Comment on Strengers & Elzenga, Availability and Applications of Sustainable Biomass (PBL 2020)

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SUMMARY

This comment addresses the PBL report "Strengers & Elzenga, *Availability and Applications of Sustainable Biomass* (PBL 2020). By failing to apply basic scientific skills and logic, the report misrepresents the science and therefore consequences of using biomass for energy in the Netherlands.

The most significant recommendation of the PBL report is that the Netherlands should continue to import large volumes of wood pellets from forest logs so long as these logs are of pulp-quality. While presented as a kind of policy compromise, it is not. Wood that can be characterized as pulp quality already provides the overwhelming source of wood for pellets being imported into Europe. And far from representing a scientific compromise, the report's recommendation runs against the strong weight of scientific advice. We cite 15 papers analyzing multiple forest types and harvest regimes that have found that any additional harvests of wood for bioenergy, *even assuming sustainable forest management*, will increase carbon in the atmosphere for decades to centuries. Based on this record, and the importance of mitigating climate change now, multiple groups of scientists have recommended eliminating all bioenergy from stemwood including the European National Academies of Science, the Science Committee of the European Environmental Agency, and 800 scientists (many with the highest levels of scientific distinction) in a letter to the European Parliament.

The problem is intuitive. When trees are harvested for bioenergy, a large amount of carbon is lost from the forest, and because much wood is lost in the process and because wood is an inefficient fuel, its use for bioenergy only saves a fraction of this carbon in fossil fuels. For many years, this use also sacrifices more carbon sequestration from forest growth, as unharvested forests typically grow faster than new plantings. Only after many decades can faster regrowth in young forests pay off the debt, which just makes the bioenergy equal to fossil fuels, and even more decades are needed for large greenhouse gas (GHG)reductions.

As many papers have explained, this reality was long ignored because of an accounting error that treats all biomass, including forest biomass, as carbon neutral. This error is based on a misinterpretation of national IPCC accounting rules. Those national rules encourage countries to report the carbon in wood as an emission in the land use sector as soon as wood is harvested. So long as this carbon is counted there, to prevent double counting, the rules therefore allow countries to ignore this carbon when it is physically emitted through burning for energy. That rule works for national reporting, but not for other purposes, such as lifecycle analyses and emissions trading rules for energy. Thinking the rule meant biomass is carbon free, governments and researchers started ignoring this carbon from biomass completely. Doing so turned a rule against double-counting biomass carbon into a practice of not counting the carbon at all. That of

course makes biomass appear better than fossil fuels. For valid lifecycle analyses, the carbon in biomass can be counted either by counting the carbon taken from or lost in the forest or by counting carbon released up smokestacks, but the carbon must be counted somewhere. The mistake of not counting this carbon at all, embedded in EU rules, is the reason Europe has used to justify burning increasing quantities of wood for electricity and industrial heat.

Although that pure assumption of carbon neutrality has now been abandoned, it can be hidden in other ways, and this report does so. It has much language about uncertain "counterfactuals," but what that language really means is that the report recommends accounting approaches that continue to ignore the carbon emitted by using biomass entirely.

The report's main argument in effect is that pulp-quality wood -- the wood now used for paper, cardboard and in many composite wood boards used for furniture -- should be viewed as carbon neutral on the theory that when this wood is diverted to bioenergy, it will not be replaced. (In the same way, consuming a liter of petrol would be carbon neutral if it just meant someone else consumed a liter less.) That is the assumption, without evidence, of one of the two main papers the PBL report relies on. The report also separately argues that pulp wood is such a low value by-product of other wood production that its diversion has little or no carbon cost. That could only be true if use of pulp logs for bioenergy would not cause more trees to be harvested, and that would only be true if the paper products, cardboard packaging and particle boards now made with pulp logs were not replaced. Yet the report offers no evidence that these other uses of pulp logs will disappear, and a little analysis would show the assumption to be unjustified.

In fact, pulpwood is one third of global industrial wood use, grew 68% between 1997 and 2017 and is likely to keep growing. Although much pulpwood is co-produced with sawn timber, the amount used from any tree can vary to meet demand. Pulpwood is also used for composite wood boards that replace other timber, and there are direct harvests of trees for pulpwood as well. If pulpwood were only a by-product, its production and consumption would rise and fall with the total production of wood. In fact, we provide data showing that even in periods when overall timber production rises and falls greatly in the U.S., both pulpwood production and consumption typically remain constant. This evidence shows a robust demand for paper, cardboard and other pulpwood products, which will require harvesting additional trees to maintain if Europe diverts pulpwood to bioenergy.

Basic numbers also show that the PBL argument must be wrong. The U.S. produces 25% of the world's pulpwood, but even if *all* of this pulpwood were diverted for European bioenergy, it would provide just 1.6% of Europe's energy demand. That is just $1/9^{th}$ of Europe's need for more renewable energy between 2017 and 2030. Even to meet just this need, the PBL report is implicitly claiming that if Europe burns this wood, Americans will entirely stop using toilet paper, cardboard packaging, and much cheap furniture.

The report also relies on another research paper that makes a more basic accounting error – discussed thoroughly in the scientific literature. This research paper suggests harvest of all wood for bioenergy (not just pulpwood) should be viewed as carbon neutral so long as trees elsewhere in a forest or country are already growing enough to offset the bioenergy harvest. But this argument confuses the basic concept of cause and effect. The effect of bioenergy harvests cannot include forest growth (or anything else) that would occur anyway. This argument is no more valid than claiming that a money-losing Dutch company is profitable because Dutch companies overall are profitable. Potential consequences for warming and forests of this error would be great. The U.S., Europe and the World all have large, forest carbon sinks (much spurred by higher CO_2 itself), which plays a vital role holding down climate change. The report is essentially claiming that eliminating this sink has no effect on global warming.

Finally, the report fails to recognize that its recommendation contradicts the policy of the Netherlands and nearly all other developed countries to recycle paper and cardboard. The pulp-quality wood the report recommends using for bioenergy is the same type of wood used to manufacture those products. Countries recycle paper instead of burning it in the correct belief that it is better to save the trees than to produce the energy. What this report calls for, in effect, is burning the trees saved. If using new pulp-quality wood does not save trees, the Netherlands should just burn its used paper. There is no rational policy for recycling used paper products, and then harvesting and burning the very wood saved by recycling.

Using stemwood for bioenergy will increase carbon in the atmosphere for decades to centuries, even as the proper imperatives of the Paris Agreement require large, immediate reductions. To produce even an additional 2% of global energy from wood would require a doubling of the world's industrial wood harvests and greatly threaten the world's forests in conflict with the goals of numerous international agreements. If the Netherlands wishes to remain a leader and retain credibility in the fight against climate change, it must phase out its uses of wood for bioenergy.

Figure 1: *If using pulp-quality wood for energy is carbon free and does not lead to more wood harvest, the Netherlands should stop recycling and just burn its used paper.*

Introduction

The report is styled as a "[s]earch for shared facts and views," and in social settings, a search for agreement may have intrinsic value. In a scientific setting, the paramount question is what are the scientific facts. Here, the core question is the effect of forest bioenergy use on atmospheric greenhouse gases (GHG) over the next decades from the use for energy of different sources of biomass.

In the end, the report recommends the continued reliance on the large-scale use of pulp-quality wood for bioenergy and presents this recommendation as some kind of middle-ground between two different, equally large scientific schools of thought. But it is not a middle-ground. Wood that can be characterized as pulp-quality wood is the major wood source for European wood pellets. Global wood pulp demand has grown 68% in the last twenty years, and burning this type of wood opens the world's forests up to massive, additional harvests.

This recommendation is also inconsistent with the bulk of scientific judgments, including those of European bodies such as the European Academies Science Advisory Council (EASC) (EASAC 2018; Norton et al. 2019), and the Science Committee of the European Environmental Agency (EEA Science Committee 2011; Haberl et al. (2012). The recommendation contradicts the views expressed in a letter to the European Parliament by roughly 800 scientists, including winners of the Nobel Prize, the U.S. Medal of Science, lead IPCC authors and many other distinguished scientists, which stated: "Even if forests are allowed to regrow, using wood deliberately harvested for burning will increase carbon in the atmosphere and warming for decades to centuries – as many studies have shown – even when wood replaces coal, oil or natural gas. The reasons are fundamental and occur regardless of whether forest management is 'sustainable.'" (emphasis supplied).

As EASAC wrote, "Given that the [IPCC] projects that average surface temperatures are likely to exceed 1.5°C between 2030 and 2052 on current trends, payback periods of decades increase the risk of overshooting Paris Agreement targets." "[F]orest biomass should not be regarded as a source of renewable energy . . . unless the replacement of fossil fuels by biomass leads to net reductions in atmospheric concentrations of CO_2 within a decade or so."

The report also shows no recognition that its recommendation contradicts the policy of the Netherlands and nearly all other developed countries to recycle paper and cardboard. If it makes sense to burn pulpwood, the Netherlands should just burn its used paper and not incur the added financial and carbon costs of recycling that paper and then harvesting the trees saved, turning them into wood pellets, and shipping the pellets to the Netherlands.

In this comment we address the following:

- We describe and illustrate the large logs that are the "pulpwood" now being used for wood pellets in the U.S. We also show the loss of forest cover that has started to accelerate around wood pellet plants.

- We explain how the sheer quantity of wood being pursued for bioenergy must result in vast additional wood harvest somewhere. The U.S. produces 25% of the world's pulpwood, and the global demand for pulpwood has grown 68% over the last twenty years and will continue to grow rapidly. But even if magically 100% of U.S. pulpwood could be used for bioenergy in Europe – leaving none for paper products –annual U.S. pulpwood would supply only 1.6% of Europe's primary demand.

- We summarize briefly the basic physical reasons vast numbers of research papers have found that any additional harvests of wood for bioenergy will increase carbon in the atmosphere for decades to centuries. These reasons start with many inherent inefficiencies, which mean initial uses of wood save far less carbon from fossil fuels than carbon lost from the forest and result in slow paybacks.

- We address the argument put forward by the PBL report that these large numbers of research papers can all be ignored because the "counterfactual" baseline – what would happen if wood were not used for bioenergy -- is a kind of uncertain, subjective, almost metaphysical question.

- The proper baseline to be used in the GHG analysis for forest biomass is no different from the type of baseline used to evaluate the coal or natural gas used in a power plant. We compare the additional use of the product, e.g., a ton of coal, with the present level of use. The fact that any particular ton of wood might have been harvested and used anyway for wood products is no different from the fact that any specific ton of coal or m^3 of natural gas would also likely have been used somewhere else. What matters is the fact that increasing bioenergy increases the aggregate demand, which leads to more harvests, just as coal demand increases coal mining.

- The report claims that four papers, using different counterfactuals, find benefits from use of wood, including pulp-quality wood. Even if that were true, the report never justifies relying on those papers and not the vast others that disagree.

    - In addition, two of the four papers strongly support the conclusion that forest biomass will likely increase emissions. One shows long payback periods even from thinning. The other finds a high chance that production-process emissions alone for wood pellets exceed the emissions saved from replacing coal even if wood is assumed to have no effect on forest carbon.

    - A third paper does offer an alternative counter-factual, but unsupported by any evidence. It simply assumes that wood now used for paper, cardboard composite boards and other pulp products, if diverted to bioenergy use, will result in less paper, cardboard, or composite boards.

- The fourth paper includes a scenario that assumes that the effects of harvesting forests for bioenergy can be ignored so long as growth is occurring elsewhere in the forest anyway. This misleading application of the "landscape" approach violates the core scientific principle that to know the consequences of any activity, we have to separate its effect from what would occur anyway. It would also sacrifice the world's vital forest carbon sink.

- Finally, the objective concept of "opportunity cost" means that the benefits for climate in displaced fossil fuels of bioenergy can be compared to the continued storage of that carbon in forests. Using this basic economic principle, If harvesting and burning that wood increases carbon in the atmosphere, that means the cost exceeds the benefit.

- The report's suggestion that the use of pulpwood is carbon-free because the primary motive for wood harvest is sawn timber is both confused and factually incorrect.

  - If the argument is that these large pulp-quality logs would otherwise be a part of true residues left to decompose in the forest, that is incorrect and the authors offer no contrary evidence.

  - If the argument is that there are now surplus trees not needed for pulp in the U.S., then the alternative is that those trees would remain standing and growing, both storing and accumulating carbon.

  - If the argument is that because pulpwood production is only a fixed by-product of sawn timber production, using pulp logs for bioenergy just reduces the quantity used for other products, that is factually incorrect. Production of pulpwood is often a co-product of sawn timber production, but not always and not in fixed amounts. U.S. data show that pulpwood production and consumption often remain constant despite large changes in overall timber production. That means producers will harvest enough trees to meet pulpwood product demand regardless of other wood production. That in tun means that "stealing" some pulpwood for bioenergy use will lead to additional harvests to meet that demand for traditional uses.

- Finally, we briefly address three basic flaws with the broader claims supporting biomass availability and use. One, the report never addresses the intense global land competition resulting from increasing demand for food, fiber, and carbon storage. Two, the report never deals with the basic opportunity cost question that devoting a hectare of land to produce bioenergy means not using it for another purpose. And three, the report fails to appreciate the significance of the gross land-use inefficiency of bioenergy, which means that alternative uses of land will be more valuable.

I. **European consumers of wood pellets are mainly using large logs primarily suitable for pulp but sometimes also suitable for some timber products.**

Much of the growing use of wood in Europe for electricity and large-scale heating comes from wood pellets, and the impression created by the report, and one explicitly offered by wood pellet producers, is that the wood being used for pellets is effectively a kind of low-level waste. In fact, as a paper for the American Forest and Paper Association found (Figure 2), roughly three-quarters is hardwood or softwood roundwood, e.g., logs, and another 12% is "wood residuals," which means in effect that is nearly all used for some kind of wood product (RISI 2015). Only 12% is true forestry residues.

For years, wood pellet companies have tended to claim all this wood is a residue. In response to such claims by the UK government, the U.S. group Dogwood Alliance provided a report that mainly just reproduced pictures from the wood pellet manufacturers' own web sites. Here, Figure 3 shows a picture previously shown from the General Biofuels website, and Figure 4 shows a picture from the Georgia Biomass website. They show truckloads and enormous stacks of large logs surrounding the pellet plants.

This source of wood is evident from anyone standing outside or flying over these plants. Figure 4 shows pictures from just outside and above an Enviva wood pellet plant. Most of this wood would probably be destined for pulp use, but as can be seen from these pictures, many of these logs are large enough to produce some sawn timber, such as traditional American "2 x 4's." (Smaller diameter logs can be made partially into timber products in a process called "chip n' saw" to make oriented strand board). And while much of the wood in the Southeastern U.S. comes from pine plantations, as the American Forest and Paper Association (AFPA) analysis shows, a sizable portion comes from natural forest hardwoods. A conservation group directly traced the logs from a hardwood clear-cut shown in Figure 5 to a pellet plant. These are not just "abuses" as suggested by the report; they are the standard sources of supply.

Figure 1: AFPA Analysis of Wood Pellet Sources in Southeastern U.S.

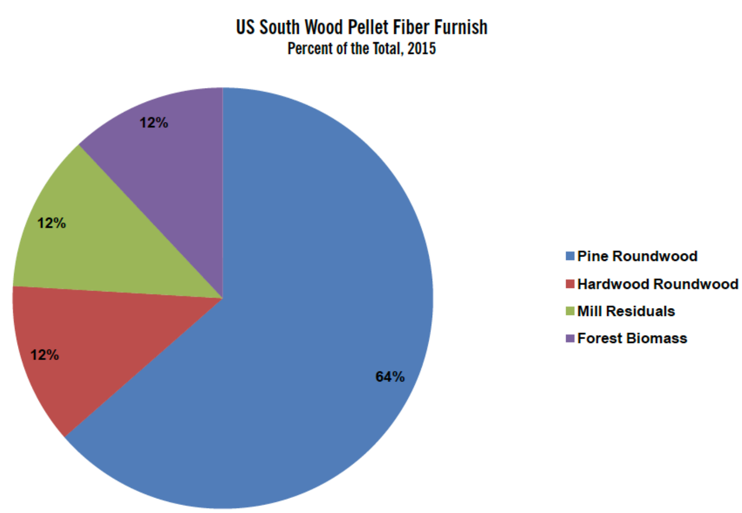


Figure 2: Picture reproduced from General Biofuels Own Website

Figure 3: Picture taken from Georgia Biomass website

Figure 4: Pictures taken by the Dogwood Alliance of Enviva Wood Pellet Plant in North Carolina

WOOD PELLET EXPORTERS RELY ON STANDING HARDWOOD FORESTS IN SOUTHEASTERN U.S.

Trucks entering Enviva Wood Pellet Mill (Sampson County, North Carolina, February 2017)

Enviva Wood Pellet Mill
(Sampson County, North Carolina, February 2017)

Figure 5: Picture of hardwood cut whose products were directly traced to trucks entering wood pellet plant in North Carolina by Dogwood Alliance

II. **The quantity of demand for pulp & paper products and bioenergy make clear that bioenergy uses require increased wood harvests.**

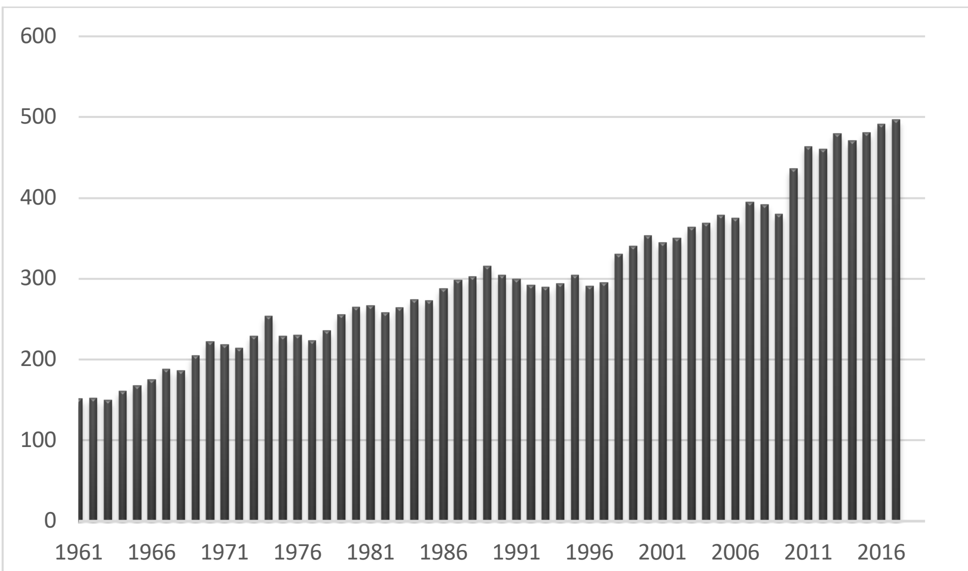
In a later section we show that consumption of pulp & paper is not just a by-product of sawn timber production. But an even more basic reason Europe's use of wood for energy must result in increased wood harvest is both that it overwhelms the available supply and that alternative uses of wood, including pulpwood, are not going to disappear.

- For example, in Searchinger et al. (2018), the authors showed that if just an additional 5% of European energy were supplied by wood due to the Renewable Energy Directive, that would require an amount of wood equal to all of the wood harvested in Europe each year (whether for pulpwood or sawn timber). That is also roughly equivalent to all the wood harvested each year in the U.S. and Canada combined.

- Even though the U.S. supplies 25% of all global pulpwood as the world's largest supplier, if all U.S. pulpwood were diverted to wood pellets, it could provide at most 1.6% of Europe's primary energy supply.[1] That is less than one eighth of the additional EU renewable energy required by the EU's Renewable Energy Directive (Searchinger et al. 2018). And Americans are not going to stop using toilet paper and cardboard so Europeans can burn the wood instead.

The challenge of meeting increased demand is further increased by the fact that the global demand for pulp is growing and likely to increase greatly in coming years (Figure 2). (The report discusses a decline in U.S. pulpwood production, which is true but very modest, but fails to acknowledge the very large global increase.) Even if European bioenergy resulted in diverting only wood from other pulp products in the Southeastern United States, global demand requires that this pulp be replaced by additional forest harvests elsewhere.

Figure 7: Global Pulpwood Consumption (million metric tons)



Source: FAOSTAT 2019. The unit is converted from m^3 to metric tonnes using a 0.7 t/m^3 factor.

In fact, the evidence is starting to show that even though most U.S. wood pellet plants have just been built recently, they are accelerating deforestation around them. In Figures 6 and 7, we provide satellite photographs with examples that show the extensive forest loss that is occurring around two such wood pellet plants in the Southeastern United States.

[1] According to the U.S. Forest Service, U.S. pulp production in 2017 was 155 million cubic meters. (U.S. Forest Service 2019 – converted from cubic feet). At .49 metric tons of dry matter (tDM) per m^3 and 20 gigajoules/tDM, the pulpwood production contains 1.66 exajoules. However, in the full storage and production pathway for pellets, large volumes of wood are lost (estimated at 38% in Roder et al. (2015). Here, we very conservatively use 25% bringing the energy quantity down to 1.14 EJ. In 2015, EU primary energy consumption was 70 EJ. so the supply would be 1.6% of Europe's primary energy. For all sources of data not otherwise cited here, see notes for supplementary table 1 in Searchinger et al. (2018).

Figure 6: Satellite images showing deforestation both before and after operation of Enviva plant in Ashokie, North Carolina

Note: Tree cover loss around the plant was 60% higher in six years after a pellet plant was constructed.

Figure 7: Satellite images showing accelerating deforestation after construction of Canondale Wood Pellet Plant in Florida

III. **Virtually all research finds that harvesting and burning wood increases carbon for decades to centuries.**

The most important uses of biomass immediately at issue are the deliberate harvests of wood for use for bioenergy. These harvests increase carbon in the atmosphere regardless of whether they are used for sawn timber or pulp. At least 13 papers (Box 1) have analyzed the results based on different forest types, different locations, different harvest regimes, different forms of management, with and without conversion of wood to wood pellets, using bioenergy for electricity or heat, and used in place of coal, oil or natural gas. When compared to leaving trees standing and growing in the forest, they all find that bioenergy harvests increase carbon in the atmosphere for decades to centuries even when wood replaces coal, the most carbon-intensive fossil fuel.

It is also worth emphasizing that fossil fuels should not generally be the right comparison. The real alternative is replacing fossil fuels with a form of energy that really does reduce emissions quickly, such as solar and wind. For example, under the EU Renewable Energy Directive, if countries do not use biomass, which increases emissions for long periods relative to coal, they will need to use renewable energy forms like solar and wind that are nearly carbon free. Such uses both decarbonize the energy sector and allow use of forests to sequester more carbon and mitigate climate change.

The basic reason harvest of wood increases emissions for decades to centuries is intuitively obvious and results from a large number of inefficiencies involved in the uses of wood relative even to fossil fuels.

- In the first step of harvest, much wood that otherwise would remain live and continue to store additional carbon is killed and left to decompose. That includes roots, and at least some above-ground residues, and overall probably a third or more of carbon is emitted as a result without doing anything to displace fossil emissions.

- More carbon dioxide is released during harvest and transportation, and when drying the wood and the wood is converted to wood pellets. Roder et al (2015), for example, calculated that only 62% of the wood harvested for pellets is actually turned into pellets.

- When burned for use, wood emits more carbon than even coal per unit of energy produced and far more than natural gas. That is due both to the chemical structure and the high water content. (Pellet use for electricity and heat can approach the conversion efficiency of coal but only after losing much wood in the pellet manufacturing process.) Lower temperatures due to higher water content also reduce the electricity generation per unit of energy.

The result is a large, initial carbon debt. This debt can be slowly repaid if trees are allowed to regrow, but:

- Post-harvesting, soil disturbance and residues decomposing on-site mean the logged area is initially a net source of carbon.

- For at least several years, newly planted trees or regenerating trees grow more slowly than the forest stands would grow if left unharvested, increasing the carbon debt.

- Eventually, older, unharvested forests will grow more slowly and new plantings will grow faster, and the *combination* of regrowth and any fossil savings can repay the carbon debt from the stands harvested in the first year of bioenergy use. However, forest stands harvested in year 2 onward continue to have carbon debt and it takes even more years for their carbon debts to be paid.

Moreover, even when carbon debts are repaid, which is typically called the "carbon parity point," that just means the use of wood has stopped increasing emissions compared to fossil fuels. It takes many more years to obtain significant reductions compared to fossil fuel use. And forest biomass will rarely ever become completely carbon neutral, particularly if harvests occur sequentially, because unharvested forests hold larger carbon stocks.

Box 1: Research Papers Finding That Harvesting Wood for Bioenergy to Replace Fossil Fuels Increased Carbon in the Atmosphere for Decades to Centuries

Laganière, J., Paré, D., Thiffault, E. & Bernier, P. Y. Range and uncertainties in estimating delays in greenhouse gas mitigation potential of forest bioenergy sourced from Canadian forests. GCB Bioenergy 9, 358–369 (2017).

Mitchell, S. R., Harmon, M. E. & O'Connell, K. E. B. Carbon debt and carbon sequestration parity in forest bioenergy production. GCB Bioenergy 4, 818–827 (2012).

Stephenson, A. L. & MacKay, D. J. C. Life cycle impacts of biomass electricity in 2020 (Department of Energy & Climate Change, London, 2014).

Bernier, P. & Paré, D. Using ecosystem CO2 measurements to estimate the timing and magnitude of greenhouse gas mitigation potential of forest bioenergy. GCB Bioenergy 5, 67–72 (2013).

Holtsmark, B. Harvesting in boreal forests and the biofuel carbon debt. Clim. Change 112, 415–428 (2012).

Hudiburg, T. W., Law, B. E., Wirth, C. & Luyssaert, S. Regional carbon dioxide implications of forest bioenergy production. Nat. Clim. Change 1, 419–423 (2011).

McKechnie, J., Colombo, S., Chen, J., Mabee, W. & MacLean, H. L. Forest bioenergy or forest carbon? Assessing trade-offs in greenhouse gas mitigation with wood-based fuels. Environ. Sci. Technol. 45, 789–795 (2011).

Manomet Center for Conservation Sciences. Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources (2010).

Zanchi, G., Pena, N. & Bird, N. Is woody bioenergy carbon neutral? A comparative assessment of emissions from consumption of woody bioenergy and fossil fuel. GCB Bioenergy 4, 761–772 (2012).

Holtsmark, B. The outcome is in the assumptions: analyzing the effects on atmospheric CO2 levels of increased use of bioenergy from forest biomass. GCB Bioenergy 5, 467–473 (2013).

Booth, M. S. Not carbon neutral: assessing the net emissions impact of residues burned for bioenergy. Environ. Res. Lett. 13, 035001 (2018).

Sterman, J.D., L. Siegel, J. N. Rooney-Varga, Does replacing coal with wood lower CO2 emissions? Dynamic lifecycle analysis of wood bioenergy, Environ. Res. Lett. 13 (2018) 015007

Ter-Mikaelian, M. et al. T. (2015). Carbon debt repayment or carbon sequestration parity? Lessons from a forest bioenergy case study in Ontario, Canada. Global Change Biology Bioenergy, 7, 704– 716.

Malcolm, J., B. Holtsmark, P. Piasckik, Forest harvesting and the carbon debt in boreal east-central Canada, Climatic Change 112:415-418 (2020)

Colne et al., Biomass supply and carbon accounting for Southeastern Forests (Biomaass Energy Resources Center, Forest Guild, Spatial Informatic Group 2012)

IV. Increased emissions due to use of forest biomass are clear and the relevant "counterfactual" is not subjective.

The PBL report does not dispute that harvesting additional wood for bioenergy increases carbon in the air for decades to centuries, but it claims that this effect should not be considered because the counterfactual baseline to using wood for bioenergy is uncertain and does not necessarily mean that bioenergy production requires more wood harvests. In fact, the report seems to treat the counterfactual as a kind of purely subjective, even a metaphysical question. There are several proper responses:

- The counterfactual is no more metaphysical or uncertain for wood than it is for coal or any other fossil fuel.
- Of the four papers relied upon, two actually provide calculations showing bioenergy increases emissions.
- One of the papers does suggest an alternative counterfactual by just assuming that every pulp log diverted to bioenergy results in equal less consumption of other pulp products, but it offers no evidence for that assumption.
- Another paper claims that the effects of bioenergy harvests can be ignored so long as other parts of the forest are growing, but that is an accounting error because the result of bioenergy harvests is still a decrease in the carbon that would be stored in the forest without that forest.
- The concept of opportunity cost provides an objective basis for determining that bioenergy from wood is worse than leaving trees standing.
- Finally, even if effects were uncertain, that is not a reason to pursue bioenergy but a reason to pursue more certain solutions.

A. The baseline for analyzing wood bioenergy should use the same approach as used for analyzing emissions from fossil fuels or any other product.

The basic "counterfactual" used in all the papers in Box 1 is that wood used for bioenergy will require additional harvesting, which means that the alternative is that the wood would remain in the forest. This is the same type of assumption used to evaluate coal, oil and natural gas, which assume that their use requires additional mining, and in fact the same type of assumption used for any product.

The PBL report seems to be playing a semantic game because, of course, we cannot know the alternative fate of any particular log used for bioenergy. But that is also true of any other product, including any coal or natural gas that wood replaces. Any particular ton of coal or cubic meter of natural gas used by a power plant would probably be consumed anyway, and we cannot be certain where the replacement will come from. The precise emissions (which depend somewhat on the precise source of oil and refinery) are therefore uncertain. But we estimate emissions by counting the likely emissions for producing one unit more, whether of forest biomass, of coal, or of natural gas. And in the case of wood, we therefore estimate the likely reductions in carbon due to producing more wood.

That is why the variety of scenarios analyzed in the papers cited in Box 1 provide confidence. Because those papers analyze wood supply scenarios from different forest types harvested in different ways for different ultimate end uses, we can be confident that increased use of wood for bioenergy will result in increased carbon in the atmosphere for decades to centuries regardless of the precise source of additional wood. We cannot be sure exactly what mix of tree species will ultimately be harvested, but because the best-case scenarios are still bad, we can be confident that the likely real result will be worse.

Particularly significant is the fact that even harvesting intensively managed plantation forests for bioenergy increases atmospheric carbon for decades. It is true that if not used for bioenergy, many and perhaps most of these precise forests will be harvested to make other wood products. But if this wood is instead diverted to bioenergy, that requires additional harvests of natural forests, which are still a half or more of all sources of wood globally, to replace the pulp products. The ultimate payback period is therefore likely even longer.

B. The four papers the PBL report relies on do not justify its conclusions.

The report relies primarily on four papers for the proposition that there might be benefits based on an alternative counter-factual, an alternative fate, for the wood used for bioenergy. Where there are scientific disagreements, the proper process is to attempt to analyze the relevant papers and determine if it is possible to determine which is more correct.

This report not only fails to do so, but it significantly misrepresents these papers.

- One is Roder et al. (2015), which the report cites in effect to claim that depending on the counterfactual scenario, emissions can range from large GHG benefits to large costs. But that paper only analyzed scenarios *in which no additional trees were harvested,* so there could be no reduction in forest-based carbon. Instead, the authors assumed that all forest biomass used for bioenergy was either residues or thinnings, which the authors assumed had no carbon debt. Although this assumption was wrgong because even the using residues has some carbon debt, what is important is that this paper does not analyze any costs of harvesting trees.

  The special result of this paper, therefore, is the opposite of that claimed in the PBL report: It is that just looking at production emissions alone, such as fossil fuel use and methane production in the supply chain, the paper found that the use wood could increase emissions by as much as 73% compared to coal. In other words, even if biomass is treated as carbon neutral, it may still have higher emissions than coal.

- Two, the report cites Nabuurs et al. (2017), but that citation is strange as this paper found that even in the most optimistic scenario of using deliberately harvested trees, which involve "thinnings," the payback time would be 80 years. The paper called this payback time the "parity point," but what this means is that there would be an increase in carbon in the atmosphere for 79 years, and even at year 80, the use of biomass would just equal the use of fossil fuels. It would therefore take even more decades more to obtain a significant reduction in atmospheric carbon.

The PBL report makes much of the fact that this paper reports claims these harvests cause no "carbon debt," but that is due to a restrictive use of that term. The authors meant that European forests would continue to grow enough in areas not harvested for bioenergy that starting carbon stocks (the carbon in the forest today) would not decline. As we discuss below, that does not mean that harvesting wood for bioenergy has no effect on reducing carbon in the forest compared to letting the forest continue to grow.

- The report also cites Hanssen et al. (2017) as reporting low pay-back periods, which is true, but the report does not explain why. When this paper analyzes the GHG consequences of pulp quality wood (which it calls small roundwood), it simply assumes, without any evidence, that for each ton of demand for wood for wood pellets, there would be a reduction in consumption of wood for paper and panels.[2] As a raw assumption, that is no more valid than assuming that every liter of petrol consumed in Holland results in someone else consuming one liter less.[3]

[2] The paper does not explicitly say this, but that is the assumption. The counterfactual analyzed for "small diameter," i.e., pulp quality wood, is that the wood would be used for alternative products, such as paper products and packaging, and that no more wood would be harvested to replace those uses. Instead the paper analyzes costs of replacing the wood products in other ways. Even then, one reason, the emissions are low is that one of the replacements claimed would be recycled paper. The assumption, without any factual support and unlikely given already existing high recycling rates, is that more recycling would replace pulp used for bioenergy. But in that event, the even better result would be to burn the waste paper, and continue to use the already harvested pulpwood for paper, because that would also produce energy and eliminate a number of inefficiencies.

[3] This paper also found short payback periods for residues and additional thinnings. Other papers have found much longer paybacks for these materials, including the Nabuurs et al. (2018) paper (thinning); Booth (2018) (residues) and Laganiere et al. (residues). The appropriate response might therefore be to take a harder look at the numbers to see which estimates are more reasonable. But even if the Hanssen (2017) analysis prevailed in this comparison, that just means that these very limited and sometimes expensive-to-collect sources of wood could generate climate savings if used to replace coal in reasonable time-frames. These findings do *not* mean that counterfactuals are uncertain or that pulpwood is an acceptable source of wood. We believe these payback periods were probably underestimated for several reasons, including a failure to count the large losses of wood during the wood pellet production process as discussed in Roder et al. (2015), and ignoring the large emissions associated with harvesting.

- The fourth paper cited is Jonker et al. (2014). Although it too finds carbon payback periods as we use the term – which it calls carbon parity periods[4] -- of many years for the closest scenario that might resemble a reasonable approach[5], it does offer an alternative scenario with no payback period and no carbon debt. The flaws of its approach are well explained in Ter-Mikaelian et al. (2015).

  In this approach, the authors start with a growing forest that if not harvested for bioenergy would accumulate wood and therefore carbon. Because such a forest is accumulating wood and carbon, harvesting a part of the forest for bioenergy can occur up to the level of the overall forest's growth rate without decreasing the initial carbon stocks. So long as harvests do not exceed this level, the Jonker et al. authors assume no carbon debt.

  Yet by definition, if some stands were not harvested for bioenergy, both those stands and even more significantly the overall forest area would not just maintain initial carbon stocks but would gain carbon. Just maintaining carbon stocks is still a reduction compared to this baseline.

  This whole approach confuses the meaning of cause and effect. The effect of bioenergy cannot be altered by any activities that would occur anyway. If the forest were growing anyway, that growth cannot be attributed to the bioenergy. That is just as false as blaming bioenergy for forest fires, or large harvests for wood for other purposes that would occur anyway.

  This "loophole" makes not just pulpwood but all wood carbon neutral, and if accepted globally would be large enough to allow a tripling of global industrial wood harvests and still call the wood carbon-free (Searchinger et. al. 2018). Both U.S. and European forests continue to gain carbon. Major reasons include reductions in uses of land for traditional forms of bioenergy in decades past and the fertilization effect of higher carbon dioxide. As eight scientists explained in Searchinger et al. (2018), "This carbon sink, in large part is due to higher atmospheric carbon dioxide concentrations, is already factored into climate projections and is not disposable.

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[4] As we use the term, the carbon payback period is synonymous with the carbon parity period: it is the number of years biomass must be harvested and used when atmospheric harm is greater than the fossil fuel alternative, and therefore the period before the harvest and use of that biomass is no worse than using the fossil fuel alternative. In Jonker et al. (2014), the authors use "carbon payback" differently, as in the Nabuurs paper discussed.

[5] For the carbon parity period, the authors do offer some range of results but do not explain the scenarios. These periods can still be over 30 years, but are shorter than other papers have found. We suspect one reason is that the authors do not appear to factor in properly the large losses of wood that occur in drying and palletization (Roder 2015).

> Harvesting and burning this biomass reduces the sink and adds carbon to the air just like burning any other carbon fuel."[6]

In short, none of these papers undermines the standard finding that the additional harvest of wood for bioenergy will increase carbon in the atmosphere for decades to centuries. None of these papers also provides any support for the idea that burning pulpwood rather than sawn timber is an exception to this rule.

C. The Proper Meaning of a "Landscape Approach"

One reason this accounting error does not always appear obvious is that the authors call its use a "landscape" approach, which sounds good. It is flawed for the logical reason explained above and is not a correct landscape approach.

A proper landscape approach is just a form of analyzing multiple stands over time. A forest landscape is just a compilation of stands. If a "landscape" model properly attempts to assess the effect of increased harvesting, it should do so by sequentially assessing the consequences of that increased harvest over time as harvest moves from one stand to another and previously harvested stands are allowed to regrow. That is precisely what most bioenergy analyses cited above have done, e.g., Mitchell & Harmon (2012); Laganiere (2017); Booth (2018). By doing this approach with a variety of possible management regimes, researchers can test if bioenergy would be net beneficial under any scenario. They have found that the answer is no. Moreover, this proper landscape analysis results in longer payback periods than analyzing a single standard because, as discussed above, even after the first stand has regrown enough to pay back the carbon debt, stands harvested in later years maintain carbon debt that require more years of regrowth to pay back. [7]

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[6] This same basic distinction between cause and effect also explains the error in the report's suggestion that bioenergy harvests might be carbon neutral because those who owned the growing forests in the first place might be credited with all that growth. (Such an approach would credit landowners everywhere with an amount of carbon of vegetation roughly equal to all the carbon in the air, which means they could cut down all the world's trees and none of that carbon would be counted as an addition to the air.) Even if policymakers chose such an approach, that still would not make bioenergy better. Such a system would credit landowners with the carbon in their forests whether the forests are used for bioenergy or not. In other words, such a system would change the baseline. But the incremental effect of harvesting those forests for bioenergy would still be to add carbon to the air relative to that baseline.

[7] The reason these papers are sometimes not recognized as applying a landscape approach is that they start with specific stands with particular growth rates and harvest types and then multiply those over a landscape. But the reason they do so is to test whether there are any scenarios in which harvesting a forest landscape for bioenergy might generate greenhouse gas reductions. They are testing "best case" scenarios for bioenergy. If applying a best-case scenario across a whole landscape does not generate GHG reductions in a reasonable time-frame, then examining a real landscape certainly will not because a real landscape will include at least some stands that are not managed and harvested in the best-case way for bioenergy.

D. Using the Basic Concept of Opportunity Cost, the Harvest of Wood for Bioenergy Objectively Increases Global Warming for Long Periods.

Finally, the basic economic concept of opportunity cost provides another reason the cost of biomass is not a metaphysical question that depends on subjective definitions of counter-factual scenarios. According to the standard principles of economics, the cost of any good is the cost of not using it for another purpose – the opportunity cost. For wood that has a very simple meaning: One opportunity cost of deliberately harvesting and burning any wood for energy is just leaving it in place.

That is particularly true because the financial cost of forest bioenergy requires high subsidies even when policymakers do not treat bioenergy as carbon neutral and therefore count no charge for the loss of forest carbon. An even fuller opportunity cost calculation would estimate the carbon gains that could be achieved by devoting funds to forest preservation.

Moreover, an additional economic principle is to discount future gains relative to current present value, which is particularly vital given the goal of the Paris agreement. Hence the carbon removed by a tree in a regrowth forests following cutting and burning is worth less than the carbon removed by a continuously growing tree in the current year.

The logic is therefore simple. If the alternative of leaving trees in place will result in less atmospheric carbon than harvesting and burning them to displace fossil fuels, and if doing so is also cheaper, then the opportunity cost of using wood for bioenergy exceeds the benefit.

V. **Pulpwood is not a surplus by-product with no carbon cost as using more pulp-quality logs will require more harvests to produce it.**

The second argument the PBL report uses for blessing the unlimited use of pulpwood implicitly as low carbon or carbon free is that the "primary motive for forestry is usually sawmill production." Because the report never truly explains why this "motive" makes pulpwood low carbon or carbon free, we here try to develop what the argument could mean and explain why any such arguments are incorrect.

There are three theoretical possible fates for pulp quality wood if not used for bioenergy. One fate is that it is left as part of a standing and growing living tree. The PBL report suggests that there may be surplus trees in the Southeastern United States due to a U.S. decline (actually only 8% in the last two decades) in pulp product demand. However, if that's true, the alternative fate is that the carbon remains stored in the forest. That is precisely the counterfactual analyzed by the various papers that find harvesting wood for bioenergy wood will increase emissions for decades to centuries.

A second possible fate is that the pulp portion of trees could be cut-down but left in the forest to decompose. In that event, it is not pulpwood but a forest residue (and should be evaluated like other forest residues.) But the report does not seriously claim that the large pulp-quality logs used for wood pellets would be left in the forest to rot if not used for bioenergy. One will very rarely if ever find large logs lying in a Southeastern forest similar to those logs piled around wood pellet plants.

The third possible fate is that the pulp-quality logs would be used for other wood products. In that event, this wood is meeting demand for paper, cardboard, composite fiberboard and a variety of other products. Diverting that wood to bioenergy is generally going to result in additional harvest somewhere else to replace the wood.

To the extent we can tell, the argument in the PBL report is that the pulp quality wood used for wood pellets would be used for other products, but if diverted instead to bioenergy use, those products would not be replaced. The argument appears to be that because pulp and paper is such a low-value, incidental by-product of sawn timber production, both the production of pulp-quality wood and their consumption are fixed by the amount of sawn timber production. Because that production level is fixed, if more of the wood is used for bioenergy, less must be used for other products.

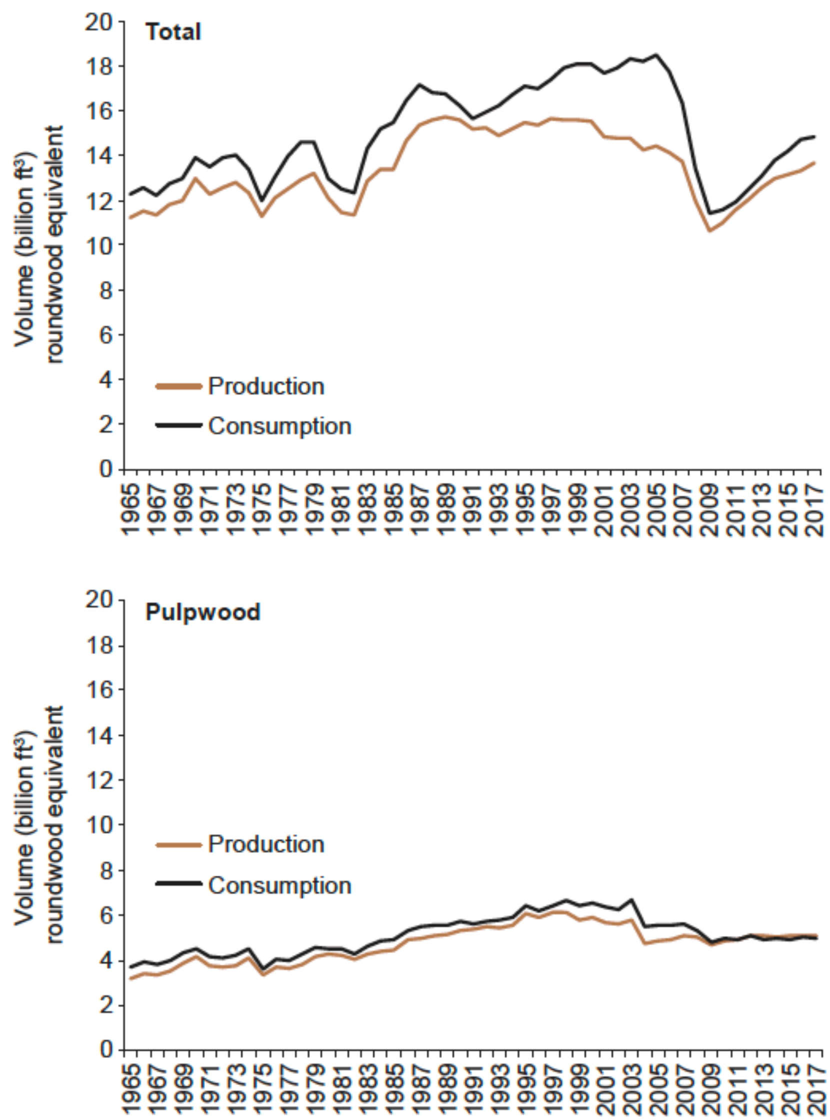
The fact that the U.S. pulp log supply could provide only 1.6% of European energy even if all U.S. consumption of pulp-log products ended makes clear this argument cannot be true at any meaningful scale. Moreover, while the report authors offer no evidence, the claim is a testable hypothesis even at smaller scales. If this assertion were true, then both the amount of pulpwood produced and consumed in the United States should rise and fall in proportion to changes in the total amount of wood production (called roundwood production).

The data shows that is not true. Figure 9 reproduces charts from a U.S. Forest Service publication (USFS 2019), which show both production and consumption of total roundwood and pulpwood in the U.S. over time. They show large fluctuations from year to year in total timber (roundwood) production without significant changes in either pulp production or consumption. For example, total roundwood production dropped by roughly 30% between 2005 and 2009 and then increased by roughly 25% by 2017, but during this time there was virtually no change in production of pulpwood and very little change in consumption.

These patterns show that pulpwood production and use is not a fixed by-product of sawn timber production. Although many harvested trees will contribute both some sawn timber and some pulpwood, what matters is that pulpwood production is not fixed by sawn timber production. Increases in pulpwood demand can be and are met by directing more of each tree into pulpwood (and less into other wood products) or by harvesting some trees just for pulpwood. And over time, there is even greater flexibility. If demand for pulp goes down, more forests can be left alone or managed with longer rotations to increase sawn timber supply and spare more natural forests. The bottom line is that pulpwood has its own product supply demand not fixed by sawn timber production and that will be replaced if existing pulpwood harvests are diverted to bioenergy.

It is true that pulpwood consumption in the U.S. has declined by around 8% from its peak in the late 1990's, which is a great achievement considering that the U.S. population has continued to grow. At least some of this achievement can probably be attributed to increased recycling rates in this period.[8] However, the goal of recycling was precisely to save trees. The trees saved in the U.S. can now be used to help meet rising global demand or can stay in the forest, continue to store and further accumulate carbon.

Figure 9: Changes in U.S. production and consumption of all wood and of pulpwood over time show large fluctuations in total timber occur with little or no change in pulpwood



Source: Reproduced from U.S. Forest Service 2019, Figure 3

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[8] American Forest and Paper Association https://www.afandpa.org/media/2019/05/08/u.s.-paper-recovery-for-recycling-rate-reaches-record-68.1-percent-in-2018

VI. **Flaws with the broader bioenergy discussion**

While the PBL report focuses primarily on the use of forest biomass the report includes broader endorsement of bioenergy. We here highlight three major limitations.

First, nowhere does the report truly acknowledge and deal with the global land use challenge. The world has large growing demand for food, and wood products, and most analyses project that agricultural land will expand at the expense of forests even with large yield growth (WRI 2019; Bajželj, et al. 2014; Schmitz et al. 2014). In addition, the loss of carbon in existing forests is responsible for perhaps one third of all the carbon added from lost vegetation to the air (Erb et al. 2017). At the same time, many climate strategies rely on extensive reforestation (Griscom et al. 2014). (For example, the EU's new Biodiversity Strategy proposes planting 3 billion trees by 2030 as part of climate and biodiversity mitigation). The report never addresses these fundamental limitations.

Second, the report never addresses the fundamental concept of land opportunity cost. Every hectare devoted to bioenergy production is a hectare that is not serving another need. That is true even for alleged "marginal" land, which assuming it exists and is underutilized, can also be managed to produce more food or more carbon storage. Any argument for devoting land to bioenergy must show greater benefits than using that land for other purposes.

Third, the report addresses but misunderstands the significance both of bioenergy's extraordinary land-use inefficiency and its need for productive land that is also needed for other uses. Bioenergy converts at most only 0.1% to possibly in the future 0.3% of solar radiation into useable energy. As shown in Figure 10 (reproduced from Searchinger et al. [2017]), on t 75% of the world's hectares, using the solar cells available today would produce at least 100 times more useable energy as using these hectares for cellulosic ethanol even assuming optimistic future estimates of cellulosic efficiency gains. For many uses, such as electric cars, the use of electricity versus ethanol or diesel in a car further achieves around a 3-fold further increase in efficiency, e.g., a 100 to 1 ratio becomes 300 to 1.

The report somewhat acknowledges this inefficiency – while incorrectly challenging one point[9]-- but dismisses it on the ground that solar cells produce electricity while bioenergy produces a solid fuel. That is certainly true, but the report fails to appreciate the significance of this vastly greater land-use efficiency.

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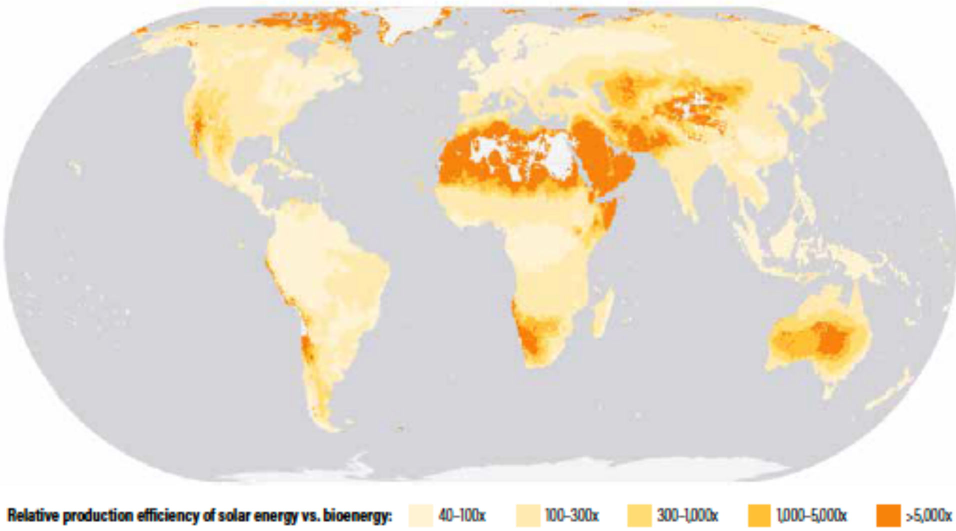
[9] The report suggests that the conversion of solar energy into bioenergy is more likely to occur at 1% than at 0.2% as reported in Searchinger et. al. (2017). But the authors confuse a typical maximum photosynthetic conversion rate with the ultimate conversion to bioenergy use. Plant growth is almost always limited by temperature, water availability and other factors that means in the real world, plants do not achieve a 1% rate, let alone over an entire hectare. In addition, for use as bioenergy, the biomass needs to be transformed. Typically, at most half of the energy in the biomass, for example, gets into cellulosic ethanol. And additional energy is used in the crop and bioenergy production process, which further reduces net conversion efficiency.

Figure 10: On 75% of the world's land, today's solar cells could produce at least 100 times more useable energy than even improved cellulosic ethanol ***(reproduced from WRI 2019).***



Source: Searchinger et al. (2017).

a. Even if, as argued, solar could only produce electricity (which is not true), it would make no sense to use biomass rather than solar to produce electricity.

b. Not only can solar utilize non-productive land and roofs, but even assuming there were 100 hectares of spare, productive land, using one hectare for solar cells and 99 for reforestation would produce at least the same amount of energy as using all 100 hectares for bioenergy while generating at least 100 times the climate benefit through energy use and carbon sequestration.

c. Although the benefit of bioenergy is that it can more easily store energy longer-term, the advantages of solar mean that even if storage system losses were extremely high, solar would still be more land-efficient than bioenergy.

d. Whatever limitations on using solar and wind exist because of storage, that is no justification for choosing bioenergy in the near-term so long as large opportunities exist today to continue to expand solar and wind even without storage. It is foolish to commit to bioenergy today based on future storage concerns because by the time storage becomes a serious limitation, innovations in storage or even solar-based liquid fuels may very well provide solutions.

e. Finally, regardless of solar limitations, cutting down trees and burning them for bioenergy increases emissions comparable to coal; hence such bioenergy is simply not a climate solution.

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(in addition to those in Box 1)

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