Bioenergy from Wood and Forest Carbon Dynamics

Kenneth Skog*

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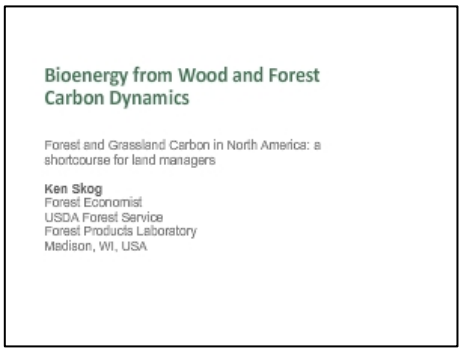
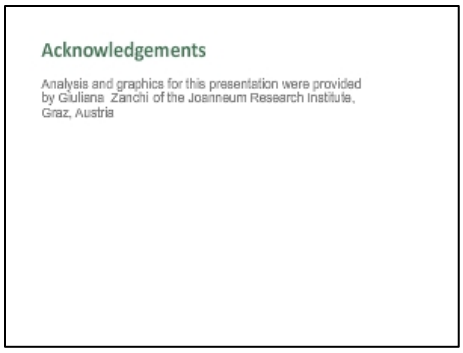
Slide 1. Bioenergy from Wood and Forest Carbon Dynamics



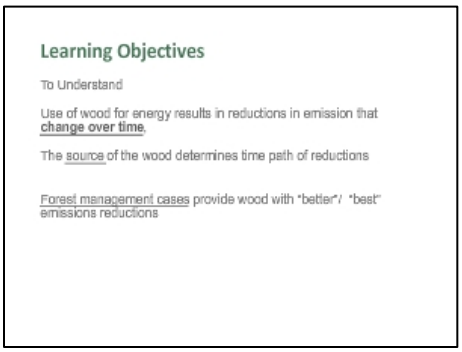
Hi, my name is Ken Skog. I'm a scientist with the Forest Products Lab, part of the USDA Forest Service located in Madison, Wisconsin, and I'll be talking about bioenergy from wood and the forest carbon dynamics associated with using bioenergy.

Slide 2. Acknowledgments



I'd like to acknowledge that I'm going to be using some analysis and slides that were provided by Giuliana Zanchi of the Joanneum Research Institute in Graz, Austria, which I found to be very helpful.

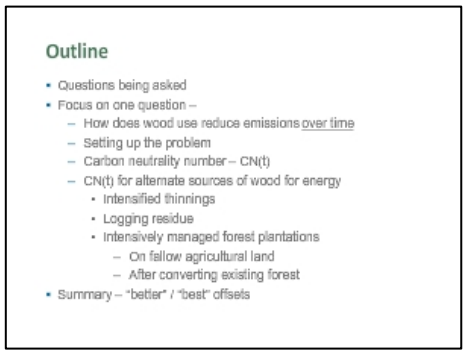
Slide 3. Learning Objectives



Learning objectives for this presentation. First of all, to help you understand how the use of wood for energy results in reductions that occur over time, that change over time. Time is very important. Second, that the source of the wood material that's used determines this time path of reductions. And then third, I'll show how different forest management cases can provide offsets that could be considered better or best at the end of the presentation.

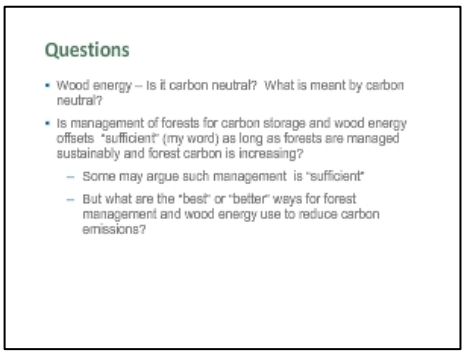
** This document transcribes the presentation given by Dr. Skog. The presentation is part of General Technical Report NRS-93, "Forest and grassland carbon in North America: A short course for land managers." The full report, comprised of 15 presentations, is in DVD format and can be obtained at http://nrs.fs.fed.us/pubs/order/40110. The presentations and related materials can also be accessed at http://www.fs.fed.us/ccrc/carboncourse/*

Slide 4. Outline



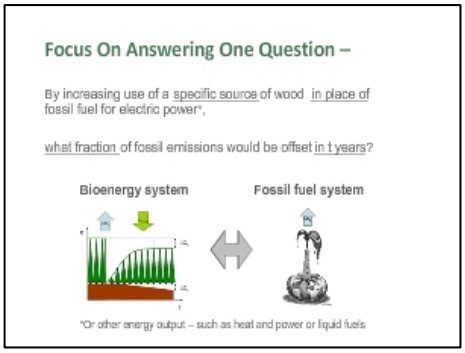
So what I'll do first is give a little bit of background on the types of questions that people are asking about wood energy, and then I'll focus on answering one particular question and that is, how does wood use reduce emissions over time.? And in order to do that, I will set up a particular problem and use a particular metric called carbon neutrality number. And then I'll show calculations of this carbon neutrality number for particular wood sources, including wood from intensified thinnings from the forest, logging residue, and then intensively managed plantations either on agricultural land or by converting existing forest. And I'll conclude by making some suggestions about what this could imply about management for wood energy sources.

Slide 5. Questions



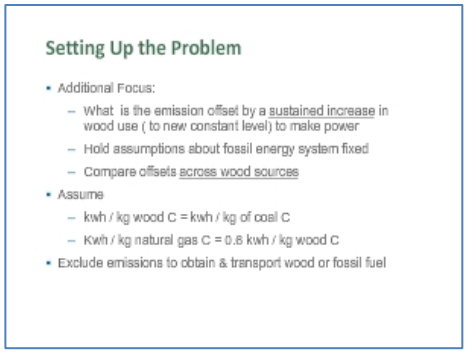
So one of the questions that's being asked quite a bit recently is, is wood energy carbon neutral in its replacement of fossil fuels? While immediately it leads me to ask a second question, what is meant by carbon neutral? I think what is commonly thought of by that term is that after there's a burning of wood material, after you've used wood to produce some energy, then it's reabsorbed by the forest, and that if you look at a long enough time span there will be a reabsorption so in its entirety over this time span, there's no net emission to the atmosphere. So that's my understanding of the common notion of carbon neutral. Well, I think one extension of this is kind of the question or maybe the assertion that, is management of forests for carbon storage and wood energy offsets sufficient? That's my word, my construction of this question. Is it sufficient as long as forests are managed sustainably and forest carbon is increasing? So here the idea is that you're reabsorbing any carbon that is taken out of the forest over time. Now are those two things sufficient? Well, in some sense they're sufficient, but it doesn't get to I think a more precise question as to whether or not there may be better or best ways for forest management to be providing wood for energy to reduce emission offsets. So I'm going to try to get at this more refined question, how to identify better or best ways to provide wood that offsets emissions.

Slide 6. Focus on Answering One Question



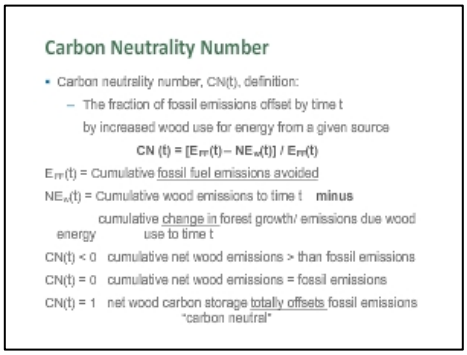
So to do that I'm going to focus on one particular question, and that is, by increasing the use of wood for a particular source in place of fossil fuels, what fraction of fossil emissions would be offset by a particular point in time? And here we're comparing on the left in this figure, a bioenergy system which has two effects as its using wood for energy. One is an initial emission taking wood out of the forest, initial emission, the carbon dioxide goes to the atmosphere, but then there's a consequence in the forest. The forest regrows so there's those two effects with a bioenergy system, whereas with a fossil fuel system you just have a one-way movement of carbon from the fossil fuel to the atmosphere. Now in my particular example I'm going to be using an electric power system. I'm going to be comparing coal use to wood use in producing electric power. But it could be generalized to other sources of fossil fuel and other types of conversion systems, but I wanted to keep it simple so I can compare the effect across wood sources.

Slide 7. Setting up the Problem



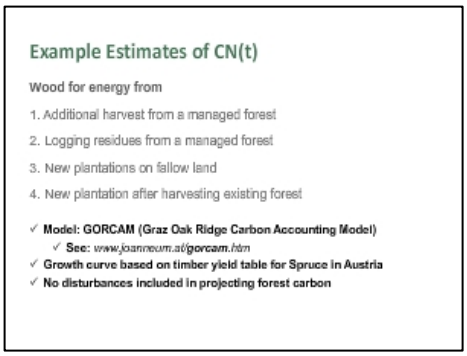
So an additional focus in setting up this problem, I want to indicate more clearly that the emission offset that I'm looking at is the offset provided by a sustained increase in wood use for energy. So you're moving from a lower level of wood use for energy to a higher level and then sustaining that higher level over time. Then I'll show some differences in the time path of offsets for different sources, and I'll be assuming that for simplicity that wood is replacing coal and the conversion efficiency both for coal and wood is the same. And in one instance I'll indicate what the effect of the calculation is if we assume wood is substituting for natural gas where it requires more wood carbon to produce the same amount of electricity as a unit of carbon of natural gas. And to further simplify this problem, I'll be excluding the emissions associated with obtaining and transporting either wood material or fossil fuels to an electric power plant. But those could be included in a more comprehensive analysis. But I don't think they would change the basic sort of conclusions that I'm going to show.

Slide 8. Carbon Neutrality Number



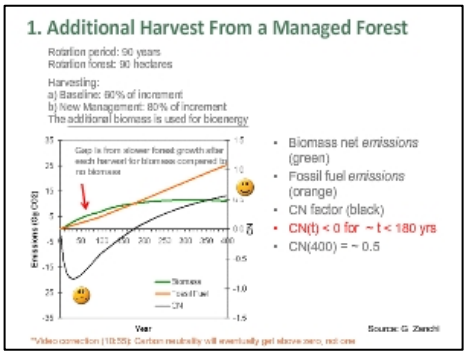
So this is the most complicated, well maybe one of the most complicated slides I'll show, but I think you really only need to understand the first few lines about defining the carbon neutrality number and then the meaning of different values of the carbon neutrality number. Carbon neutrality number definition is, it's a fraction of fossil fuel emissions that would be offset by time T by increased use of wood for energy from a given source. So, it's this fraction of offset by a particular time T. And this is the equation for it. I'll just mention briefly the components of the equation, but then I particularly recommend you look at a paper by Giuliana Zanchi, which is in the references, to learn more. So in the denominator is the cumulative fossil fuel emissions that would be avoided up through time T, and then the numerator there are two effects from using wood for energy. One is the cumulative emissions of the wood energy over time, but then that is offset by what would have happened or happens to the source of the wood material. So you deduct from the wood emissions the change in forest growth or emissions due to using wood energy for use up to time T. So that's the most complicated element in understanding this. So, particularly what the carbon neutrality numbers mean, if you have a carbon neutrality number less than zero, that means the emissions from wood energy up to a particular point have been greater than the fossil emissions would have been, so that's bad. You wouldn't want that to be the case if you could avoid it. And if it's zero, if carbon neutrality number is zero at a particular point in time, that means the level of wood energy emission are identical to what the fossil emissions would have been up to that particular point. And then if you get to a carbon neutrality number of one, that's the common notion of carbon neutrality where the use of the wood system has totally offset what the fossil emissions would have been up through that 'time T', and that would be great if you can get there. And there's some systems that I'll show that do get you there.

Slide 9. Example Estimates of CN(t)



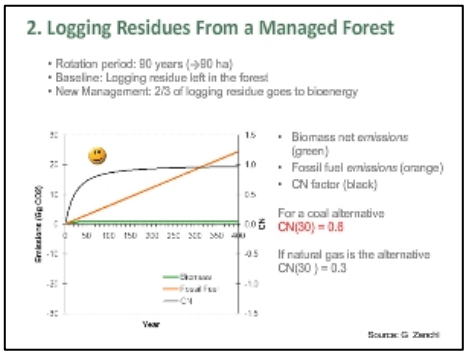
So I'll show estimates of this carbon neutrality number first for additional harvest from managed forest, logging residue, plantations from fallow agricultural land or plantations established after existing harvest. And to do this, we're using a model called GORCAM[1]. And the forest management example uses timber yield for its biomass growth for spruce in Austria, so it may be somewhat similar to temperate conifer forests in the United States. But once again, I want to caution we can't overgeneralize from this one example. And for this particular example, we're going to be excluding disturbance effects, although they could be added to a more complicated example.

Slide 10. Additional Harvest from a Managed Forest



So this shows a graph of the case where you're changing management in a managed forest, and in this particular case you have 90 hectares, 90 rotation age, so each year you're harvesting one hectare. In one case you're harvesting 60 percent of the growth. In the other case you're harvesting 80 percent, and that difference, that 20 percent difference between the two cases, goes for energy, for bioenergy. So the figure shows an orange line, which is the cumulative emissions that would have occurred in the fossil fuel case, and those march up over time, and then the green line is the net emissions from the biomass energy case. And you have two components. One is the emission every year where you're taking some wood and burning it and sending it to the atmosphere, but at the same time you're changing what would have happened in the forest between the two cases. In the case where you take more biomass out of the forest, you're actually slowing the forest growth. You have less tree stock there to grow, and as a result, the growth is going to be slower in the case where you've taken more biomass. And because of that net effect, the slowing of growth in the forest, it actually takes quite a number of years, in this particular example 180 years, before the growth in the forest gets to be offsetting this slowness initially and you have it matching the fossil fuel emission. So the carbon neutrality number is negative for the first 180 years, which is bad. And eventually it will get above one, which is good and could get on the order of 0.5, but it takes several hundred years in this particular example. I don't want to overgeneralize because this case could be substantially different depending upon the growth rates between a stand before you do the biomass removal and afterwards, and I think we need to do more evaluations to understand this more clearly in different places in the United States.

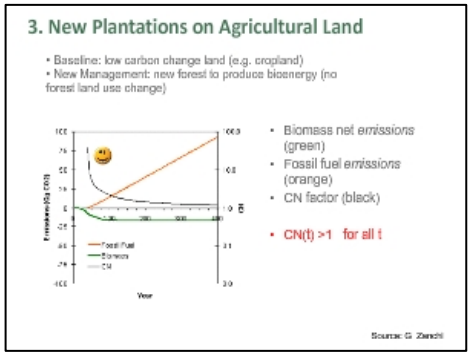
Slide 11. Logging Residues from a Managed Forest



So logging residue case is much, much better because the green line here is the net amount of biomass emissions with logging residue, and once again this has two components. You have the emissions each year from the bioenergy system. But then you have, because you've taken wood out of the forest, you have an avoided emission. You're avoiding the logging residue decay because you're taking it out of the forest. So each year you have an emission, but then you have avoided decay from the prior year's removals, that logging residue that's not in the forest. So you quickly come to an equilibrium

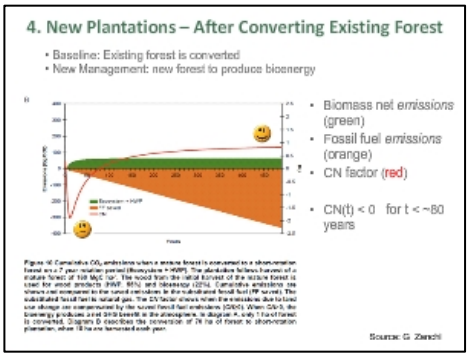
between the emission and the avoided emission that is at a relatively low level, and as a result, you get carbon offsets which are quite high quite quickly. Within 30 years you get 60 percent offset, in a 100 years you're 80 percent offset. This is comparing coal to wood. If you are looking at natural gas, the offset is much less, 30 percent for 30 years and 60 percent for 100 years.

Slide 12. New Plantations on Agricultural Land



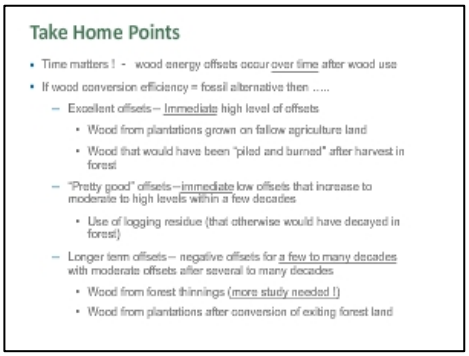
New plantations, the picture is really good because you actually accumulate carbon on the land before you ever start using a part of the plantation to offset energy. So you have carbon neutrality numbers are very, very high, initially up 20, 30, 40, and then they come down slowly as you use more of the plantation to replace fossil fuels over time. And eventually your carbon neutrality number will approach 1 but will always be above 1 because you actually have some standing stock in the plantation that was placed on fallow agricultural land. So that's always good.

Slide 13. New Plantations



When you convert an existing forest you have a circumstance where you are causing an emission because of the conversion, so it really matters what you do with the forest you convert. If you send it all up in the air for energy, you have quite a bit to offset in the future. You have all of that emissions before you ever start growing the plantation. So in this case, it's kind of a mixture of uses. Some of the wood goes for products which are long-lived, some of it goes for energy. In this particular case they're showing a negative carbon neutrality number of about 80 years, so clearing land can have a negative effect for quite a long period of time.

Slide 14. Take Home Points



So my take home points. Time matters in assessing wood energy offsets. Now in this particular example when we're looking at comparing wood energy to coal energy in producing electric power, assuming equivalency of conversion efficiency, then I think you can draw these conclusions about different sources. You get excellent offsets that are immediate and high. If you're getting wood material from plantations that are established on fallow agricultural land, and another case that I didn't mention which is equally as good, is that you, if you are taking material from a harvest site that would otherwise been piled and burned where you would have had an immediate emission, and you're avoiding that by taking it out and using that for energy, that's also an excellent immediate offset. You get pretty good offsets from use of logging residue. You'll get immediate low-level offsets which will grow quite a bit over time because of this avoided, you're avoiding the decay of leaving logging residue in the forest. You have longer-term offsets for cases where you're doing some sort of getting thinnings from the forest, because what really matters there is the comparison of the growth rates that would have occurred without harvest, without that thinning, and with the thinning, so that can vary considerably by

forest condition. And also a case which is problematic is use of wood from plantations where you had to convert land, because there's a long time to offset the emissions from that initial conversion. Thank you.

Footnotes

[1]GORCAM=Graz/Oak Ridge Carbon Accounting Model