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POSITION PAPER
BIOFUEL AND WOOD AS ENERGY SOURCES
Effect on Greenhouse Gas Emissions

Introduction

The combustion of oil, coal and gas produces CO_2 and other greenhouse gases. Plants, on the other hand, absorb CO_2 as they grow. Dutch and EU legislation therefore encourage the combustion of wood in power stations and the use of plant-based biofuels (biodiesel and bioethanol) for road transport. Policymakers hear diverging views on the effectiveness of this policy. This document summarises the views of independent experts. It is restricted to the main outlines (for details, see the references[1]) and does not aim to provide an overview of the entire energy problem or of future developments. It discusses solely the effect that regulations regarding the co-firing of wood with coal in power stations and biofuels for transport have on greenhouse gas emissions. New technologies may change the situation and research on such technologies therefore needs to continue.

Use of wood in power stations

The EU considers wood and wood waste as an important source of sustainable fuel. Thanks to the subsidy provided for this[2], Dutch coal-fired power stations are increasingly burning wood from the United States and Canada[3]. As demand grows, more and more forests will need to be cleared[4]. This will lead to the release of large amounts of greenhouse gases because burning wood produces at least as much CO_2 as burning coal[5]. Newly planted trees can absorb this CO_2, but even if every tree felled is replaced by a new one, it would take from 20 to 100 years for the CO_2 to be captured again.[6]

Co-firing wood does not lead to innovation and the contribution that it makes to reducing CO_2 emissions is uncertain. It is not an effective way of reducing the emission of greenhouse gases.

Biofuel for cars

The production of bioethanol and biodiesel as fuel for road transport involves a number of fundamental problems:

- *Using plants to generate energy is not effective*

Oil, natural gas and coal are the product of compressed plants and animals. They are therefore biofuels. Their creation has taken four hundred million years, since plants are very inefficient when it comes to storing solar energy. Plants and trees are only able to capture 0.03% of the solar energy reaching the earth[7]. In the Netherlands, we would need to plant a zone as large as the area north of a line between Amsterdam and Enschede with rape in order to replace 5% of our petrol and diesel fuel by rapeseed oil[8]. Solar power plants can capture a great deal more of the sun's energy[9]. The scientific and economic future lies in the *direct* use of solar energy, via photovoltaic or bio-organic means.

- *There is not enough suitable agricultural land*[10]

Biofuels compete with food[11]. As there is a shortage of agricultural land, natural land is brought under cultivation for food crops that have been displaced elsewhere by crops grown for biofuels ('Indirect Land Use Change' or ILUC). Cultivating these areas of natural land for biofuels produces a large amount of greenhouse gases. The net benefit of replacing fossil fuels by biofuel is therefore limited and uncertain.[12]

- *Biofuel competes with more valuable and more urgent use of biomass*

To a large extent, so-called 'waste' needs to be returned to the soil to maintain its fertility[13]. Moreover, it is better to use waste – and biomass in general – as a raw material for cattle feed and for high-value chemical production rather than as a fuel. Biorefining enables the extraction of proteins, fibre, and materials from waste for use in plastics; only unusable residues of biorefining are burned.[14]

However, the mandatory use of biofuel in Europe means, for example, that used cooking oil is now more expensive than fresh oil[15]. As a result, the oleochemical industry is no longer using cooking oil as a raw material for lubricants, paint, and soap, but is using palm oil instead[16]. Using cooking oil for biodiesel therefore leads to natural forest being cleared to grow oil palms.[17]

- *Fuel is needed to manufacture biofuels*

Tilling the soil, pesticides, artificial fertilisers, transport and converting plants into liquid all consume electricity, natural gas and petrol. Part of the CO_2-related benefit is therefore lost. If we take the substitution effects into account (Indirect Land Use Change), then some biofuels produce more greenhouse gases than does regular petrol.[18] [19]

It is doubtful whether second-generation biofuel from plant waste, grass and trees can provide a solution. It requires the use of fertile land and water. Harvesting, transporting and liquefying grass and wood consume fuel, as does biofuel from food.[20] Extracting biofuel from algae offers more prospects, but its feasibility is uncertain.[21]

Conclusion

The combustion of wood in power stations and fuelling cars with bioethanol and biodiesel make virtually no contribution to reducing CO_2 emissions. These technologies are therefore unsuitable for facilitating the transition to sustainable energy generation.

European legislation

The EU and the Netherlands are encouraging the use of biofuel and wood. The assumption is that this will automatically lead to a reduction in the use of coal and oil, in the same way as drinking more water reduces consumption of soft drinks. But while a person consumes, on average, up to two litres of liquid each day[22], there is no natural upper limit to the consumption of fuel and electricity. As long as energy is affordable, consumption will rise, for example for air conditioning. The EU's rules allow unrestricted CO_2 emissions by road traffic as long as about 10% of the petrol or diesel fuel is derived from biofuel; the remaining 90% then comes from petroleum.

The EU's volume target for biofuels and the Dutch subsidy for co-firing do not, therefore, lead automatically to a reduction in CO_2 emissions. Moreover, they have undesirable effects such as the destruction of nature and competition with food and with high-value use of biomass. Expensive monitoring systems are also necessary to verify the origin of fuel and 'waste'. This is not an effective system. Reducing greenhouse gas emissions requires dealing directly with the emissions themselves.

Recommendations

1. Phase out the obligations regarding biofuel. In the meantime, impose more stringent sustainability requirements for the origin of biomass and demand transparency in this regard.
2. Phase out the subsidy for firing/co-firing of wood in power stations.
3. Increase the cost of emitting greenhouse gases.
4. Encourage the use of biomass as a raw material for high-value products (cascading, biorefining) rather than for energy.[23] Only burn what remains if it cannot be used for anything else.
5. Encourage energy efficiency and fuel saving; there is much to be gained by doing so.[24]
6. Encourage innovations in the direct use of solar energy (photovoltaic, bio-organic).[25]

About this publication

The Royal Netherlands Academy of Arts and Sciences sometimes publishes short position papers dealing with current themes about which science can provide factual information. In this way, the Academy aims to contribute to the public debate. 'Biofuel and Wood as Energy Sources' is such a theme.

This position paper has been produced by Academy members Prof. Martijn Katan, Prof. Louise Vet, and Prof. Rudy Rabbinge.

A draft of the document was reviewed by Prof. Johan Bouma and Prof. Lucas Reijnders.

Important references

- **EASAC 2012**: European Academies Science Advisory Council, 2012. The current status of biofuels in the European Union, their environmental impacts and future prospects. www.easac.eu/home/reports-and-statements/detail-view/article/the-current.html

- **FAO 2013**: Food and Agriculture Organization of the UN, 2013. Biofuels and the sustainability challenge. www.fao.org/docrep/017/i3126e/i3126e.pdf
- **FAO/OECD 2011**. FAO, IFAD, IMF,OECD, UNCTAD, WFP, the World Bank, the WTO, IFPRI and the UN HLTF. Price Volatility in Food and Agricultural Markets: Policy Responses. www.oecd.org/agriculture/pricevolatilityinfoodandagriculturalmarketspolicyresponses.htm
- **GEA 2012**: International Institute for Applied Systems Analysis, 2012 - Global Energy Assessment. Toward a Sustainable Future. www.globalenergyassessment.org Ch. 9.4.1.2 Biofuels, Ch. 9.6.4.3 Reducing the Carbon Intensity of Fuels, and Chapters 11 and 20
- **HLPE 2013:** High Level Panel of Experts, 2013. Biofuels and food security. A report by the High Level Panel of Experts on Food Security and Nutrition of the UN Committee on World Food Security. www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_2013_Reports/HLPE-Report-5_Biofuels_and_food_security.pdf
- **IEEP 2013:** The Institute for European Environmental Policy, 2013. The European Commission's proposal to mitigate indirect land use change from biofuels. www.ieep.eu/work-areas/climate-change-and-energy/2013/06/ieep-s-latest-reflections-on-the-european-commission-s-proposal-to-mitigate-indirect-land-use
- **IPCC-SSREN 2011:** IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. ET AL. (eds)]. Cambridge University Press, United Kingdom and New York, NY, USA, p. 1-1075. http://srren.ipcc-wg3.de/report
- **JRC 2013**: European Commission, Joint Research Centre – Institute for Energy and Transport, 2013. Carbon accounting of forest bioenergy. http://iet.jrc.ec.europa.eu/bf-ca/sites/bf-ca/files/files/documents/eur25354en_online-final.pdf
- **PBL 2013**: Ros, J.P., Minnen, J.G., Arets, E.J.M.M., 2013. Climate effects of wood used for bioenergy. PBL Netherlands Environmental Assessment Agency. www.pbl.nl/publicaties/klimaateffecten-door-gebruik-van-hout-voor-bio-energie
- **UK 2008**: House of Commons, Environmental Audit Committee, 2008. Are biofuels sustainable? www.publications.parliament.uk/pa/cm200708/cmselect/cmenvaud/76/76.pdf
- **UNEP 2014:** United Nations Environment Programme. 2014. Assessing Global Land Use: Balancing Consumption with Sustainable Supply. A Report of the Working Group on Land and Soils of the International Resource Panel. Bringezu S., Schütz H., Pengue W., O´Brien M., Garcia F., Sims R., Howarth R., Kauppi L., Swilling M., and Herrick J. Paris, France. http://www.unep.org/resourcepanel/Publications/AreasofAssessment/AssessingGlobalLandUseBalancingConsumptionw/tabid/132063/Default.aspx

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[1] See above under Important references

[2] Letter from Economic Affairs Minister Henk Kamp to the House of Representatives regarding the SDE and SDE+. 11 November 2014 www.rijksoverheid.nl/documenten-en-publicaties/kamerstukken/2014/11/11/kamerbrief-over-sde-2015.html

[3] USDA Global Agricultural Information Network. EU Biofuels Annual 2014. The Hague, 2014 http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_The%20Hague_EU-28_7-3-2014.pdf

Rácz K et al. From Whence the Wood? Supply Chain Transparency and the Origin of Solid Biomass for Electricity Generation in the Netherlands. SOMO, June 2013. www.somo.nl/publications-en/Publication_3971

[4] Agostini, A., Giuntoli, J., Boulamanti, A., 2013. Carbon accounting of forest bioenergy - Conclusions and recommendations from a critical literature review. Joint Research Centre of the European Commission, Ispra. P. 52: 'the amount of bioenergy from such residues (called indirect wood) is expected to be stable (or even to decrease slightly) while the wood sourced directly from the forest (from additional fellings, harvest residues, complementary fellings, salvage loggings, etc.) is expected to increase by 50% between 2006 and 2020'. P 52: 'the new large pellets plants (such as Greencircle, Florida, 500 ktonnes; Waycross, Georgia, 750 ktonnes; Vyborgskaya, Russia, 1000 ktonnes) will rely mostly on stemwood from dedicated bioenergy harvest as feedstock' http://iet.jrc.ec.europa.eu/bf-ca/sites/bf-ca/files/files/documents/eur25354en_online-final.pdf

[5] JRC 2013 p. 16: 'the combustion of woody biomass releases, in most cases, more CO2 in the atmosphere, per unit of delivered energy, than the fossil fuels they replace. This is because biomass normally has less energy per kg of carbon and also lower conversion efficiency'

[6] JRC 2013 p. 75: 'Most of the forest feedstocks used for bioenergy, as of today, are industrial residues, waste wood, residual wood (thinnings, harvest residues, salvage loggings, landscape care wood etc.) for which, in the short to medium term, GHG savings may be achieved. On the other hand, in the case of stemwood harvested for bioenergy purposes only, if all the carbon pools and their development with time are considered in both the bioenergy and the reference fossil scenario, there is an actual increase in CO2 emissions compared to fossil fuels in the short-term (few decades). In the longer term (centuries) also stemwood may reach the fossil fuel parity points and then generate GHG savings if the productivity of the forest is not reduced because of bioenergy production.'

PBL 2013 p. 10: 'In many cases, it will take more than a century to realise a situation with the carbon losses in the forest equal to the carbon harvested.'

Bowyer, C, et al. (2012) The GHG emissions intensity of bioenergy: Does bioenergy have a role to play in reducing GHG emissions of Europe's economy? Institute for European Environmental Policy (IEEP): London.
www.ieep.eu/assets/1008/IEEP_-_The_GHG_Emissions_Intensity_of_Bioenergy_-_October_2012.pdf
P. 5: 'increasing the intensity of forestry management and increasing biomass extraction rates over time will lead to a 'carbon deficit'. This then needs to be 'repaid' before the exploitation of bioenergy from such resources can deliver emission savings compared to burning fossil fuels.'
P 7: There are two important reasons why the net impact is often negative. One concerns the significant delay that is likely to occur in the onset of carbon sequestration on a scale additional to the payback of emissions comparable to those from the replaced fossil fuel system. This time period depends on the composition and history of the forest affected and the rate of acceleration of absorption of carbon from the atmosphere through re-growth compared to that in an unharvested forest. The second reason is that it is not sufficient to assume that consumption of bioenergy at time X is simply followed by an immediate period of regrowth until a GHG balance has been attained, as it is often assumed in life cycle assessments relying on a more schematic approach. In reality, successive episodes of bioenergy exploitation may well occur and keep creating a GHG emission debt so that the additive effects keep pushing the date for the eventual balance in GHG emissions further and further into the future.'

[7] The sun radiates annually 4 million ExaJoule of energy towards the earth, from which 1300 EJ is stored by plants and trees, so 0.03%.

IPCC SSREN 2011, p 172: 'On a global basis, it is estimated that RE accounted for 12.9% of the total 492 EJ of primary energy supply in 2008 (IEA, 2010a).'

p. 341: 'the amount of irradiance at the Earth's surface (land and ocean) that is theoretically available for energy purposes, has been estimated at 3.9 x 10^6 EJ/yr (Rogner et al., 2000; their Table 5.18)'

P 222: 'the total annual aboveground net primary production (NPP: the net amount of carbon assimilated in a time period by vegetation) on the Earth's terrestrial surface. This is estimated to be about 35 Gt carbon, or 1,260 EJ'... 'the global harvest of major crops (cereals, oil crops, sugar crops, roots, tubers and pulses) corresponds to about 60 EJ/yr'

[8] Calculation:

Gross production of 1 ha of rapeseed is 1.18 tonnes of oil equivalent biodiesel (Janssens B. et al. Beschikbaarheid Koolzaad Voor Biodiesel. Rapport 6.05.07. Landbouw Economisch Instituut (LEI) 2005, Table 5.1).

The production process requires an investment of about 0.5 ton per ton, so net yield of one hectare is 0:59 ton. (Zah, R. 2007. Life cycle assessment of energy products: environmental impact assessment or biofuels - Executive Summary Bundesamt für Energie BFE Bundesamt für Umwelt BAFU, Bundesamt für Landwirtschaft BLW, Berne, Figure 4: cumulated non-renewable energy.. demand for rape ME CH is approximately 56%.)

The Dutch road traffic consumed in 2012 463 PJ of fuel (CBS).

1 PJ = 23 885 tonnes of oil equivalent, i.e. 5% of Dutch consumption is 552 938 tonnes of oil equivalent. That requires 937 183 ha to 1 ha of rapeseed if net yield is 0.59 tons.

That is about 67% of the land area north of the line Amsterdam-Enschede (http://www.holland-info.nl/holland.php?page=provincies.nl&menu=menu_nl). The remaining 33% is probably not cultivable; The Netherlands has a land area of 3.382 million ha 1,895,194 ha of cultivated land, which is 56% [CBS].

[9] IPCC SSREN 2011, P 342: 'resulting technical potentials for 2050 are 1,689 EJ/yr for PV <photovoltaics (solar panels)> and 8,043 EJ/yr for CSP <Concentrated Solar Power, for example power plants with concave mirrors >'

[10] UNEP 2014, P. 5: 'the growing demand for food and non-food biomass could lead to a gross expansion of cropland in the range of 320 to 850 million hectares by 2050. Expansion of such magnitude is simply not compatible with the

imperative of sustaining the basic life-supporting services that ecosystems provide". P 13-14: "Major options to reduce cropland requirements and to relieve the social and environmental pressures associated with land use change include: <…> Delinking the markets for fuels and food by reducing the direct and indirect subsidization of fuel crops (including the reduction and phase out of biofuel quotas in consuming countries);'

Edwards, R., Mulligan, D., Marelli, L., 2010. Indirect land use change from increased biofuels demand - Comparison of models and results for marginal biofuels production from different feedstocks. European Commission Joint Research Centre, Ispra.
http://ec.europa.eu/energy/renewables/studies/doc/land_use_change/study_4_iluc_modelling_comparison.pdf

Laborde, D., 2011. Assessing the land use change consequences of European biofuel policies. Carried out by the International Food Policy Institute (IFPRI) for the Directorate General for Trade of the European Commission. http://trade.ec.europa.eu/doclib/html/148289.htm <See Edwards 2010 for a comparison of the results of IFPRI with other models>

[11] FAO/OECD 2011 p. 10: 'biofuel production will exert considerable upward pressure on prices in the future.' P 27: 'world market prices of these products (and their substitutes) are substantially higher than they would be if no biofuels were produced. Biofuels also influence products that do not play much of a role as feedstocks, for example wheat'.

HLPE 2013 p. 107: 'It is the very expansion of the consumption of biofuels, their beginning to have an impact outside the frontiers of the major producers, either by reducing exports of food or by increasing imports, driving the increase of international prices, which can have a negative impact on food security, on poor importing countries, poor consumers.'

[12] EASAC 2012, p. 20: 'in most countries, using liquid biofuels instead of fossil fuels does not lead to a net reduction of greenhouse gas emissions.'

FAO 2013, p. 68: 'LCAs of the environmental impacts of biofuel production and consumption have shown a wide disparity in results, from net reduction in GHG emissions to a net increase'

IEEP 2013, P.1: ' When these additional emissions are taken into account, the potential GHG emissions savings arising from the use of biofuels rather than fossil fuels are reduced significantly (or in some case emissions could increase compared to fossil fuels)'

International Institute for Applied Systems Analysis, 2012. Global Energy Assessment – Toward a Sustainable Future, Cambridge University Press, Ch 9, P 601: CO2 emissions from direct and indirect land-use change are often neglected, tend to worsen GHG benefits, and add considerable uncertainties over the net GHG benefits of biofuels. Ch 9, p 602: 'biofuels currently available in the market place have questionable impact on GHG emissions'

Scharlemann, J.P.W., Laurance, W.F., 2008. How Green Are Biofuels ?(Perspective). Science 319, 43–44. 'The findings of Zah et al. are striking (13). <….> nearly half (12 out of 26) of the biofuels—including the economically most important ones, namely U.S. corn ethanol, Brazilian sugarcane ethanol and soy diesel, and Malaysian palm-oil diesel—have greater aggregate environmental costs than do fossil fuels'

Searchinger, T., et al., 2008. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 319, 1238–1240. www.sciencemag.org/content/319/5867/1238.long Abstract: 'These analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland to replace the grain (or cropland) diverted to biofuels. <…> we found that corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. Biofuels from switchgrass, if grown on U.S. corn lands, increase emissions by 50%.'

IPCC-SRREN 2011, Ch 9, p. 735: 'The total lifecycle GHG emissions of fuels critically depend on the sign and magnitude of direct and indirect LUC effects, which could potentially negate or exceed any GHG reduction benefit from the displacement of petroleum fuels by biofuels'. P 735-736 give an in-depth overview of the problems around changes in land use resulting from biomass production.

[13] IPCC-SRREN 2011, ch 2, p 229: 'the cost of soil productivity loss may restrict residue removal intensity to much lower levels than the quantity of biomass physically available in forestry'

Schils R. 30 vragen en antwoorden over bodemvruchtbaarheid. 2012. Alterra/Wageningen UR. P. 109: 'Een risico op verschraling van de bodem ontstaat bij een toename van het gebruik van primaire bijproducten uit de landbouw. Als gewasresten als stro of bietenloof worden afgevoerd zonder compensatie, komt de organische stofvoorziening van de bodem in de knel.' <translated: An increased use of agricultural primary by-products cause an increased risk of soil depletion. If crop residues such as straw or beet tops are discharged without compensation, this may have a negative influence on the supply of organic matter>

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[14] The Social and Economic Council of the Netherlands (SER), 2010. More chemistry between green and growth: The opportunities and dilemmas of a bio-based economy (2010/05 E) www.ser.nl/en/publications/publications/2010/2010_05.aspx

[15] Arup URS Consortium, 2014. Advanced Biofuel Feedstocks – An Assessment of Sustainability. Produced by the Arup URS Consortium for the Department for Transport (UK). P. 21: 'UCO <Used Cooking Oil> now trades at a 5- 20% premium <over virgin vegetable oils> ….. stakeholders pointed towards evidence of fraud in reporting of volumes of UCO, and the perverse incentive created for artificially increasing the volumes of UCO in the market …. it was asserted by one stakeholder that other industries which use the same wastes and residues have been disadvantaged as a result of double counting incentives. The example of animal fats as used by the oleochemicals industry was given'

[16] Voorlichtingsbureau margarine, vetten en oliën <Information office for margarine, fats and oils>. Gebruikt frituurvet – de keten gesloten. Augustus 2012. Used cooking oil was used as a raw material for the manufacturing of lubricants, plasticizers for plastics, coatings and paints, inks and solvents www.frituurvetrecyclehet.nl/resources/File/Factsheet%20Gebruikt%20frituurvet%202012.pdf

[17] Moreover, the available quantities of waste are too small. Using Dutch cooking oil to produce biofuel would result in fuel for only one day a year for Dutch road traffic. In 2012, 1.1% of the energy for traffic and transport, accounting for 3.9 days driving per year, was provided by double-counting biodiesel (FAME). About two-thirds was produced using animal fats and tallow and one-third, 1.3 days a year, using cooking oil, Reference: Nederlandse Emissie Autoriteit. *Naleving jaarverplichting 2012 hernieuwbare energie vervoer en verplichting brandstoffen luchtverontreiniging.* P. 26: 9119 TJ (or 4560 TJ counting once), delivered by double-counting FAME. P. 18: of which one-third is cooking oil. This equals 1520 TJ or 41 000 tons of cooking oil. On an annual basis potentially 44 000 tons can be collected from the hotel and catering industry and 10 000 from individuals. So the use of 41 000 tons of cooking oil into fuel in 2012 approached the maximum achievable.

(www.frituurvetrecyclehet.nl/meest-gestelde-vragen).

A greater contribution of used cooking oil to fuel production is only possible by imports from Asia. This can provoke fraud; Labeling new Indonesian palm oil as 'Used Cooking Oil' increases the price by 5-20%. (Source: Arup URS Consortium, 2014, see above)

[18]EASAC 2012 p. 20: 'using liquid biofuels instead of fossil fuels does not lead to a net reduction of greenhouse gas emissions'

GEA 2012 Ch 9.4.1.2 P 601: 'corn ethanol has twice as high lifecycle emissions as gasoline' P 602: 'biofuels currently available in the market place have questionable impact on GHG emissions'

IPCC-SRREN 2011, p 214: 'land use conversion and forest management that lead to a loss of carbon stocks (direct) in addition to indirect land use change (d+iLUC) effects can lessen, and in some cases more than neutralize, the net positive GHG mitigation impacts'

Hiederer, R. et al, 2010. Biofuels: a new methodology to estimate GHG emissions due to global land use change–A methodology involving spatial allocation of agricultural land demand, calculation of carbon stocks and estimation of N2O emissions. European Commission Joint Research Centre Report. http://iet.jrc.ec.europa.eu/remea/biofuels-new-methodology-estimate-ghg-emissions-due-global-land-use-change-methodology-involving Table 35: Indirect land use change (ILUC) causes, depending on the model used, an extra production of 34 to 63 gram CO2 equivalents per MJ energy. Table 36 and 37, all models, crop conversion over 20 years: the total net emission value of biofuels is 56 to 111 gram CO2 equivalents per MJ energy. Well-to-wheel emission of both fossil petrol and diesel is 83-87 gram CO2 equivalents per MJ energy. It is therefore uncertain if replacing petrol and diesel by biofuels will decrease or increase the emissions of greenhouse gases: the emission is 56/85 to 111/85 so 65% to 130% of the emission of petrol or diesel.

[19] European objectives require an emissions reduction of at least 35% compared to fossil fuel and this limit will further increase in the coming years. However important sources of greenhouse gas production are not taken into account in the calculation of the emission reduction. Leading experts estimate that replacing fossil fuel by biofuel leads to between 35% less or 30% more greenhouse gases. [See Hiederer et al, 2010, above]

[20] EASAC 2012, p. 15: 'Some second-generation technologies appear to offer much improved reductions in greenhouse gas emissions. However, they will not be in fullscale production before 2020 and the anticipated improvements remain to be demonstrated at the commercial scale.'

GEA 2012 Ch 9.4.1.2, P 602: 'recent studies question the economic viability of second generation biofuels and point out that these biofuels compete with food production, too'

Sims, R.E.H., Mabee, W., Saddler, J.N., Taylor, M., 2010. An overview of second generation biofuel technologies. Bioresource Technology 101, 1570–1580. www.sciencedirect.com/science/article/pii/S0960852409015508. P. 1578:

‘full commercialisation of either biochemical or thermo-chemical conversion routes for producing 2nd-generation biofuels appears to remain some years away. This is in spite of several decades of research and development, and more recent investment in several pilot-scale and demonstration plants in US, Europe and elsewhere. Even with generous government subsidies, the commercial risks remain high’

Richard Doornbosch and Ronald Steenblik. Biofuels: is the cure worse than the disease? Organisation for Economic Co-operation and Development (OECD / OESO) Round Table on Sustainable Development. Paris, 11-12 September 2007. www.oecd.org/dataoecd/9/3/39411732.pdf p 5: ‘As second-generation technologies are still in the demonstration phase, it remains to be seen whether they will become economically viable over the next decade, if ever. Even with positive technological developments there are serious doubts about the feasibility of using residue material as biomass feedstock on a large scale. The logistical challenge of transporting biomass material to large production facilities is likely to impose a floor below which production costs cannot be lowered. This leads some to believe that the second-generation biofuels will remain niche players, produced mainly in plants where the residue material is already available in situ, such as bagasse (cellulosic residue from sugarcane pressing) and wood-process residues.’

The Costs Of Biofuels. Two views on whether corn ethanol and, eventually, ethanol from cellulosic biomass will efficiently deliver national energy security. Chemical & Engineering News. December 17, 2007.Volume 85, Number 51 pp. 12-16. http://pubs.acs.org/cen/coverstory/85/8551cover.html

[21] Reijnders, L., 2013. Lipid-based liquid biofuels from autotrophic microalgae: energetic and environmental performance. Wiley Interdisciplinary Reviews: Energy and Environment 2, 73–85. doi:10.1002/wene.29 http://onlinelibrary.wiley.com/doi/10.1002/wene.29/full P 81: ‘assumptions about the future impact of proposals for improving energy return on investment seem overly optimistic. In other cases, the impact of proposals for improvement of EROI is highly uncertain because research is at an early stage. So, prospects … appear to be largely dependent on breakthroughs in production technology which may, or may not, occur.’

IPCC SSREN 2011, Ch. 2, p 304: ‘The prospects of algae-based fuels and chemicals are at this stage uncertain, with wide ranges for potential production costs reported in the literature’

Scott, S.A., Davey, M.P., Dennis, J.S., Horst, I., Howe, C.J., Lea-Smith, D.J., Smith, A.G., 2010. Biodiesel from algae: challenges and prospects. Current Opinion in Biotechnology 21, 277–286. https://course.ku.ac.th/lms/files/resources_files/3900/130564/biodiesel_from_algae-challenges_and_prospects_2010.pdf ‘Life-cycle analyses suggest that – using current methodologies – the process is marginal in terms of positive energy balance and global warming potential. Prospective schemes for the scale-up of algal production need to be informed by careful process modeling and LCA from the design stage. Without careful assessment of the energy balances and environmental impacts, there is a danger that many proposed schemes would be nonsensical from the point of view of sustainability. Moreover the lack of data from real-life demonstrations means that economic assessments are essentially hypothetical, and there is a pressing need to conduct pilot studies at a realistic scale and under prevailing weather conditions, so as to assess productivities likely to be achieved in practice.’

Sander, K., Murthy, G.S., 2010. Life cycle analysis of algae biodiesel. The International Journal of Life Cycle Assessment 15, 704–714. www.rshanthini.com/tmp/DPR514/Module07_LifeCycleAnalysis_of_algae_biodiesel.pdf P. 704: ‘The potential of green algae as a fuel source is not a new idea; however, this LCA and other sources clearly show a need for new technologies to make algae biofuels a sustainable, commercial reality.’ (According to them biodiesel from algae costs more fuel than it produces. Only if algae produce other valuable constituents the process may become worthwhile)

Lardon, L., Hélias, A., Sialve, B., Steyer, J.P., Bernard, O., 2009. Life-cycle assessment of biodiesel production from microalgae. Environmental science & technology 43, 6475–6481. https://wiki.umn.edu/pub/Biodiesel/WebHome/life_cycle_assesment_of_biodiesel_form_micro_algae.pdf P. 6280: ‘algal biodiesel suffers from several drawbacks at the current level of maturity of the technology. In comparison to conventional energetic crops, high photosynthetic yields of microalgae significantly reduce land and pesticide use but not fertilizer needs. Moreover, production, harvesting, and oil extraction induce high energy consumption, which can jeopardize the overall energetic balance. It appears that even if the algal biodiesel is not really environmentally competitive under current feasibility assumptions, there are several improvement tracks which could contribute to reduce most of its impacts.’

[22] Meinders, A.-J., Meinders, A.E., 2010. Hoeveel water moeten we eigenlijk drinken? Ned Tijdschr Geneeskd 154, A1757. A person consumes, on average, 1.5-2 litres of liquid each day.

[23] The Social and Economic Council of the Netherlands (SER), 2010. More chemistry between green and growth: The opportunities and dilemmas of a bio-based economy (2010/05 E) www.ser.nl/en/publications/publications/2010/2010_05.aspx

A. Brinkmann. Biomassa als grondstof of als brandstof - praktijkvoorbeelden van ongewenste concurrentie om Nederlandse biomassastromen. May 2014. Commissioned by Greenpeace NL, Stichting Natuur & Milieu, IUCN – National Committee of the Netherlands and World Wide Fund for Nature. www.natuurenmilieu.nl/media/1131057/concurrentie-om-biomassa-nederlandsepraktijkvoorbeelden.pdf

[24] IPCC-SRREN, p. 663.

[25]In addition, research is performed on many other technologies that might reduce emissions of greenhouse gases including CO2 storage (possibly in solid form), nuclear fusion, geothermal energy, hydro, wind, and tidal energy etc. Discussion of this research is beyond the scope of this document.