MODERATOR

Robert L. Edmonds - Denman Professor in Sustainable Resource Sciences, UW School of Environmental and Forest Sciences

PARTICIPANTS

Tom Gower – Professor, Department of Forest Ecology and Management, University of Wisconsin, Madison, WI
Rick Gustafson - Professor of Bioresource Science and Engineering, UW School of Environmental and Forest Sciences.
Mark Harmon – Professor, Department of Forest Science, Oregon State University, Corvallis, OR
Mike Jostrom - Director of Renewable Resources, Plum Creek Timber Company, Seattle, WA.
Patrick Mazza - Research Director, Climate Solutions, Seattle, WA.
Elaine Oneil - Research Scientist, UW School of Environmental and Forest Sciences.
Craig Partridge - Director of Policy and Government Relations, WA Department of Natural Resources, Olympia, WA
Steve Rigdon - Generation Manager, Yakama Power, Toppenish, WA.
Kate Simonen - Assistant Professor, UW Department of Architecture.
Edie Sonne - Hall Manager, Sustainable Forests and Products, Weyerhaeuser Company, Federal Way, WA

MODERATOR: Unfortunately one of our speakers, Professor Shi-Ling Hsu, Faculty of Law, University of British Columbia, Vancouver, BC, was unable to participate in this question and answer session. All the other speakers could, so I am anticipating an interesting and energetic question and answer session. Let’s open it up for questions.

AUDIENCE: This question is for Professor Gustafson and anybody else who wants to answer it. A lot of the discussion today had to do with energy flow and I saw some consideration of life cycle analysis. However, I saw no consideration of energy return on investment. I would like to know if the return on financial investment is distorted by subsidies and if the energy return on investment is separate. Can you please explain if you are quantifying the energy return on investment as you work through the biofuels equation?

RICK GUSTAFSON: Well, we don't calculate that directly but the carbon emission assesses that in sort of an indirect fashion. That's about the best we can do with the whole system. In addition, we calculate the fossil fuel usage to produce the fuel. For the case of ethanol from woody biomass this value is very close to zero and it can be negative because of displaced production of electricity from burning coal or other fossil fuel. The only fossil fuel used to produce cellulosic ethanol is the little bit for harvesting the biomass, and transporting the feedstock and final product. All the energy for the biorefinery comes from the biomass itself.
ELAINE ONEIL: Why not calculate energy return on investment?

RICK GUSTAFSON: We could do it but we chose in our environmental assessment to concentrate on emissions and direct impacts on carbon, water, fossil fuels and a few other environmental indicators for the whole system. Also because carbon and energy are linked they typically look very similar to each other in the end.

AUDIENCE: I heard when the program started that there are 75 million acres of dead trees in British Columbia. I wonder what is being done with these dead trees and if they have any value?

ELAINE ONEIL: In British Columbia they have an aggressive program for utilizing those trees and are actively harvesting them. They are dealing with wood from beetle-killed trees ahead of all other wood. Of course, nearly all the wood they have now is from beetle-killed trees. That started probably in the early 1990s, and is continuing on today. In the mills they are processing all the wood they can produce as dimension lumber. There is more waste produced than normal from those mills, so they have developed a very active bioenergy industry processing pellets for the European market. In the U.S., the biomass to energy market is much less developed, and there isn’t a lot of pellet production, particularly in the in the inland west. There are only a few places doing this. We really don’t have the infrastructure and the strong focus that they have in British Columbia to aggressively manage the beetle problem. Also, there are a lot of affected acres in the U.S. that are located in national forests so there are caveats and protections in place because the management objectives of Forest Service are not necessarily focused on harvest. So it is extremely difficult to harvest in a timely manner to produce dimensional lumber; you have to look at producing an energy product. However, we don’t have the infrastructure to do this so the wood is rotting and burning.

PATRICK MAZZA: I'd like to make a related point. As you know there is a lot of debate on the effect of thinning the forest to improve forest health. Is thinning a carbon win or not? We need to have a clearer understanding from the scientists of what the optimal fate of the carbon is relative to the thinned materials we get from bug-killed forests. Is it combusting it, is it burying it, or is it pyrolyzing it and making bio-char? We need that information from the life cycle analysis community.

AUDIENCE: I'm a water resources manager. When I listen to the demand for using trees and wood for purposes other than they are currently providing, I worry about the potential impact on the health of the receiving waters that have been protected by forest cover. Any comments from anybody on the panel on conflicting objectives from a social environmental standpoint? This might be similar to using corn for fuel and then driving up food costs. How do we maintain forest cover to protect the hydrological regime of an area and fish habitat of the fish in streams?

PATRICK MAZZA: I'll give a really quick answer. The biocarbon initiative is driving us to also look at water. Accumulation of carbon in the forest is also very favorable toward water. As a result ecosystem services markets for water are being really actively developed in Oregon.

EDIE SONNE-HALL: That's a really good point and a really good question before that. We
talk a lot about possibilities for uses of fiber. However, the important thing is doing it efficiently and doing more with the same amount or less. What is coming off the land and what is it doing to the land? From a biomass perspective, there are lots of economic reasons why you're not going to take everything off the land. However, it is still important to understand what happens if you do. There is a lot of research being conducted on this right now and Weyerhaeuser is participating in a $40 million DOE grant to establish a long-term site productivity study in Oregon to look at the effect of biomass removal on long-term soil productivity.

MIKE JOSTROM: We have taken a look at biomass removals and have concluded that harvest levels will not appreciably increase, even if bio-renewable energy targets were set unrealistically high, because of the low value and the high cost of removing biomass. The other thing is what was mentioned in one of the presentations is that biomass removal is a forest practice and thus subject to forest practice regulations which cover stream-side cover and other water quality issues.

CRAIG PARTRIDGE: I think that the science shows that the most damaging consideration for water resources is land conversion. Creating opportunities, particularly for small forest land owners, to receive more revenue for continuing to manage their lands as forest lands is probably the best way to forestall conversion to other uses by that class of owners. It will slowdown development patterns and sprawls. One of the big take-home messages is to increase economic incentives for both large and small forest landowners to keep their land in forestry.

AUDIENCE: My name is Carrie Lee and I have a question for Dr. O'Neill and Professor Gower about the field data you presented in Wisconsin and the modeling results. Could you please clarify how soil carbon fluxes and carbon storage in the soil were or were not included in your results. If they weren't, could you elaborate on how you would include them?

TOM GOWER: Are you referring to the model results that I showed or the curve with all the NEP (Net Ecosystem Production) responses in the different forest ecosystems?

AUDIENCE: You showed the model for them and then you showed the data for the different ecosystems.

TOM GOWER: O.K. Almost all of the data were from Eddy Flux Towers and so they are measuring the net exchange of carbon dioxide. So they showed the accumulated effect of vegetation as well as soil. So early on, when you saw it go negative, it was totally dominated by changes in soil carbon flux. And then you start seeing the combined effect of losses of carbon from heterotrophic respiration as well as the carbon accumulation by NPP (Net Primary Production). So it does account for the soil carbon flux. As far as modeling goes we are trying to account for accumulation of carbon in the soil and the way we do it is the same as everyone else. It's extremely open to criticism and all the results should be viewed with open eyes since we make the assumption that the soil is in steady state right now. It's the only way we know how to move forward. So you run the model for 10,000 years until you get the soil carbon pool stable, then you start running your treatments. There are scenarios in agriculture where that's probably incorrect. Also there are probably scenarios in recovering forests after deforestation where the system is not in steady state. But that's typically the way everyone does it. I think for
ecosystems that have been in forest for a number of decades or centuries, it's probably a reasonably safe assumption. We have attempted to validate our model by looking at the predicted rate of carbon accumulation compared to data from Eddy Flux Sites, and we are within the ballpark. However, it is a potential shortcoming of all of these models. Something that we don’t know a lot about is how land use history and removal of residues are going to affect the fast, medium and slow carbon turnover pools. So it's a very good question.

**KATE SIMONEN:** So did I understand you correctly that when you say it's in steady state, you assume that the amount that's decomposing exactly equals the amount that’s being grown (captured)?

**TOM GOWER:** That's correct. All the carbon pools are in steady state right now.

**ELAINE ONEIL:** And we have used the same assumption in that when you're harvesting you are going to change your inputs and outputs, but over time it's a steady state. The charts that I showed are not actually modeling that. But we have shown that soil carbon increased under willow planted as a bioenergy crop on abandoned agricultural land in the northeast U.S. With a change in land use you're going to see soil carbon increase. In forests you reforest almost immediately after harvesting because it's a planned investment. Thus you should maintain soil carbon at a relatively stable level. There is still a lot of work that needs to be done on that. We have scientists here at the University of Washington who argue that in many cases, we typically only measure soil carbon in the top 30 centimeters and there is a lot of soil carbon below that.

**KATE SIMONEN:** So you could actually be sucking more in and it never rots?

**ELAINE ONEIL:** Yes.

**PATRICK MAZZA:** So is it just a convenience that you assume a steady state just to allow you to run the model, or do you think that's what's really going on?

**MARK HARMON:** It's largely a convenience. But part of the issue is that some of the fluxes are very hard to measure precisely. So it's really hard to get at it. However, we do know that the steady state is dependent on the input because it equals the output. Also we know for different intervals of harvest we have different inputs, which means we must have different outputs. So the problem is when you change from a short rotation to a long one, you could really change the inputs significantly and the stores won’t stay the same. Perhaps they won't change a lot because soils are dampened and respond really slowly. So maybe over a decade, you wouldn't see it. It might take a century or two but it definitely isn't static and that really comes from convenience. We have to do better on that.

**TOM GOWER:** I’ll just follow up. I agree it's not static but it is, as Mark just alluded to, a very slow pool compared to the carbon in the vegetation. So it's buffered way out. I still contend in some systems, it's a reasonably safe assumption. I think in the New England states where you've had lots of forestation and harvesting or in the southeast where you've gone through multiple rotations, you probably are at steady state. However, you are not at steady state in agriculture. To see this you just have to drive through the mid-west U.S. where fence bottoms are sitting a
foot above the agricultural fields. That represents a loss in soil carbon and it is not steady state.
So I think in some systems it's a reasonable assumption. In others, as Mark pointed out, it isn't.
It's a conceptual model that we're trying to link to different carbon pools that are turning over at
very different rates. So it's a challenge. We certainly need to do better.

AUDIENCE: I would like to ask Mark and Elaine what the variables are that would tip the
models one way or another. Forest products are long-lived unless a house gets pulled down early
and in that case dimensional lumber gets chipped up. Forests might burn up, but after a fire trees
still store carbon. We just heard some debate about soil carbon, but again I would like to ask
what variables will tip your model one way or the other and perhaps lead to different
conclusions?

MARK HARMON: Okay. I've got the microphone. I'll go first since Elaine went first in the
presentations. I thought I outlined it pretty clearly, but perhaps I didn't. There are three real
assumptions and it's all about how you count the substitution of the products. I don't think there
is a displacement of fossil energy. Don't get me wrong. That number can vary probably from 1
ton per ton used to 2 or maybe 4. I mean there's a huge range. I don't dispute that substitution
occurs. But I do have questions about the assumptions that are being made. The first is that it is
permanent. I don't believe it is permanent because of the leakage phenomenon. Maybe it isn't
related to the housing industry. For leakage, that doesn't really matter. It's largely an economic
and policy thing. For the second assumption I think there really has to be a tie between the
longevity of housing or buildings and the substitution. I think they have to be linked. I don't
think Elaine believes that. She can speak for herself, however. The third thing is, as Kate
showed, that energy costs (embodied energy in products) are going down. There is pressure to
decrease the embodied energy in steel and concrete for wood. They are all collapsing but
concrete and steel have further to go. They have more to gain. With time that means your
displacement factor has to decrease. I'm not saying it every goes to zero. I think we'll always
have an advantage, but it's not going to be a static number. When you project 100 or 200 years
into the future, I think you need to address that. A lot of these things we haven't explored fully. I
am raising them as subjects we need to explore more fully to really understand what we're doing
with regards to the atmosphere. That's my standard, making a difference for the atmosphere.

ELAINE ONEIL: I think that we're looking at two different conceptions here. Listening to
Mark's talk made me realize that we haven't been as clear in our explanation as we should.
When you look at the graphs I presented the wood in the house does decay over time. In fact, in
the last year we have figured out how to make that decay function a little bit more accurate. At
the landscape level there is a relatively steady state in the forest. But you have to recognize that
with the accumulation of wood products over time, those wood products have a life. And then
they fall off the table. They are consumed. We do not collect the energy from those products.
Neither do we account for the fact that if they go in the landfill about 75 percent of that carbon
remains there. We are burning it for energy and not taking that value. So you'll actually see that
wood products coming out of that wood basket over time would flatten out. Now, the difference
in opinion here is whether or not the substitution benefit is permanent or tied to the length of life
of the house. And so when Mark gave us his thoughts on this he indicated that you can build it
out of any number of materials. In fact, you use many materials. When we went through the
analysis of housing, and U.S. housing in particular, we found that the average life of a house was
about 78 to 80 years. That's based on houses built in the early 1900s. Now we can expect that they last longer. The Bullet Foundation says we should expect 200 years. A decision to use wood, or a product with a higher embodied carbon and a higher fossil fuel use, can be made at the time you build a house. That's an either or decision and you are going to have a substitution benefit. That benefit changes over time because, for example, if the house does blow down in 10 years in a hurricane like Katrina, you have to make another decision. You lose the value of the wood but you are making an either/or decision on substituting for an energy value. I am sure we are going to be arguing this for a long time. However, there is one point I want to make. The allocation among products, forest growth, and the substitution benefit are all based on current modeling for forest growth, the current allocation of the wood products and the energy it takes to produce them plus the energy it takes to produce steel and concrete based on the US Life Cycle Inventory (LCI) database. I agree that these values should get narrower over time, but we don’t have any way to predict what that would be. So at this point in time it's a fixed rate.

**KATE SIMONEN:** I just want to add that substitution models are hard to understand from the perspective of people who make choices about which building products to use. That’s because houses are built out of wood and there's a workforce available to build them out of wood. People are expect that here. I’m not an economist but there's got to be much more complex economic modeling that comes into play. Adding that substitution chart just makes it confusing.

**MARK HARMON:** That’s a good point and substitution gains will be made in countries and areas where they don’t currently use a lot of wood. I just don’t believe that you call it substitution when you substitute wood for wood and want wood in the future.

**ELAINE ONEIL:** Substitution is about what the atmosphere sees at that point in time. People talk about incrementality and additionality and that is all about who pays and who gets the benefit. But if you're going to build a house, or a hospital, or a school, it's going to be built out of something. Of course, another option would be to reduce the number of houses or the size of houses which might be a good thing to occur as well.

**AUDIENCE:** This needs to be stated really clearly. So for every board foot of wood that is being produced you are assuming that it is displacing steel or cement and none of that wood is displacing wood that has already been used?

**ELAINE O’NEIL:** That's correct.

**AUDIENCE:** I have a question for Kate Simonen. Do you see an opportunity from the architectural point of view to use wood in non-traditional ways? We have seen new uses of laminated lumber in construction and taller wooden buildings. Do you see opportunities for using more wood use in construction?

**KATE SIMONEN:** Elaine showed us examples of the use of cross-laminated timber in high-rise wood framed buildings. That is an excellent example of how the wood industry could help advance the use of wood products in a more efficient manner. You could study whether or not it is more efficient to use solid cross-laminated timber than studs. You could develop testing protocols for seismic safety and get an understanding of seismic performance of cross-laminated
timber walls. There are a lot of possibilities for innovative use of wood products in expanding markets. I would recommend these be industry focus areas if they sincerely believe that using more wood is both good for the bottom line and the environment.

**ELAINE O’NEIL:** I need to go back to the substitution topic. I think it depends on the way that I interpret the graph that CORRIM (Consortium for Research on Renewable Industrial Materials) uses. In the U.S. we build houses out of wood. This isn’t true around the world. The same type of life cycle assessment (LCA) studies have been conducted in Europe, New Zealand and Australia using their own LCAs of wood products. They might build houses using 10 percent wood. They could go further towards meeting Kyoto protocol targets by replacing brick and concrete with wood. So that's how it's being used elsewhere in the world. In the U.S. we use wood and we're doing something that is smart for once.

**AUDIENCE:** This is a question for Edie Sonne-Hall. I was very excited a number of years ago to see Chevron and Weyerhaeuser get together to form Catchlight Energy, but I haven’t seen anything come from that yet. Could you tell us more about that?

**EDIE-SONNE-HALL:** Second generation cellulosic fuel is under development, and building a new technology takes time. Catchlight Energy has been working on the entire supply chain, from forest to fuel, and has made progress in many areas. One area to mention is Catchlight Energy has two agreements with KiOR, a next-generation renewable fuels company, for KiOR's first commercial production facility in Columbus, Mississippi; a feedstock supply agreement to supply forest-based feedstocks, and a conditional offtake agreement to purchase gasoline and diesel fuel blendstocks. CLE's purchase of products is contingent on, among other things, satisfaction of product specification criteria and RIN certification of the products as cellulosic biofuels under the U.S. Renewable Fuel Standard.

**AUDIENCE:** Will that be this year or next year?

**EDIE-SONNE-HALL:** The feedstock and offtake participation are tied to the start-up of KiOR's first commercial unit, which is currently scheduled to occur in the second half of 2012.

**AUDIENCE:** This question is for Mark Harmon. Your excellent discussion of credibility and dissonance in the forest products industry ended with a slide listing three conclusions which should be implemented to restore or enhance credibility. So I’m waiting for the next slide. How do you do that?

**MARK HARMON:** It may be difficult, but we have to come up with a set of agreed upon assumptions about things like product substitution and the effects of thinning. Does thinning really make forests productive? From an ecosystem point of view it really doesn’t. However, it does from a harvest point of view for sure. We have to start with the basics; laws of thermodynamics, mass balance, etc. When a forest is killed by insects, the carbon doesn't go into the atmosphere instantaneously. It takes some time. In fact, our harvesting of the trees could actually release carbon faster because we process it faster. So we have to start with some basic things. Then we have to look at things that could be done, the odds of achieving a positive effect versus a negative effect, and where they might be applied in terms of area and region. Regions vary vastly. We have lots of old-growth forest in the Pacific northwest compared to the southeast. There are lots of open areas in the mid-west that could be turned into new plantations.
But we don’t have any set of guidelines like that yet. And there are tradeoffs. If we harvest less forest we will have fewer wood products. If you want substitution benefits, then harvesting is the way to go. The biggest disagreement right now is about how substitution counts? How do we account for it? It is two different things. So we have to agree upon at least understanding this. I think what Elaine does is compute what might be a maximum theoretical number. O.K., that's valuable. It's sort of a potential, but I don’t think it's necessarily realistic in terms of what the atmosphere will see.

CRAIG PARTRIDGE: If we want to answer questions about how can we improve credibility then we have to want to improve credibility. If we all have the goal of improving the credibility of the sector, then I think we should all try to focus more on what we agree on than what we disagree on. We should carve out an area where everybody is saying the same thing more consistently and more often. That way we would be the way to improve credibility in public debate rather than perpetuating debate.

AUDIENCE: I have a question for Steve Rigdon. The tribes have a real interest in bio-energy development and also have an interest in salmon restoration. Can we put these pictures together in operations that produce energy, that improve carbon sequestration, and improve watershed characteristics for salmon?

STEVE RIGDON: I think we can. If we look at the Columbia River and all the restoration work in fisheries that the tribes are doing there, it involves watersheds. It involves the uplands where meadow restoration projects are happening. Trees are encroaching into meadows and need to be eradicated or taken out. There are different land use management choices for riparian areas, mountain pine bark beetle and fire, and the whole spotted owl situation. I am talking predominantly about eastern Cascades. The restoration work involving timber stand improvement and ecological restoration in watersheds complement each other because the take care of the habitat. Also you are taking care of water as well as using the products for timber, pulp, and biomass. And so it's finding those synergies that make sense and having the infrastructure in place. The philosophy of the tribes is that if you take care of the environment and the natural resources they will take care of you. As an American society we have not done that well. We are still trying to figure out how to address the problems of fire exclusion, logging activities and road placements that have been detrimental to fisheries and meadows while still harvesting fish and timber. It's a balance. Too much conservation one way and you're dealing with insects, disease and fire. Too much industry the other way results in exploitation of resources. It's a very fine line. The tribes have made land use management choices that fit them best. It must be good long-term management since the tribes are permanently located where they are;they aren't going anywhere. They have to protect what they have for themselves and for future generations. Others look purely at profit margins and sometimes disregard many ecosystem services or the environment. I think we can complement restoration activities from both the forest and aquatic perspectives to meet most of the needs in our region. But only by sensibly investing in our region can we do that.

AUDIENCE: Is the Yakama tribe thinking about building a 20-30 megawatt biomass power plant or are you just thinking about a small-scale operation?
PHIL RIGDON: I have given four or five proposals to our tribal council on creating efficiencies within our existing infrastructure and saving energy costs on the reservation with our two mills. However, we have not implemented anything yet. We have been distracted with casino expansions, mismanagement lawsuits, settlement agreements and other activities. We are in a survival mode with our timber industry at this time. It's being heavily subsidized. Having the tools in place to manage our forests for our benefits and needs will have to have socio-economic-environmental benefits. But this detracts from the $10-80 million investment for biomass power. Where is that money going to come from? How do we prioritize? We understand our forests and what makes a healthy forest. We understand water and fisheries. It’s my job to make the connections for our people. There are energy efficiencies that we can use to pay for ourselves and our local economies so that we're more autonomous and self sufficient.

PATRICK MAZZA: Carbon tax should be on the table and part of that carbon tax should go for carbon building restoration activities and used directly for land management activities. We anticipate that the next round of climate tax discussion will occur sometime within the next several years.

AUDIENCE: I have a question for the general group. Anyone could answer this, but perhaps Dr. Harmon or Mr. Mazza. I’m thinking about greenhouse gas emissions generated through the combustion of forest biomass. A lot of the material presented today makes assumptions and generalizations about how those combustions are mitigated forward through time. But no one mentioned how different scenarios will play out relative to when that mitigation occurs. In other words, we are front loading a system through emissions under the premise that we are going to mitigate for them 20 or 30 years from now. If we are contributing to a dangerous rise in global temperatures now, then mitigation efforts in the future really don’t do you any good because we've already passed the point of no return. So to use the house analogy that you keep mentioning, it wouldn't matter if the house decayed or not because it might be underwater if it's on the beach. So I’m wondering if there has been any attempt to link what you are doing to the information that's been provided by the International Panel of Climate Change (IPCC) on implications of global warming and other climate change issues through time while you're waiting for the mitigation from front-end loading.

PATRICK MAZZA: By mitigation do you mean the re-growth of the forest?

AUDIENCE: Yes.

PATRICK MAZZA: There is a lot of debate going on right now about burning of biofuels having the same global warming potential as burning fossil carbon. Also how long is it going to take for forests to re-grow and re-accumulate that carbon. And that's only one side of it. The other side is that any fossil carbon you release is going to have ultimately a much longer tail, 125,000 years or something like that. So you're in a kind of dilemma. Instead of burning wood, should we burn natural gas, which is going to have that 125,000 year tail, but is going to put less immediate carbon into the atmosphere? I think my paradigm for this is that we should be using biomass for energy where we don’t necessarily have other good options; jet fuel perhaps. But when we have other potentially good options that have no carbon emissions, then we should go for them. Then we've got this in between area where we need a base load power source to
balance our variable renewables. Is it biomass? Is it geothermal? I'm not giving you a good answer here because it's really complex.

AUDIENCE: There is a lot of discussion on carbon accounting going on right now. Should you account for the emission now and replace it during the time that a tree grows back, or should you count the growth first and then account for the emission after the tree has grown? If you were going to do this from the point of view of a forest biometrician, you would look at the balance between growth and harvest that's occurring right now, and the balance going through time based on your anticipated inputs and outputs. It can become a chicken and an egg discussion.

MARK HARMON: Or a scrambled egg. It is scrambled in that you're looking at a stand, a little plot of land. The chicken and egg makes a difference, but if you're looking at the whole complex that is producing chickens, it involves both chickens and eggs so it doesn't really matter which came first. It's irrelevant. But to get to your question, I think there are a couple parts to the answer. One is that although a lot of people view bioenergy as always carbon neutral, that's not necessarily true. There could be systems where you drive down the carbon stocks as you harvest and that would create a debt. On the other hand if you plant poplars or willows in an agricultural field you might actually increase the carbon store. There's no debt in this case. If you turn an old forest into a short-rotation plantation, you cut the cost of carbon debt. Then there is the issue of how long it takes to repay that debt to get back to where you started. If you have a gain or it is neutral, it's instantaneous. But where debts occur it takes time to recover. Some recoveries can take centuries. The more intensively and frequently you harvest the more you increase the payback period time, but you also increase the debt. So it's kind of a zero sum game. In terms of the time period, studies by Francesco Cherubini and also by Allen show that the climate system is like the soil. It responds slowly. So there is a wide range of emission scenarios over a 100-year period that don’t have really big consequences for climate warming, especially if you constrain the total amount of emissions. They didn’t examine everything in year 1 or all in year 99, but in the mid-range. This tells us that if we deplete the stores for 100 years or more, then climate will sense that. If it is just for a decade, the climate may not really sense it much. So we are dealing with sort of an instantaneous release or a very fast one versus a system that is responding slowly. Although it might take 100,000 years to form fossil carbon again, the time span for ocean uptake is only 10,000 years. I sleep better knowing that it's not 100,000 years; only 10,000 years.

PATRICK MAZZA: I will cite David Archer, author of the book “Long Thaw: How Human’s are Changing the Next 100,000 years of Earth’s Climate.” His time period is more like that for the ocean part. But when we're talking about that last increment that needs to be weathered into rocks, that’s 125,000 years.

MARK HARMON: All right. Fair enough.

EDIE SONNE-HALL: I just wanted to add I agree with Dr. Harmon. What he pointed out was that you're looking at average carbon storage instead of plot level carbon, if I interpreted him correctly. So if you're doing the same management in the same rotation, there is no carbon debt which is similar to looking at it at a landscape level. The other thing that I want to add, and I think Mike Jostrom might have been alluding to this, is that we have increased harvest in the
southern U.S. since the 1950s by a tremendous amount yet inventory has increased the same amount. You can do both. You don’t have a set amount of actual harvest and actual growth on the land. You can actually increase harvest and increase the actual inventory on the land.

**MODERATOR:** We have the end of the time allocated for our session. I would like to thank all the speakers for participating in this very interesting discussion. Thank you very much.