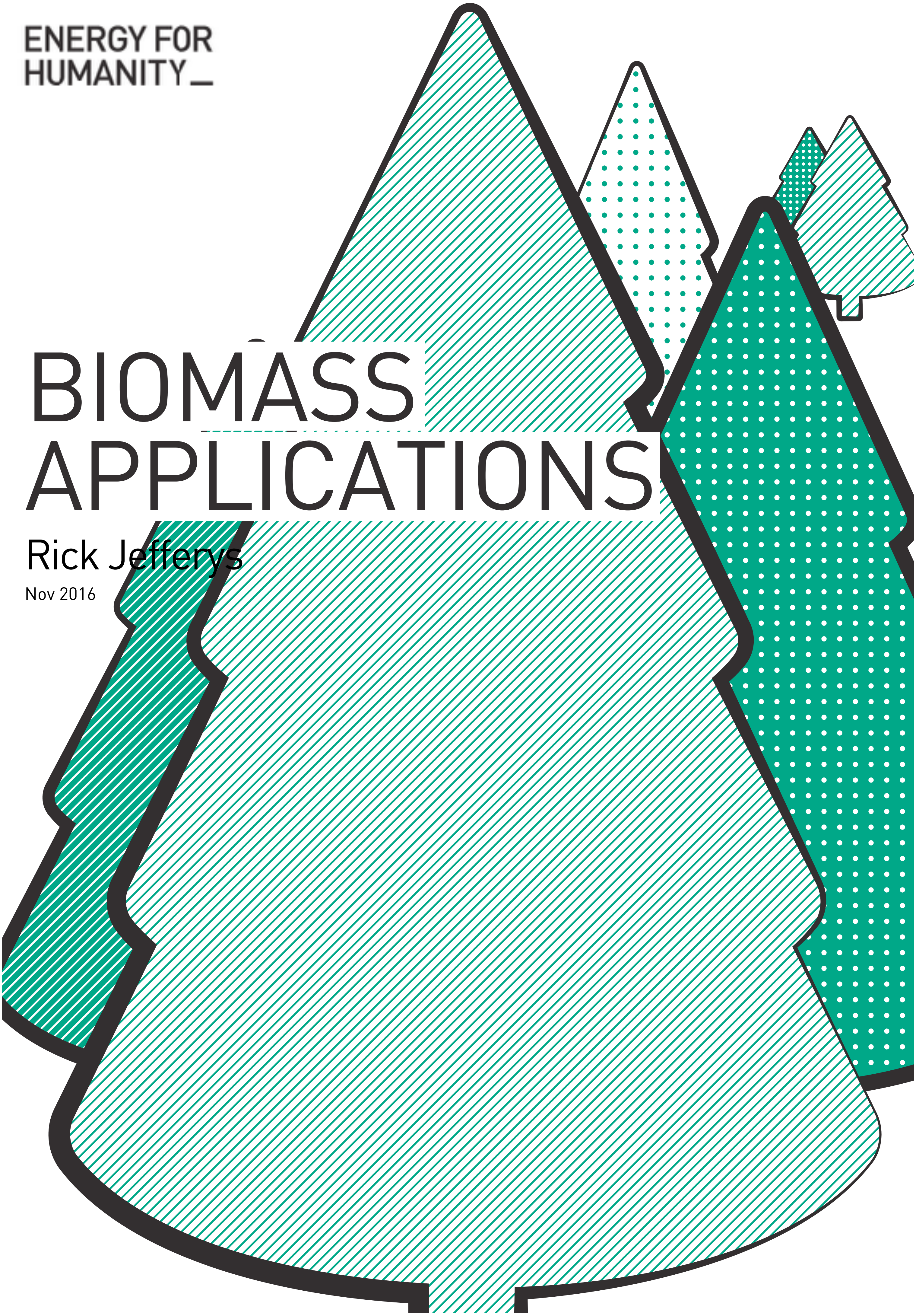
ENERGY FOR HUMANITY_

BIOMASS APPLICATIONS



Rick Jefferys

Nov 2016

World population is on the increase and improving living standards are driving up meat consumption (vastly less efficient than direct consumption of plants). How should we make the most of our available land resources?

Biomass - food, agricultural waste, forestry waste and products - can be used for 'clean' energy in a number of ways. Subsidies and other support schemes are usually devised in a piecemeal fashion at the instigation of sectional interests, with little thought given to overall efficiency, sustainability and side effects. There are many types of biomass, a large variety of ways to convert them to useful energy and a corresponding plethora of products. It makes sense to review the feedstocks and related sustainability issues before diving into processing and products.

World population is on the increase and improving living standards are driving up meat consumption (vastly less efficient than direct consumption of plants). Using land to grow energy feedstocks would necessitate conversion of wild land to agriculture (e.g. rain forest to palm oil plantations). Both food to fuel (e.g. corn to ethanol) and energy crops grown on agricultural land should therefore be ruled out. Forest crops grown on land unsuitable for agriculture are potentially viable, but wood may be better used as a building material, displacing energy intensive steel and cement, than as an energy source (see Julian Allwood, 'Sustainable Materials'). Old growth forest should not be felled for biomass since the time to recapture the CO_2 released is excessive, even if the forest is replanted immediately.

Agricultural and forestry wastes are potential sources of energy. But it is imperative to return enough carbon and other nutrients to maintain soil quality. We are 'mining' many agricultural soils, with less than 60 harvests left in many areas. Invasive species (e.g. Mesquite in the US, thornscrub in SW Africa) are also sustainable sources of biomass.

> The best sources of energy would use land unsuitable for agriculture and not valuable for nature. Fuels based on food are ethically dubious.

The best sources of energy would use land unsuitable for agriculture and not valuable for nature. There is a lot of it and we need a lot since nature is extremely inefficient.

Sugar cane, for instance, yields 9000 litres of ethanol per hectare per year, sufficient for around 53,000 miles of driving (at 40 miles/UK gallon, allowing for the lower energy density of ethanol), while photovoltaic (PV) electricity generated from the same area of panels would, depending on site, technology and layout, drive electric vehicles about 3 million miles per year, over 50 times further.

This may seem unbelievable but the calculation is simple: for PV, the National Renewable Energy Lab estimates 2.8 acres (1.13 hectares) of land in SW US could generate one GWh per year. Electric vehicles travel about 3.5 miles per kWh, so one hectare of PV would generate 3.5 miles/kWh / (1.13 hectare/(GWh/y)) = 3.1 million miles/hectare/y. Transposing agricultural and PV productivity to UK sites would likely leave the relative effectiveness constant. PV does not need fertile land, so does not displace agriculture into existing wild areas. The best renewable vehicle fuel may well be electricity from renewables.

Transport of raw biomass to processing plants over long distances is expensive, so technologies which work at moderate scale are preferable. Biomass is not a large resource compared to world energy needs so it should be used to the maximum effect. Biomass combustion can contribute to our (large) needs for low grade heat. There is no justification for conversion of corn to ethanol or bio-oils to biodiesel while heating oil (very similar to diesel), LPG and natural gas, all practical vehicle fuels, are being burnt for low temperature water and space heating. Conversion by displacement is typically at least a factor of two more efficient than physical conversion to liquid or gaseous fuels – and the biomass can be low cost wood waste, not high value food. The UK renewable heat incentive is already encouraging such fuel switching; for instance distilleries in Scotland are converting from oil/LPG to wood fuel, which has the same effect as 100% efficient conversion of wood to oil/ LPG. Modern furnaces must be used to avoid the emission of black soot, a health hazard and a driver of Arctic warming.

As noted above, first generation 'food to fuel' biofuels use far too much land to offer any substantial reduction in fossil fuel use. The US (for instance) uses 40% of its corn crop to displace less than 10% of its petrol, would need more than one Texas under corn to displace the lot - and yet more to substitute for diesel, jet fuel etc. There is a substantial co-product of 'distillers dry grains', a high protein animal feed, but significant fossil fuel inputs for planting, harvesting, transport and processing balance this out.

Fuels based on food, or inputs from land which could be growing food, are therefore ethically and practically very dubious. While there are (not necessarily unbiased) studies which suggest that diversion of corn to fuel feedstock does not increase grain prices, it is hard to believe that corn is the only market without a connection between price and the supply/demand balance. The enthusiasm of farmers for ethanol mandates suggests that they do not really believe that prices would be unaffected by their abolition. The effect on food supply and the indirect land use change effects suggests that conversion of

Fuels based on waste cellulosic biomass (corn stover, straw, forestry waste etc.) may well play a substantial part if costs (net of CO_2 saving value) can be made competitive. While the world cellulosic ethanol capacity is currently small, pioneering plants are working to reduce treatment costs and may eventually provide fuels at competitive prices.

Biomass be converted to charcoal for cooking or use as a soil amendment or to create a coal substitute that is denser and more stable than wood chips. Traditional 'artisan' charcoal production from wood is typically very inefficient and a major driving of (often illegal) deforestation. Modern technologies using sustainable feedstocks could contribute to agriculture and sustainable development. Biochar is stable over millennia in the soil and is hence a route to CO_2 capture out of the air, although it would be challenging to do this at significant volume.

Gasification of biomass to create syngas, followed by Fischer-Tropsch synthesis (diesel / jet) or biological conversion (ethanol) to fuels may beat the enzymatic route mentioned above on cost/efficiency if valuable uses for the waste heat, such as process energy, can be found. Other technologies such as liquid phase catalytic depolymerisation appears promising but are far from commercialisation.

Anaerobic decomposition of (optionally wet) feedstock, such as waste food and livestock 'slurry', to natural gas and CO_2 seems to be competitive as a route to vehicle fuel with current cellulosic ethanol technology. Natural gas fuelled vehicles are cleaner than diesel and this route to use of wastes should be encouraged. Alternatively, the biogas can be cleaned of CO_2 and injected into the grid, or burnt in a gas engine on site to provide power and heat.

Displacement of fossil fuels from low grade heat applications would appear to beat all other current conversion technologies for dry wastes. There is no rationale to encourage biofuels if lower cost routes to CO_2 reduction are available and unexploited within transport or the wider economy. While it is tempting to say 'the transport sector must play its part', all costs are ultimately paid by end users through prices or taxes, and it makes sense to get the most CO_2 reduction per incremental spend. On-road liquid fuels are adequately taxed in the UK (duty plus VAT is about 77p/litre, around 300% of the current commodity price of petrol and diesel) so conservation is already strongly encouraged. Additional taxes on off-road, marine and aviation fuels are probably non-starters politically, but would be economically rational.

Biomass can also be combusted in conventional power stations or gasified to make syngas for combined cycle gas turbines, thereby displacing coal. This is a low value use for an expensive resource, but does displace a lot of CO_2 at low capital cost, if the biomass can be assumed CO_2 neutral, not necessarily the case. Biomass combustion combined with CCS can in theory take net CO_2 out of the air, but is in competition with other technologies.

Third generation liquid fuels created by genetically modified cyanobacteria that excrete products such as ethanol and diesel (www.jouleunlimited.com) or sugar (www.proterro.com) for conversion to ethanol, appear to have huge potential. They are 20-40 times more efficient than first generation biofuels in terms of land use. As of 2015, Joule were over 8 times better than cane at around 75000 litres of ethanol /hectare/y. These algae are grown in closed 'bags', do not need fertile land, do not use much water, but do need a CO_2 supply at exhaust gas concentrations (4% in air). While currently 'not quite there' economically, they will swamp other biofuels as and when they work, so long as CO_2 is available, either from unabated power generation or by concentration from seawater or air. This approach should be supported as the only sustainable route to very large scale liquid biofuels, vital for shipping and aviation, even if land transport is largely electrified.