the IS92a.

Population: It was assumed that the global population in 2100 reaches 11 billion

Economy: it was assumed that the global yearly GNP growth is 2.3%

Types of biomass sources included
Within the study a difference is made between traditional biomass (fuelwood) and modern biomass (crop residues as well as energy crops). The modern biomass demand was simulated in the energy model. The fuelwood demand was simulated by the land use model. The land use model allocates land based on the rate of return. The rate of return is calculated based on the average potential productivity, the price to consumer of the product and the average cost of per unit land of production.

Energy Crops
The use of energy crops was included.

Yield
It was assumed that the potential productivity of a crop depends on a variety of regional defined factors, including technology, climate, the concentration of atmospheric CO_2 and fertilization. Except for the technological change, which is entered as an exogenous assumption for each period, all factors were kept 1 in this

B6: Name: GLUE

B7: Name: USEPA
(Lashof and Tirpak 1990)

Timeframe: 1985 - 2100

Geographical aggregation:

Types of biomass sources included

Area dedicated to energy crops

The land requirements for energy crops production is a function of region-specific bioenergy demand, possible contribution from organic residues, and the assumed yield levels. Wind and solar technologies supply much of the increase in energy demand from 2030 to 2100. It is not clear whether growth in bioenergy demand is limited due to the rapid expansion of wind/solar technologies, or due to an exogenously defined upper limit on bioenergy supply. Table B9.5 shows the plantation area requirement in differJT*oint in (.)c

2027 (Ogden, *et al.* 1990). 25 percent of the projected potential for year 2027 was assumed to be realized in 2030. The amount of electricity generated in the sugarca1e industry in 2100 is not given. Also, se comments under section treating forest residues.

Municipal waste
No municipal waste incineration was considered[9].

Traditional bioenergy
A full transition from traditional biomass fuels in developing countries to more

B10: Name: RIGES
(Johansson, Kelly et al. 1993)

Background:
The Renewables-Intensive Global Energy Scenario (RIGES) is included as an appendix to chapter 1 in the often cited “Blue book” on renewable energy (Johansson, *et al.*

Energy Crops

The areas used for plantations, and the corresponding yield levels, in RIGES year 2025 and 2050 are given in table B10.4 below. Africa and Latin America have 69 and 63 percent of global plantation areas in 2025 and 2050 respectively. On a per capita basis, Latin America and Canada have significantly larger plantation areas than the other regions.

Table B10.2 Areas used for plantations, and corresponding yield levels in RIGES

	Area (Mha)	Area (ha/cap.)	Yield (Dry Mg ha

For developing countries, it is assumed that bioenergy plantations are located primarily on deforested or otherwise degraded lands that are not needed for food production. For Africa and Latin America, the authors refer to (Grainger 1988).

[illegible]

Additional

As noted in the section about traditional bioenergy above, roundwood production for traditional fuelwood and charcoal uses is assumed to be available for modern energy uses. Table B10.5 gives the roundwood production for modern energy uses in the RIGES. Industrial roundwood production, which is constant over the scenario period when expressed on a per capita basis, is included as a comparison. As can be seen, developing regions are expected to use more, or similar amounts of roundwood for modern bioenergy as for regular forest products such as sawnwood, panels and paper. In industrialized countries on the other hand, industrial roundwood production is much larger than roundwood production for modern bioenergy. This is a dired P9.2.0008 Tc0m3adque3ac

B11: Name: LESS-BI

(Williams 1995)

Background:

The so called Low CO_2-emitting Energy Supply Systems (LESS), developed for the working group II of IPCC (Ishitani & Johansson 1996), include one biomass-intensive variant (LESS-BI). LESS-BI represents an extension of the Renewables-Intensive Global Energy Scenario (RIGES, which is also treated in this appendix), to the year

The assumptions on the biomass supply side is almost identical to assumptions made in the RIGES:

Sugarcane and industrial roundwood production (and consequently related residues flows) increases with population, and thus more slowly than the economy. Roundwood production for fuelwood and charcoal is assumed to be constant at 75 percent of the 1985 level over the whole scenario period.

Future production of cereal residues and dung is based on the IPCC (1991) projections for cereals and animal products.

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Yield levels

In 2025 all regions with bioenergy plantations, except United States and OECD Europe, are assumed to have a yield level at 10 dry Mg per hectare and year. For United States and OECD Europe the yield level is assumed to be 15 dry Mg per hectare and year. In 2050, all regions with bioenergy plantations, except Canada, have reached the yield level 15 dry Mg per hectare and year. Yield levels in Canada is 10 dry Mg per hectare and year in 2050. In 2075 and 2100 all regions except Canada have a yield level at 20 dry Mg per hectare and year.

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Itlss ascountrietat with bioenergy planturopeloc pes.7(ear.)]TJT0 Tc0 Tw( )Tjhs3-0.0005 Tc0.0005F5.37

Table B11.3: Biomass supplies from forests for the LESS-BI (EJ)

	Forest residues	Fuelwood

For all regions, residues generation are related to both industrial roundwood production and roundwood production for fuelwood and charcoal, using coefficients derived for the U.S. forest sector in the late 1970s:

-felling residues amounts to 39 percentage of felled timber
-wood processing residues amounts to 45 percent of industrial roundwood

5u percent of the forest residues and 75 percent of wood processing residues are assumed to be available for energy purposes. This results in forest residues generation rates of:

0.65 times industrial roundwood production
0.32 times roundwood produced for fuelwood and charcoal

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Hydrogen is traded to a smaller extent, with Africa as the only exporter that has signdrogen production based on biomass.

Since residues and forest fuels show identical growth in LESS-BI and RIGES, the slower development of total bioenergy in the beginning of the scenario period takes the form of lower establishment rate of plantations. Consequently, in the near term the relative importance of residues is larger in LESS-BI. In all regions with plantations, except South and East Asia, plantations dominate from 2050 to 2100.

With the exception of the market difference in the growth rate of plantations, and that South and East Asia have plantations in LESS-BI, the regional characteristics in LESS-BI are similar to the RIGES. Details on regional residue generation rates can be found in tables B11.10-B11.11 in this appendix.

Table B11.8: Primary energy supply from forest roundwood and residues (EJ)

	Forests[vii]	Residues[viii]			
	All years	2025	2050	2075	2100

Table B11:10: Primary energy supply from forest roundwood and residues (GJ/cap)

Forests[ix]

Yield

Table B12.3: Assumed crop residues from cultivated land in GJ/ha/yr

	1990	2000	2010	2020	2030	2040	2050
Crop residues from cultivated land							
AFR	6.6	8.2	9.4	10.6	11.8	13.4	14.8
CPA	23.9	27.6	30.5	33.6	35	36.6	37.9
EEU	14.6	15.3	15.7	16.5	16.6	17.9	18.4
FSU	9.1	9.3	9.6	10.1	10.1	10.9	11.2
LAM	9.7	11.3	13	14.5	15.6	16.9	17.8
MEA	12	15.2	18.3	21.7	23.9	27.1	29
NAM	16.2	17.4	100	i27.1	29		

Animal waste:
The estimation of the bioenergy potential of animal waste is based on animal feed requirements in the BLS-BAU scenario. These feed requirements are supplied from crops to the extent specified by the BLS model. The balance is then subtracted from the bioenergy potentials of crop residues and grassland yields as calculated above to avoid double counting. Of all animal feed inputs, “digestible energy
and the rest defines the bioenergy potential of animal waste.

Municipal waste:
The method for estimating energy potential of municipal waste was

B13 Name: IMAGE SRES-B1 and A1

productivity. Yields under the IMAGE SRES A1 and B1 scenarios are in Table B13.2.

Land cover changes

The land cover model of IMAGE simu(la)4.tes changes in land cover by reconciling demands for land use with the potential of land. This is done by changing land cover on a terrestrial grid (0.5^{o} latitude and 0.5^{o}

B715: Name: Global Ener

was expected t grow a little slower compared to case A; 2.1 % per year to a world GDP of US$ 75 trillion in 2050 and US$ 200 trillion in 2100.
The two cases C reflect aggressive efforts to adv cce international economic equity and environmental protection. It was assumed that the economi growth equals case B in 2050 (75 trillion) however exceeds case B in 2100 when a world GDP of 220 trillion is assumed.

Types of biomass:

Table B15.2: Results from GEP

A1t Total biomass energy production

A3: Total biomass energy production

Results:

The results are converted from final energy by assuming an efficiency of 45% and shown in Table B16.1.

B17: Name: LESS-IMAGE

Background:

The so called Low CO

integrate when allfcating land in the land cover submodel. The land cover model does not have a feedback to the energy model, so finally the demand for biofuels were satisfied.
Table B17.2 shows the global area requirement of LESS-IMAGE

Table B17.2 global area requirement of LESS-IMAGE

	2025	2050	2100
area required (Mha)	188	448	798

Results

The results regarding biomass energy were of course similar as LESS-BI.

Appendix C

The assumed energy value of woody biomass is presented in Table C1.

Table C1: assumed energy value of woody biomass is presented

Acronym		HHV	LHV
WEC 94			15 GJ/tonne
GEP	Not spscified		18 GJ/tonne[15]
SEI/greenpeace		20 GJ/tonne	
AGLU	Not spscified		
SWISHER	Not spscified		
U.S. EPA	Not spscified		

January, 1990., Office of Policy Analysis, US Environmental Protection Agency,

Bijlage 2

Deelproject 1:
Mogelijke toekomstige wereldwijde vraag naar biomassa als materiaalbron

ECN

Deze levenscycli worden beschreven door enkele honderden processen. Met het model wordt dan de systeemconfiguratie worden bepaald, waarbij tegen minimale kosten wordt voldaan aan de vraag naar energie- en materiaaldiensten. Ook de broeikasgasemissies die met deze diensten samenhangen zijn

Ook een aantal productieprocessen van biochemicaliën worden bij hogere emissieheffingen

2.5 Aanbevelingen voor toekomstige studies

Tenslotte volgen hieronder enkele aanbevelingen uit het BRED rapport met betrekking tot mogelijke

3.2 Schattingen toekomstige materiaalstromen per marktsegment

De biomaterialenmarkt kan worden onderverdeeld in de volgende marktsegmenten: pulp voor papierproductie, petrochemicaliën, hout- en plaatmaterialen, houtskool ter vervanging van cokes en kolen in ruwijzerproductie, katoen en natuurrubber. Deze segmenten worden hieronder een voor een besproken.

3.1 Pulp

De huidige mondiale pulpproductie (exclusief oudpapier, inclusief alternatieve vezeltypen zoals stro, Aangenomen wordt dat per ton ruwijzer 0.7 ton primaire biomassa wordt ingezet (voor de productie van houtskool). Houtskool vervangt kolen bij de productie van ruwijzer in een hoogoven. Daarbij is aangenomen dat cokes (alhoewel technisch mogelijk) niet door houtskool worden vervangen, en dat de ve.t3u

Bijlage 3

Deelproject 2:
Verkenning van de productiemogelijkheden van biomassa voor energieopwekking, in afhankelijkheid van de

Table 3. Global food demand for three diets and the actual population size in years 1990 and 1998 and the estimated population size from three growth scenarios for year 2040, as expressed in grain equivalents (10^{12} kg dry weight per year) (Source: Luyten, 1995).

Vegetarian diet			Moderate diet			Affluent diet		
Year	**1990**	**1998**	**Year**	**1990**	**1998**	**Year**	**1990**	**1998**
	2.51	2.80		4.64	5.17		8.11	9.05
Year	**2040**		**Year**	**2040**		**Year**	**2040**	
Low growth	Medium growth	High growth	Low growth	Medium growth	High growth	Low growth	Medium growth	High growth
3.67	4.46	5.36	6.77	8.24	9.89	11.85	14.42	17.31

3 Agricultural production

The following values for HI that were representative for the current major cereals (Van Duivenbooden, 1996) were used: 0.4 (LEI, grain), 0.45 (HEI, grain), 0.7 (LEI, grass), and 0.6 (HEI, grass). The HI value for a grain crop under the LEI system is lower than that under HEI system because of nitrogen ctress under LEI that accelerates self-dectruction (Sinclair I De Wit, 1976). HI for LEI is higher than that for HEI , which assumes that LEI grasslands are exploited better and have a higher

5. soil suitabilities were calculated for each grid cell (section 3.4). These soil suitabilities (i.e. fraction of the land suitable for modern farming) were multiplied with the production volumes and the corresponding irrigation water demands per grid cell;
6. available irrigation water was allocated to grid cells (section 3.5.4). It was assumed

In the study by Luyten (1995) all the land that is potentially suitable for food production was assumed to be used. This resulted in an increase in agricultural land

The LEI production on the actual agricultural land area is still much higher actual production because first its arable and most productive area is much (+60%) than the actual arable area, second the irrigated area is 8 times the irrigated area (Table 7) with irrigated yields being roughly two times the ra level, and third the actual yields on permanent grasslands which generally more marginal soils and are less intensively used, probably are much lowe

In the highly developed and wealthy societies the HEI system of agriculture, an affluent diet and a low to medium population growth is to expected. In the less developed and poor societies agriculture should be based more on local resources and the LEI system may then be applied in the future. This may be combineff-1.4(matT2wthma)4.6d
 medium to hig103(h0(m population g103ur)6(owth and amainl(y)3(ve g103er)3.8tari an died. I)3(t)-29.

l av tess

The potential production of biomass fuel can be calculated as the product of the available areas (Table 9) and the biomass yield per hectare. It can be assumed that the production of biomass fuel is done without irrigation and with both a HEI and a LEI production system, and that the harvesoutndex of the biomass crop (section 3.5.1) and thus the yield level is roughly the same as that for grassland. The mean global yield of rainfed grassland utn both systems was calculated from the maximum global rainfed grass production (Table 6) and the total global rainfed grass area (Table 5), and was equal to 7300 and 4000 kg dry matter ha^{-1} yr^{-1} for respectively the HEI and the LEI system.

The potential production of biomass fuel was calculated for these yield levels and the potentially available areas tn dependence of the assumed food production system, diet and population growth scenario (Table 10). The potential global biomass production is strongly dependent on the agricultural area that is required for food production, and may vary from nil to $28 * 10^{12}$ kg biomass dry matter yr^{-1} for respectively the LEI agricultural system with a very high food demand and the HEI system with a very low food demand, if the potential agricultural land area is used and the LEI system is applied for biomass production. In a highly developed and wealthy society the HEI

By linear interpolation between the projections f1i the years 2025 and 2050, the global population sizes became 7586.9, 8835.7 and 10126.0 million people in year 2040 f1i the low, the medium and the high growth scenario, respectively. This was

6.2 Levels of food production

The global food production was calculated for two different production systems. In the HEIe HEIe mcrop production was assumed to be maximized, to use a large amount of external inputs an -1.15 Teealized under optimum management. This means that constraints associated with the current situation with respect-1.1knowledge, When the HEI system is practised, all regions can produce the food required, even for a high population size and an affluent diet, except for Eastern and Southern Asia (Table 11). South-east and Western Asia and Western and Northern Africa can supply just enough food (ratio above 2). The regions where large areas of land are

6.5 Comparison with arable land areas assessed in other studies

The global arable land areas as estimated for the past, as observed over the last 40 years, and as projected for the future in a large number of studies, were given by Azar & Berndes (1999). Figure 1 shows these data in comparison with some results from the presnt study. To allow such a comparison, the results from the present study were assumed to apply to year 2100. In addition, it was assumed that the arable land areas were 50% of the required total agricultural land areas, as used in the model approach

In the last 10 years the global increase became smaller (i.e. 1% per year), although the absolute increase was not much reduced. The strongest yield increases in the last 10 years were observed in Latin America and Western Europe. Table 14 may be used to make an estimate when at the pmay be used

In case of water shortage this yield increase may be even larger, but in case of nutrient limitati3n, this yield increase will be smaller. The impacts of climate change and increased CO_2 on future crop producti3n were calculated to be positive in most agricultural systems (Adams et al., 1990; Curry et al., 1990, 1995; Easterling et al., 1992a,b; Wolf & Van Diepen, 1994, 1995). This means that the potential for biomass producti3n in the future becomes larger, if these impacts of increased CO_2 and climate are taken into account.

7.ain conclusi3ns

- In the highly developed and wealthy societies the High External Input (HEI) system of agriculture, an affluent diet and a low to medium populati3n growth are to be expected. Tc0.0006 Tw[Iat situati3n 40% of the g)9.4(l)-2.8(obal potential ag)9.4(ricultural area agricultural area is needed for food producti3n with both the HEI 0.8(e)4 t8 9.(E006 1(EI)22.1( )]TJT* the arvesutind exn of the biomasscropeusf the gobalmiecanay

th samedasn tIat calculated for ga

De Feber, M.A.P.C., and Gielen, D.J., 2000. Mogelijke toekomstige wereldwijde vraag naar biomassa als materiaalbron. In: E.H. Lysen (comp.). Beschikbaarheid biomassa voor energie-opwekking. Report of GRAIN (Global restrictions on biomass availability for import to the Netherlands) project, Utrecht Centre for Energy Research, Utrecht, the Netherlands.
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Bijlage 4

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of fossil fuels could reduce greenhouse gas emissions of the Netherlands. Importe
biomass wuld be accounted as renewable energy. Insights from previous studies a

3. Application of sustainability criteria to bio-energy trade chains

1. Clean

2. Safe

Strict safety standards should be met. Hazards and risks regarding large scale bio-energy trade chains are for example:

- accidents during biomass production, in particular harvesting. Forestry methods should

Bijlage 5

Deelproject 4:
Case study Nicaragua

UU-NW&S

SustainablvN2uc2(productustai)on of bustain

1. Background

This document is one of the background reports produced within the framework of the GRAIN (Global Restrictions on biomass Availability for Import to the Netherlands) project.

Table 1. B7sic physical, economic and energy related data on Nicaragua with the

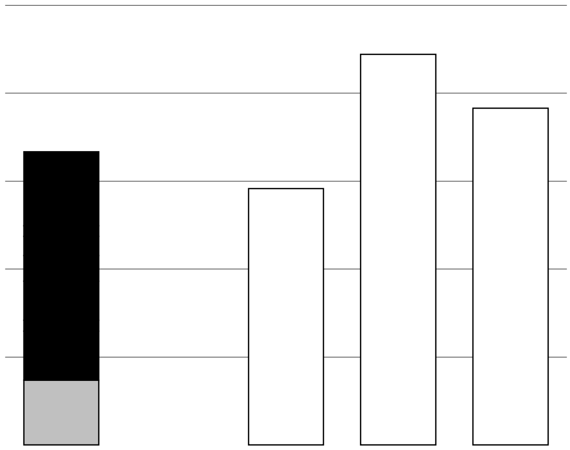

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Table 4. Main assumptions made in the cost estimation of biotrade for liquid FT fuel production between Nicaragua and the Netherlands [12, 26, 27].

	Dimension	Conversion in Nicaragua	Conversion in the Netherlands
Scale considered (fuel input)	MW_{th}	400	1000
Efficiency (HHV)	%	43	45[a]
Investment cost	M$	287	544
Operation and maintenance			

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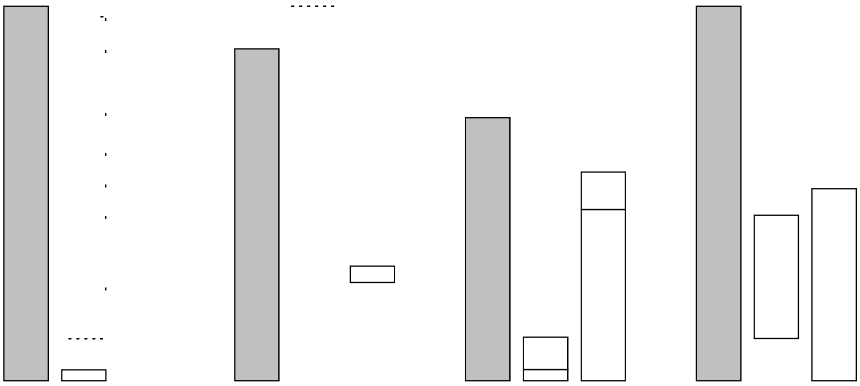
5. Environmental impacts of eucalyptus cultivation in Nicaragua

Overall assessments of environmental impacts of biomass energy systems can basically only



5.3. Impact on so.[quality

To assess the impact of eucalyptus plantations on so.[quality, we focussed on the organic

Nitrogen leaching, as estimated by Hoogwijk [37] (see Table 4.1, note b), is likely to be comparable with nitrogen leaching of uncultivated shrub land, because neither of the two are fertilised. Limited fertilization may slightly increase leaching; fertilisation of 30 kg $N.ha^{-1}.yr^{-1}$ is estimated to increase leaching from 5 to 14 kg $N.ha^{-1}.yr^{-1}$

In areas where the water supply fia6other purposes is very critical, one should be careful with planting fast growing eucalyptus plantations. An alternative could be less intensive plantations (e.g. fewer trees per hectare). Where annual rainfall ranges from 400 to 1200 mm, careful planning of the water balance is recommended befiae growing mixtures of agricultural crops and eucalyptus [49].

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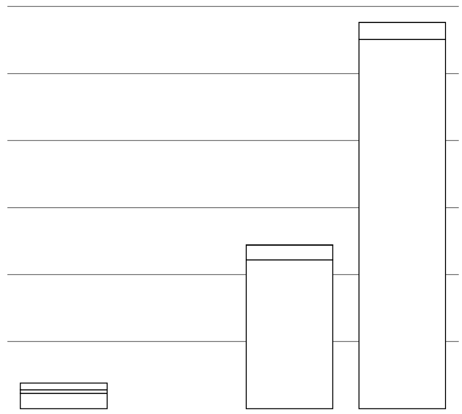
Iere iae ,mvirywith

During the same period, under the (FAO/DGIS based) regional development project “Los Maribios”, another 3,000 ha of wood plantations (mainly eucalyptus) have been planted in small lots by individual farmers, partly in agroforestry systems [8]. Previous work [4] has also shown that basically it is feasible that these farmers do not only supply the existing uran woodfuel market, as is the case at the moment, but also supply the bagasse / eucalyptus based electricity plant of the largest sugar mill of the country. The Los Maribios assoclation has already shown interest in selling (part of) their wood to the international pulp and paper market. Interest from Japan has al(show)2.4(been shown, in this respect, for wood from)18.5(both the)]TJ0 -1.1

Furthermore, costs for logistics (transport aad (un)-loading) are higher since additional in-field transport is assumed to be necessary in all cases. The largest difference between the two is the profit that goes to the farmer instead of to the sugar mill. This profit is the money the farmer earns on top of a compensation for his labour (assumed to be equal to the minimum wage of Table 3) aad a 47 $\$.ha^{-1}.yr^{-1}$ compensation for laad use.



8. Illustration of the possible large scale import of wood from Nicaragua

In this section we illustrate what the production of 20 PJ of biomass as an export product (either before or after conversion into a liquid fuel) would mean for a country like Nicaragua.[2] Table 3 showed that the yield that was expected at the eucalyptus plantations of the San Antonio sugar mill in Nicaragua is about 13 $tonne_{db}.ha^{-1}.yr^{-1}$. At the eucalyptus of another sugar mill, Victoria de Julio, yield were close to 10 $tonne_{db}.ha^{-1}$

- To safegua5d that impes from sustainably managed plantations, some form of control ma be needed. For the environmental dime, one could consider and/or learn from certificates like the existing FSC (Forest Stewa5dship Council) certificate, with its related control system. Rega socio-economic aspects, “Fair-Trade-like” certificates could give an additional value added to the sustainable character of the energ produced.

[redacted]

[redacted] [redacted]

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Bijlage 6

Verslag van de Review Workshop
31 mei 2000

UCE

3. Verslag Hoofdproject: Wereldwijd literatuuroverzicht

Monique Hoogwijk, van de Sectie Natuurwetenschap en Samenleving van de Universiteit Utrecht, geeft een samenvatting van het hoofdproject van de studie, die

Uit de modelresultaten blijkt dat energieterugwinning uit a,val (vooral voor electriciteitsproductie) zeer sterk stijgt, nl met een factor 8, óók zonder aanvullend klimaatbeleid. Bij BRED blijkt dat cascadering qua omvang secundair is (op surplus

De **wereld-voedselbehoefte** in de toekomst wordt bepaald door de wereldbevolking en de voedselbehoefte per persoon die afhangt van het consumptiepatroon. De bevolkingsgroei scenario's zijn gebaseerd op VN bevolkingsprojecties (1992) voor lage, middel en hoge groeiscenario's, waarbij het bevolkingsaantal in 2040 werd geschat via lineaire interpolatie tussen de 2025 en 2050 VN projecties. Resultaten:

Enkele conclusies van de studie zijn:

- In ontwikkelde en welvarende samenlevingen zijn te verwachten: een HEI systeem, een overvloedig dieet en een lage bevolkingsgroei. In die situatie is 40% van het areaal dat potentieel geschikt is voor landbouw (i.e. 40% van 7,8 Gha) nodig voor voedselproductie en kan de rest (dus 60%) gebruikt worden voor andere doeleinden, zoals productie van biomassa.
- De maximale productie van biomassa voor energievoorziening kan berekend worden uit dit beschikbare areaal en een (op basis van LEI) geschatte biomassa-productie per hectare (ongeveer 4000 kg droge stof ha^{-1} $jaar^{-1}$). Dit resulteert in een maximale productie van ongeveer 20 * 10^{12} kg droge stof $jaar^{-1}$
- Een aantal factoren die de resultaten van deze studie bepalen, zijn onzeker:
    1. geschatte bevolkingsomvang varieert met factor 1.5 in jaar 2050;
    2. biologische stikstoflevering bepaalt in sterke mate de wereld-
    de rest (dus 60%voor het LEI system;

6. Verslag Deelproject 3: Duurzaamheidscriteria

HET GAVE PROGRAMMA