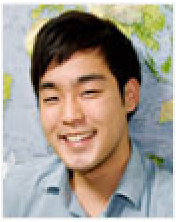
환경에너지공학

지속 가능한 바이오매스 생산

- ✓ **Instructor:** James M. Tiedje
- ✓ **Institution:** 연세대학교
- ✓ **Dictated:** 이병찬, 윤은영, 김현준, 정회빈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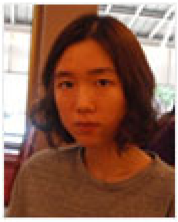
윤은영


김현준

[00:00] So I was told that you are dealing with bio energy in this portion of the class.

[00:06] And since Dr. Park [?00:08] know something about that the map became my topic.

[00:14] But I don't know really how well this fits in with what you have learned before

[00:18] But I think I can point out some of the major issues and advances with bio energy production.

[00:27] So, in this portion, I draw from material that Phil Roberson who leads the sustainability group and Bruce Dale who is chemical engineer who leads the deconstruction group.

[00:42] And Michigan state university and university of Wisconsin are one of the three centers funded by the department of energy to try to solve the problem of cellulose conversion to bio fuels.

[00:58] These centers are funded at 25 million dollars per year

[01:02] So it's in grand terms it's substantial amount of money.

[01:06] But the challenge is large to within ten years achieve an economically buyable cellulose to liquid bio fuel product.

[01:22] So this diagram here shows sorts of the major components.

[01:27] So, using the energy from sun, converted to carbon-carbon bonds in plants, those then converted into sugars, to fuels, and then a variety of human uses.

[01:47] So the first part of this is some background information on the challenge for energy and bio fuels.

[01:56] So this is, I think, particularly interesting figures.

[02:00] So what it shows… what it says..

[02:05] It's for any population to be wealthy, or least have reasonable standard of living.

[02:14] They need energy.

[02:16]So energy is given need for desirable human living.

[02:23]So this is the Gross Domestic Product for capita of different countries,

[02:30] And this axis is the energy consumption per capita in BTU per person.

[02:34] So you see there's a quite clear relation here between energy consumption and standard of living, basically.

[02:47] So you see South Korea's right here, Japan, French, United Kingdom are here, Russia's here

[02:57] So you look up a down here this would be same energy consumption per capita with these countries being more efficient in using that energy consumption for Gross Domestic Product.

[03:17] And Russia, for example, is in the same area, but much less efficient.

[03:26] However, the upcoming problem is that many countries, low income countries, have rapid economic growth rates.

[03:36] Certainly China does, Mexico does, it suggest so some small countries do as well here.

[03:45] But there probably others within this categories that one to move up the scale in terms of their wealth which means their energy consumption will go up, which means the price, the world price of fuels will also increase.

[04:04] So with that scenario then, we need other source of fuels.

[04:10] The fund amental problem is how do we take from the energy from sun and convert it to electrons.

[04:21] So the sun has plenty of energy, so the sun deliver to earth in 1.5 days the energy equivalent to all of the recoverable oil in the world

[04:34] The annual human consumption energy is 4.6x10^12 joules and that is supplied to Earth by sun each hour.

[04:44] So sun is huge resource for which we're not using as efficiently as one might hope.

[04:58] So those who are stuck on oils as the essential energy source that we need should also think about how much energy were losing by not capturing from Sun

[05:15] So, this is the fundamental point.

[05:17] Energy from sun to electrons.

[05:21] And there are three issues to go with that

[05:26] What is the efficiency of that conversion?

[05:29] Whether it be biomass, solar, wind, there's some efficiency of that conversion all of which are inefficient.

[05:41] So all of those are prone to more efficiency.

[05:44] The second is what about storage.

[05:49] So with wind, and solar storage becomes an important issue

[05:55] We don't have very efficient technologies for storage meaning batteries.

[06:02] The other issue is transportation.

[06:05] So, finishing up with storage.

[06:09] Biomass, however, is the cheapest storage because it causes nothing to store carbon-carbon bond.

[06:15] The other issue is transportation.

[06:17] How do we move that electron to where we need it.

[06:22] And with solar, and with wind, we can move over parallel lines rather efficiently

[06:34] But with biomass, we can't move it so efficiently.

[06:38] So each of those means of the product of solar have their issues.

[06:50] So we need fuel for of course heat, light, and other things that electrons power for movement for industrial power for transportation.

[07:02] So this was our old way of dealing with

[07:07] This is our a current situations.

[07:10] And so the problem is we are depended on liquid fuels.

[07:18] About fifty percent of U.S. transport fuel must be liquid because it is for air and sea transport.

[07:28] Cars, of course, could eventually become electric maybe even some trucks, but not air and not sea.

[07:39] So we are depended on some substantial amount of liquid fuel in the future.

[07:47] Now because of this problem, in 2007, when Bush is still president, he signed the energy independence act, independence and security act of 2007.

[08:02] Which said that 22% of that liquid transportation fuel by 2022 should be ethanol or now it is recognized some liquid fuel not necessary only ethanol.

[08:22] So this was felt to be feasible if one can convert the cellulose to this liquid fuel products.

[08:33] And I was felt that this was scientific issues that could be addressed that it was technically feasible for science to advances to achieve this goal.

[08:47] That's what led to the funding of this bioenergy centers and other energy activities in the U.S.

[08:57] So, what are the problems?

[08:59] One of the problem is this.

[09:01] It is called food versus fuel controversy.

[09:05] And this diagram illustrates it.

[09:08] Some say it's a crime against humanity to use this products which could be a food for people who need food instead for fuels.

[09:21] Excuse me, I'm going to need this to run my car.

[09:26] And I gave a talk two years ago before former researchers at the Rockefeller foundation international research centers.

[09:37] Like aerie in the Philippines that develop high yielding rises, or the center in [?09:43] Columbia, or Mexico, or in Africa.

[09:48] And they are absolutely opposed to this approach of using bio fuels for fuel.

[09:56] Because they know that it [?10:00] will eventually the hurt supply of food for people who need it because of price.

[10:06] It will become more expense those who can afford for fuels buy it those who can't afford it will go without food.

[10:18] So, this remains a controversy.

[10:24] I don't think it is one that's not solvable, but it is certainly one that one needs to be aware of.

[10:34] So this is the comparison of energy source, and their various carriers, so this would be old oil, 1930 years so readily available oil.

[10:48] This is newer oil, pass 1970's so it's more expansive to produce.

[10:54] Tar sands, shale oils, these are large reservoirs of oil, some, in fact, just two weeks ago I was seating by sides somebody from Oklahoma and said, 'Oh there is no energy problem.'

[11:08] There's just huge amounts of oil and tar sands and shale oil.

[11:11] We need no other sources.

[11:15] Of course he worked with the oil industries.

[11:19] Wind for electricity, solar, biodiesel, corn ethanol and cellulosic ethanol.

[11:28] This is the energy return on energy invested.

[11:33] So this is the key parameter here... is actually one getting ahead by producing energy from any of resources.

[11:43] So old oil the value was a hundred and now it's very good, that was very cheap to produce.

[11:49] But you see new oil already drops to thirty.

[11:54] Tar sands, and shale oil rather poor return.

[12:02] And Bruce Dale who is the chemical engineer at MSU who prepare this slide believes that these are very problematic because there are very expensive and he thinks the rate of production could never really keep up with the oil demand.

[12:20] And you see that the gain is not so great.

[12:23] And the pollution associated with those is very high.

[12:28] So wind is pretty good, solar is still not so good, biodiesel, at lease from oilseeds that can be improved, corn ethanol is about 2 to 1 now.

[12:42] So that is what is large amounts of these produced in the U.S. and the reason is the U.S. has a highly sophisticated long history of corn production.

[12:58] So all of the technology to produce better corn makes it affect the production but it's only the starch and the seeds that is converted to ethanol.

[13:08] So that's why this ratio is slow.

[13:11] But the cellulosic ethanol is much better.

[13:14] So that's ten to fifteen.

[13:17] So that's pretty good.

[13:19] This is whether it scales well.

[13:23] This is the cost, to actually implement that from a invest point of view, and you can see for the shale oil it's very high as is the tar sands.

[13:37] Will it replace petroleum, meaning electro-fuel for transportation need of source solar and wind do not, and these are sustainability issues.

[13:50] How long will it be sustainable.

[13:52] You can see shale oil is truly awful

[13:55] And for tar sands are awful because of the huge amount of pollution that those create and massive use of water.

[14:06] So this, I think, is very important overview of those different sources what are the issues that surround them and how cellulosic ethanol which is the goal here compete with this other resources

[14:24] So I should point out here that the sustainability issues which is one of the things that I'm talking about is all of all of these the most positive.

[14:34] So there are positive environmental effects for this approach.

[14:41] Ok, so, this is the energy independent act which I said there is 22 percent of transportation fuel mix in 2022, so we have 36 billion gallons ethanol, 15 billion gallons of grain-based ethanol, that's from corns, and 21 billion gallons of advanced ethanol more than 16 coming from cellulosic.

[15:13]So European Union also has goals, 20% renewable energy by 2022 and 10% of transport fuels by 2020.

[15:23] So in the U.S., the existing ethanol plants will this numbers here, with this capacity, new plants under way, now this is all corn based ethanol.

[15:37] And this is the production in billion gallons per year.

[15:40] So 2009, up to 9 billion gallons per year, with a capacity of about 15 billion gallons per year.

[15:55] Ok, so this is the capacity and will almost there, with what we can do with corn ethanol, but what we need is the cellulosic input.

[16:09] So, what's this 21 billion gallons of advanced bio fuels, this is the chart that are the goals.

[16:18] So this 21 billion gallons here is made up of some other fuels but this yellow is all the cellulosic fuels.

[16:27] Now this is drawn in as a steady progress, but with regard to the technology breakthrough that we needed, it's not quite appropriate.

[16:39] I would expect more of step function where there would be small advances early on, so major breakthroughs which would increase it and then maybe some more breakthroughs.

[16:52] That's more the way science in the developing stage works.

[16:58] When something is developed, then there are always small adjustment that make product more efficient.

[17:04] So this was established in 2008 were already 2020 which doesn't have very much cellulosic ethanol that's the case

[17:13] There are a few plants, there are not very efficient, there are certainly not ones that will solve the problem for future.

[17:20] Because of big breakthroughs have not yet then made.

[17:26] So this is the U.S. Petroleum flow in million barrels per day, so crude oil production, and the crude oil imports.

[17:36] So, Big issue in the U.S., I'm sure also in Korea, is that one imports a large amount of oil, rather than produces locally.

[17:47] We probably produces more locally.

[17:49] Does Korea produce any oil at all?

[17:53] So all imported?

[17:59] But then this is what is energy independence issues is not depend on the external supply of crude oil.

18:11] And then as you move this direction you can see the various uses.

[18:17] So this is the industrial use but you can see the huge amount goes to the transportational fuel, very little for electric power, for homes or commercial uses.

[18:27] It's this number.

[18:18] It's a big number, 142 billion gallons of gasoline per year.

[18:34] So, as I said then, 22% of that should become ethanol.

[18:48] Ok so we're now at 142 billion gallons per year, the projection is that… and this is millions of barrels of oil per day.

[19:03] So this is conservation efficiency and smart growth.

[19:08] So that this amount of demand can be taken care of by more efficiency smart growth.

[19:17] And certainly many corporations whether they are users or producers are developing other technologies are working on this aspect.

[19:32] Then, the gasoline use, the imported gasoline use will go down and bio fuels with make up 107 billion gallons per year which compares to this 36 billion gallon per year target for 2022.

[19:58] So to do that, how much biomass is needed?

[20:03] So for corn grain, the conversion factor is 0.39 L/kg of grain, and to make 1 gallon of ethanol you need 9.6kg of corn, of the seed.

[20:17] For cellulosic biomass, this amount of biomass and that amount of straw.

[20:26] That's the conversion factor.

[20:29] So at today's needs when this was 2009 so 9.0 billion gallon of ethanol means that is 3.5 billion bushels of corn.

[20:40] Tomorrow's needs is 15 billion gallon and 5.8 billion bushels.

[20:45] Future needs 2050, 107 billion gallon from the last slide and 42 billion bushels.

[20:52] And made U.S. corn crop in 2007 was 13 billion bushels of corn.

[21:03] So that yield is not nearly sufficient to achieve those liquid fuel goals.

[21:13] Ok, so that's points those out.

[21:19] Now, this is from cellulosic biomass.

[21:24] So today's needs [?21:25] <u>we're at, we're</u> producing none, basically none.

[21:29] Tomorrow's needs which would be 2022 this 21 billion gallon like I talk about before will be 205 million metric ton of biomass and by 2050 92 billion gallon meaning 9 million metric ton.

[21:50] So what are the sources?

[21:52] So the existing amount in forest products that are not used for about 109 million metric tons.

[22:03] Municipal solid waste about another hundred million.

[22:09] Corn Stover, meaning the corn stocks that are leftover, using 55% of the corn stocks, 39% of corn the stocks, or 13% of the stocks would give you this amount of metric ton.

[22:30] So nobody is arguing that all of the Corn Stover should be taken off the field because that would move all of the carbon and the soil would become depleted of organic matter.

[22:44] Studies that had been under way show that actually normally around leaving 40% will maintain soil fertility.

[22:56] So harvesting 60% leaving 40%.

[23:02] So that's 254 million metric ton leaving 650 million metric ton yet to be grown.

[23:18] Ok. so I pointed out those numbers.

[23:22] Ok, so that's an overview of the picture in whether you can do that.

[23:29] Now remember the conversion of sunlight to biomass through these plants is not very efficient as consider to be around in the normal good fertility situation, 1%.

[23:41] Maybe in some cases like miscanthus of little higher than that.

[23:47] So that can also be improved.

[23:51] Okay, so this is the normal production process.

[23:57] Sugar cane for ethanol has been used for some time.

[24:03] Probably 30 years ago, Brazil began producing ethanol for transportation fuel from sugar cane.

[24:09] And I'd been to major, um, sugar cane farms in Brazil and they are quite efficient in doing that.

[24:19] They have the advantage is that they can produce either sugar for the market or ethanol depending on the price that weak.

[24:29] They can just shift the process stream to either granola sugar or ethanol depending upon the price.

[24:39] So that's allowed them to have a pretty efficient system over time because they have two products that they can easily adapt to.

[24:26] But sugar can be directly fermented by yeast and so they have to do know pre-processing.

[24:56] So that is well developed.

[24:59] But then if we go to corn kernels, we now have starch, not sugar.

[25:06] So we have to convert the starch to sugar and we can do that by cooking your enzymatic digestion.

[25:14] And those are the plants that are currently in operation especially in mid west U.S.

[25:19] So this is the process under way now, this is corn process.

[25:24] What does it need is that is the cellulose process.

[25:29] So using the corn stover, which means the corn stocks, other grasses, MSW, forest residues, Ag residues, wood chips, any other biomass, anything stored in the carbon-carbon bond.

[25:44] Can that be treated to release the cellulose so that it can be hydrolyzed to sugars and then fermented and produce ethanol.

[25:59] So that's the overall scheme.

[26:06] Now I will say here, that one of, that's apparent here is that there can be other co-products that come out of this process.

[26:19] This is now recognized to be important for the economic viability that the co products are quite important.

[26:31] So not thinking of only ethanol, but other co products that may be higher value.

[26:38] And also there's more interested butanol, not just ethanol.

[26:44] Because butanol is a higher energy caring product, also produced by microbes.

[26:51] So what are the crops?

[26:52] This is one company that is in this business of producing crops, so sweet corn or sweet sorghum, high biomass sorghum, switchgrass, and miscanthus.

[27:07] Those are the four crops that are most discussed in the U.S. because primarily of their high productivity.

[27:19] The first thing you have to have is the high biomass yield.

[27:23] That's where fourth products are secondary, fourth products cannot compete in terms of an annual yield to these grasses.

[27:38] Secondary is the fourth products, so waste product, of course, can be used.

[27:41] So this sorghums have the advantage in that their water usages in low.

[27:53] And one thing I will point out is water is one of the major limiting factors, one of the major determining factors of yield.

[28:00] So anything that is more efficient in use of water is advantageous in the long run, long term.

[28:10] Switchgrass has been the popular plant for a long period of time.

[28:17] It's a summer producing grass so it grows well in the summer.

[28:24] There are native [?28:26]콜도발즈 that are present throughout the eastern U.S.

[28:31] So it's well adapted to the U.S., it's not invasive.

[28:36] And it can be produced from seed, and thus quite easily established.

[28:45] Miscanthus has been the popular product, because it's biomass yields are very high.

[28:56] This is the wild relative of sugar cane that comes from the southeast Asia.

[29:00] So it's not at all native to the U.S.

[29:04] It has been grown before, in botanical gardens as an ornamental.

[29:09] U.S. has this experience with it.

[29:15] It can now only be propagated by root pieces and that's very expensive.

[29:22] So companies now are trying to develop lines that can be produced from the seeds.

[29:30] But then there's a considerable worry that if seeds spread, it will become a major invasive problem.

[29:37] And our center has chose not to work with the companies that are working with the seed because it looks like a disaster waiting to happen.

[29:48] Because this is a very aggressive plant, and once it's established, it's extremely difficult to control.

[29:57] But it's the highest biomass producer.

[30:05] Okay, so this is an evaluation, a unit for energy, 20 percent of the world energy use, 16 quads of cellulosic crop residues.

[30:30] 200 to 1000 million acres would give 64 additional quads at modest biomass yields, where 3,400 million acres of world pasture.

[30:39] So this is trying to evaluate it on a more global scale, or before I gave it for the U.S.

[30:48] And it costs no more than two times current oil production.

[30:54] Sugar cane ethanol is now lower than gasoline on equal energy basis, but mature cellulosic ethanol is under 2 dollars per gallon gasoline energy basis.

[31:10] So actually the gasoline price this year, I don't know what they've done in Korea this year compared to 2 years ago.

[31:16] Is gasoline higher now than 2years ago? Much higher?

[31:20] How much? What percent?

[31:27] 50 percent more?

[31:31] Not that much?

[31:33] Less than that.

[31:36] So in the U.S., it's probably 25 percent higher, but that changes dramatically the targets for cellulosic ethanol conversion makes much more economically feasible as the gasoline price goes up.

[31:55] And this is the energy return on energy investment, today it's 12.

[32:02] It could be recently 30 in the near term and the ultimate potential 100 to 1.

[32:08] That is comparable to old oil.

[32:15] This is the learning curve, which means what you learn from continued development of the product.

[32:25] So this is what happened in Brazil.

[32:28] Those I said Brazil has been producing ethanol for some period of time.

[32:34] So this is 1980, down to 2002, and this is the U.S dollars per Giga jules of ethanol produced and this is the accumulated ethanol production.

[32:48] So the ethanol production went up, technology got better, and the cost for the amount of energy went down.

[32:59] This is the same for gasoline at the global market meaning Rotterdam.

[33:06] So when would expect?

[33:10] The same took curve with cellulosic ethanol.

[33:17] Okay, now on sustainability side.

[33:24] Can energy crops actually be carbon negative?

[33:29] So the above-ground harvested biomass is carbon neutral.

[33:36] Below-ground un-harvested root biomass creates soil organic carbon and may be considered carbon negative.

[33:41] So certainly the root biomass carbon would remain, and as I said before, the current estimates are leaving about 40 percent of this top carbon will maintain the productivity of the soil, harvesting only 60 percent, for example, with the corn example.

[34:07] The other issue is, especially nitrogen.

[34:16] Nitrogen is one of the major crossed items, and of course there are crops that fix their own nitrogen.

[34:20] This is Alfalfa growing in my home state, Ohio.

[34:22] So nitrogen fixation is by the plant, is an important goal.

[34:30] Another important goal and that is very true of switchgrass and miscanthus.

[34:37] It is maintaining those nutrients in the plant over the winter.

[34:45] So one of the features of the biomass products that is important is perenniality.

[34:52] So corn is not a perennial, it’s annual.

[34:58] But its production is highly developed.

[35:05] But it can never compete with a perennial.

[35:07] So that's the advantage of miscanthus and switchgrass.

[35:11] What I mean here is that …

[35:22] So with these perennial plants that remain that over winter is that when they [?35:29]쓰네스 in the fall, they move their nitrogen and phosphorous to the roots.

[35:39] And when you have a left up here is only a carbon-carbon bond, principally.

[35:46] So that's what you want because then you are reusing your nitrogen and phosphorous each year for the production.

[35:55] And you are not having to add additional nitrogen and phosphorous.

[36:00] That's lowing the cost, lowing the environmental impact, and making it more sustainable.

[36:09] Now this isn't going to be an 100 percent efficient, but it's pretty efficient.

[36:15] You have to probably add some.

[36:18] But it also means that you don't harvest this plant at maximum biomass.

[36:24] Because if you harvest this at maximum biomass, then you are taking off the nitrogen and phosphorous as well.

[36:32] So contrary to traditional agricultural production, you don't harvest it a t maximum yield.

[36:39] You harvest it at maximum carbon-carbon versus nitrogen and phosphorous.

[36:51] Okay, so here are energy return estimates for energy invested at various scenarios.

[37:01] So this is the yield for today, this is what is possible, and this is what is the potential.

[37:11] The fertilizer needed, the fuel.

[37:17] This is what the cellulosic ethanol.

[37:19] This is what poor technology today, and this is what should be feasible and what would be potentially feasible in the long term.

[37:27] So you can see the from the agricultural production part, the percentage return on investment goes way up over time.

[37:40] This would be the entire system meaning the whole life cycle analysis.

[37:49] This would be the surplus energy in Giga Jules per ha, this would be the land required in millions of ha.

[38:00] So these many things look promising.

[38:07] Okay, uh, so I talked about this before.

[38:14] So some additional estimates here, for liquid fuel and CO2.

[38:19] So what is the two big things?

[38:23] Liquid fuel output versus input and the gigatons of carbon sequestered.

[38:31] So today, what seems feasible and later potential, today that's feasible and long term potential.

[38:42] This is the annual CO2 reduction in gigatons.

[38:53] So these kinds of pieces of information make the source of energy look very attractive, the only thing needed is science to achieve those goals.

[39:09] So how much land is required for this 650 million metric tons of biomass?

[39:18] And switchgrass today at 7 million metric tons per hector and 86 million ha.

[39:32] So to compare that one point seven million hector in cropland, so this is what would be available.

[39:39] So now hundred and seventy eight million hector in cropland, 240 million hector in range and grasslands, and 15 million hector in CRP.

[39:52] That's dense for conservation reserve program.

[39:56] The government pays farmers to keep some land out of production.

[40:01] But they have to sign up for a long period of time, the contract for ten years that you will do nothing, you will produce a product on that land.

[40:09] Usage of that land is not very productive and so that's why it's considered to conservation reserve.

[40:16] But, one can break that contract and put it into production and you could put it into bio fuels.

[40:23] So this is a U.S. region for the enrollment is in the CRP.

[40:30] So the highly productive area is a northern Iowa, northern Illinois have very little CRP because it's worth more to produce the crop.

[40:41] But you go into this drier area is here the north, these drier areas here, the hillier area in southern Iowa, then there's more in CRP.

[40:52] But the point is that there is a land available.

[41:00] Now, so what about the sustainability issues of this biomass products?

[41:05] So the components are, it is got to be economically profitable.

[41:13] What are the environmental impacts?

[41:15] Can it be carbon negative?

[41:18] What about its nutrient, water conservation, what about it's about biodiversity benefits?

[41:22] And what are the social impacts?

[41:27] For example, rural community health meaning does it help to sustain rural communities and how does it contribute to food energy security.

[41:39] So one of the research activities of this center stands for the Great Legs Bioenergy Research Center(GLBRC).

[41:49] That's what [?41:51] interested Wisconsin, Michigan state center.

[41:52] And one of the four research areas is sustainability.

[41:56] It's the only center that has this sustainability component and it has these research components.

[42:05] Cropping systems, what are the appropriate cropping systems?

[42:11] What are the system's responses, the biogeochemical services including the hydrology, the biodiversity services, the economic services?

[42:25] How can this information be put together so that one can marvel it over a larger area incorporating all of these components, along with the economic life-cycle analysis.

[42:41] And then that can lead to how one designs a system that is more optimum.

[42:49] So the outcome is optimal configuration of the services.

[42:55] So the cropping systems follow this trajectory.

[43:03] So this is a low diversity meaning low plant biodiversity, high input.

[43:11] That's the typical production in U.S Midwest.

[43:14] High inputs meaning large amounts of fertilizer, high valued seed, use of insecticides, appropriate tillage, those kinds of things.

[43:31] All the way up to low diversity in input, which there's not input.

[43:36] Basically the original restored prairie of the U.S mid west.

[43:40] And then in between, some rotations, miscanthus, switchgrass, native grass poplar trees, early successional.

[43:50] So each of these are evaluated in this area in a randomized design.

[43:57] So they can all be compared side by side for not only their yield but their other environmental components.

[44:11] Now this study has five experimental spatial scales.

[44:14] So this one is what I just talked about is called the intensive field plots.

[44:20] Meaning they are studied intensively , they are side by side 8 cropping systems, 5 replicated blocks, they are established in 2008 in their 2 locations, in Michigan and Wisconsin.

[44:35] So Michigan is a…has less fertile soils, more sandy; Wisconsin is more representative of the major west, more fertile soil.

[44:47] So it represents the two conditions of the upper mid west.

[44:53] And they are scale-up fields in Michigan meaning larger areas such as these areas here.

[45:02] And one of the purposes of these is gas flux measurement.

[45:05] And I will show you in a moment that gas flux towers that are put in those fields so that they need a larger area to integrate the gas flux because of air movement over that area.

[45:19] And those have only three crops, corn, switchgrass, and the native vegetation.

[45:30] So the third experimental scale is extensive field sites.

[45:36] These are 30 matched sites of corn, switchgrass, and prairie both in Michigan and Wisconsin.

[45:43] And they are well established… sites, 5 to 15 years old.

[45:51] So they represent this area, Wisconsin and this area of Michigan and representing the soil conditions of those regions.

[46:01] So, in Michigan, the soil conditions in this area, here are more heavy textured soils, clays, and it's more sandy as you go in to this direction.

[46:11] So that the information then can be used to represent a larger area.

[46:18] The fourth is regional intensive modeling areas called RIMAS, and they provide modeling context with existing social and biophysical attributes

[46:28] This is those sides in Wisconsin and this side in Michigan.

[46:33] And five that is regional modeling, which is for the entire north central region of the U.S.

[46:39] We are taking information from this smaller scales, and moving it up and then making a modeling producti ons for the entire region.

[46:55] So what does switchgrass look like?

[46:58] So this is what it looks like, on July 28th, so about this height and this is an area in a state managed, conservation area and that switchgrass is 20 years old.

[47:14] So it's perennial, unmanaged, and remaining productive.

[47:20] So the big advantage of this summer grasses as I mentioned is they fix carbon in the summer; many of the grasses are cool season grasses.

[47:30] So they go dormant in the summer.

[47:31] They are not productive [?47:35] even the cents where these summer grasses, the native summer grasses are [?47:40] what of necessary.

[47:41] They return nutrients to the roots in the fall, this point that I made here and they are native cultivars to most of the U.S. ranging from the, actually to north America ranging from Canada down to the gulf of Mexico.

[48:01] They are not native in the far west of the U.S. But that far west has not enough water anyway.

[48:07] Now miscanthus which I mentioned is very aggressive sugarcane relative.

[48:18] This is a root mass after all the one year production.

[48:20] And so after several years of production the soil just becomes of massive roots.

[48:26] That's why I concern of it being invasive from the seed to variety.

[48:30] But a group of Illinois who started working on this first published in 2008 in Global Change Biology, I mean 30 metric ton per hector a maximum of 60 metric per hector for 1 point 2 percent solar energy conversion.

[48:52] And they say 9 point 3 percent of the U.S. arable land would offset 20 percent of the U.S. gasoline use.

[49:02] If the cellulose could be converted to ethanol.

[49:06] So that kind of yield shows that this can be this large yields can be productive.

[49:17] Now with these studies, because this is sustainability study, and the overall environmental affect becomes important.

[49:25] A lot of work is done with the gas sampling.

[49:30] So these are gas flux samplers set out on the field.

[49:32] The lid closes every [?49:35] subopen and the accumulation of gases like CO2, methane, nitrous oxide are measured and then is opened up again.

[49:46] So that's how the gas flux is measured at this scale.

[49:53] A lot of effort goes in to measuring water, the water balance.

[50:00] So these are the 2 methods that are used TDR and electrical resistivity imaging with crops and the soil environment.

[50:11] So the water balance I mean which of this, each of this 8 crops can be measured.

[50:20] And at this research plot, this is the control center, which manages all the instruments on the field, collects all the data and sends the data then to the laboratory.

[50:36] Now I mentioned this larger scale of flux for gas flux measurement.

[50:45] And these of the gas flux tower here that are put in this larger areas, so they measure carbon dioxide and water flux energy balance and I think now they also have nitrous oxide sensors.

[50:58] So they measure a vertical radiant and they also measure lateral movement.

[51:04] So with that information they can calculate the budget of these components coming of this larger area.

[51:15] On a continuous basis, okay, so what do we know about bio-fuels sustainability?

[51:29] Okay so with green-based fuel, the current production of ethanol comes with environmental costs that are not different from conventional food crops because it's the same system.

[51:42] And the farmer doesn't know whether his grain is going into ethanol or to food because when he sells it, it can go either place depending on where the buyer sends it.

[51:55] So there is not much effect on climate stabilization but there would be predicted to be greater intensification of existing farm-scapes because of new crop.

[52:15] So landscapes that are now used in true production like CRP or more marginal would then be so there will be more erosion or nitrate phosphorus loss or pesticide loading or biodiversity loss.

[52:26] This is the, the U.S. corn and soybean acreage up to 2006.

[52:34] And you can see it begin to divert at this point, so it went down and corn would up because valued corn went up because of ethanol.

[52:44] In the last year corn reached a price of almost 750 of bushel which is a third higher to they have ever been in history.

[52:56] So this year, farmers are planning more corn because they made so much last year, do it again!

[53:45] And soybean production is going down but now the soybean price is going up.

[53:13] So when can expect this kind of shift of course, depending on the market, now okay, what do we know about bio fuels sustainability?

[53:26] So the best performance practices can mitigate many effects.

[53:36] So more complex rotations provide landscape diversity.

[53:40] So instead of continuous corn, you can have other products with rotations for landscape diversity can have cover crops.

[53:35] And I mentioned dual cropping already at the attentive slides for shifting from the rotation to a dual crop to plant a cold season crop in the spring, and then warm season crop after that.

[54:09] And we can get 2 metric tons more yield plus maintain more nitrogen in the soil

[54:16] Conservation tillage meaning not conventional plowing of soil, and then I might hope to say that Iowa nobody plows soil anymore.

[54:27] Anyway because it's because the productivity is actually higher not flowering with the new seeds with the new technology and you don’t spend gasoline plowing a soil.

[54:38] Better fertilizer technology and good biocontrol practices.

[54:50] And so cellulosic crops would provide major contrast, perennial herbaceous and woody crops, landscape diversity, no carbon debt in ecosystem services meaning biodiversity, biogeochemical services.

[55:06] So over this perennial landscape of switch grass for example, the water would be cleaner biodiversity of number of species would be higher nutrients would be maintained locally.

[55:30] Now I said that water is big issue in terms of what field would be.

[55:40] So these are the amounts of ethanol produced per amount of water used, used from various studies and if we take that example to Michigan, my home state, so this would be the soil water holding capacity.

[56:00] This is the amount of water that would be held in Michigan soli which is somewhat sandy, so 36 inches of soil and that water holding capacity would be 6 inched of available soil water.

[56:13] The average rainfall of region is 15 inches, so 15+6 the total available water is 21 inches.

[56:25] And the yield of miscanthus at 21 inches of water is 19~23 dried tons per hector, the ethanol yield would be 8 ~9 grams of ethanol per kilogram of water from miscanthus.

[56:45] Switchgrass is less as you can see down here, so water will limit yields but 8 ton per acre is reasonable.

[57:00] So in the U.S. as one goes west, west of Iowa for example, where it gets drier or south of Iowa also it get drier and so the yield would be less.

[57:14] Then south of Iowa then, is where sorghum becomes an important biomass crop because it is more efficient in dry conditions.

[57:27] Okay now I talked about these five scales, of experimental study and the modeling information so this is the framework from modeling.

[57:37] So in this direction it's scale, so from a site to a landscape to region to nation and global and in this direction is different kinds of model.

[57:51] So the EPIC model is an existing biophysical model, APEX is a watershed biophysical model, there are economic models life cycle analysis model, and so the modeling group there goal is to integrate this [?58:09]information over kinds of information and scales.

[58:14] So that one can evaluate different scenarios at different scales and then hopefully those would be to some policy implications.

[58:37] Okay, now, so there is no cellulose ethanol plant in Michigan, there is one in northwest Iowa but as I have said it’s not very efficient, not very efficient technology but there is one.

[58:54] So how can we gain some information of the aspects of biomass?

[58:49] So one thing that is being done is this is switchgrass that is grown and stored for the winter combustion so not converting of ethanol but simply using it for combustion.

[59:11] Because then one can evaluate other things about productivity, harvest, storage, transportation, BT used produce.

[59:24] So this is what was done for these past years and yeah.

[59:40] So this is this large bails of switch grass stored until the winter and this is then being taken to a power plant and here they mix this kind of material with other tree and material.

[60:04] For example so you see branches and so forth from other solid waste because mixing it together like this gives a good product for those kinds of burners for combustion.

[60:17] Then one can evaluate the [?60:21] BT used produced and the overall cost with that.

[60:25] Of course that's not cellulous to liquid fuel but it gives some experience with producing fuels from this report, from this type of new product.

[60:43] So this is from the national research council which often does studies and provides government advice on technical issues and so this is about the major science gaps for bio fuel productions which was done maybe four years ago.

[61:02] So it said that there are few direct comparisons of how alternative bio fuel crops and native ecosystems compare with intensive annual monocultures in terms of water use, nutrient leaching, need for fertilization under harvest regimes.

[61:20] Also then the global warming potential and climate change and water scarcity issue.

[61:28] So all of these kinds of things are what being evaluated in this particular sustainability study.

[61:35] So the water uses is very extensively measured nutrient leaching is major different of harvest regimes, the global warming potential, by the carbon balance that gas fluxes and water scarcity also.

[61:57] Now what about other area of the world?

[62:01] There was a report in 2007 out of French.

[62:06] They ,of course, high energy consumers now and projected into the future.

[62:14] All of that have launched bio fuel programs, but water scarcity is the limitation and I was just at a it was at a conference last fall in Harbin in China.

[62:24] On water, because that whole north east region of China is water short, and one of the Chinese water expert said that their average water availability is only one quarter of the world's mean water per capita.

[62:45] So they are water deficient country.

[62:48] Furthermore, their distribution is very problematic, very wet in the southeast, and drier to very dry in other areas.

[63:05] So in China, the water issue has to be a major one, that they consider in dealing with bio fuel production.

[63:22] Bio fuels could provide impetus for large-scale water transfer schemes of course that's what would be suggested if you don’t have appropriate water distribution, and you want to capture sunlight.

[63:41] This year [?63:42]pien report also had some other key findings.

[63:44] They feel that it's a basically a model scenario for environmentally compatible bio fuel production.

[63:56] Sustainability is the key for this, seeks no additional environmental stress, in the conclusion is good potential even under their strict environmental constraints in Europe.

[64:09] So Europe is high on bio fuel production because of its environmental benefit.

[64:20] It also says that their number of environmental synergies, maintaining landscape diversity, less farmland abandonment, open areas for wildlife, reduction in fuel for wildfires and nitrogen removal from eutrophied forests.

[64:39] And of course Europe has a big problem with the forest decline because of excessive nitrogen from combustion.

[64:45] So summary points.

[64:54] So energy sources will likely be diversified?

[64:56] We need all of them that are economically feasible and safe so petroleum, coal, wind, solar, bio, nuclear, too many unknowns including discoveries to project any to dominate.

[65:15] I actually don’t think it will dominate I think that they were all at some level under some conditions be useful for the affective and I was just talking about last week to Japanese about the situation in Japan after the nuclear incident.

[65:37] And they said all of their nuclear plants were shut down now.

[65:44] At least in the short term, to evaluate their safety, and maybe in the long term, based on the political position of a public but that's 30 percent of their energy production that has been shut down.

[66:01] Now made up by imported natural gas, but of course that's not probably sustainable situation either, but price of that will go up and of course that contributes to see a two production of the nuclear plant did not.

[66:22] I actually personally think that nuclear is an important source of energy and I do think that it can be managed appropriately and safely any of the technology has some potential disadvantages.

[66:42] Then we should move out from nuclear.

[66:50]The issues are solar energy conversion efficiency, then I will talk about storage and transportation cost.

[66:57] Among these they all have their advantages and disadvantages in all have their opportunities, for improvement, something engineer is like to do, make improvements.

[67:13] Transportation fuel will likely remain liquid with slow conversion to electric for the automobile but air and ocean requires to be liquid.

[67:27] [?67:27]Brusteil who is a chemical engineer who does a lot of works in this area makes a point that he thinks that there is no other option.

[67:38] At least for the U.S. then have biomass for liquid fuels because he thinks that liquid fuels supply from other sources just as not there.

[67:51] He thinks that oil, sands and shale, won't have the way to production be too closely too energy damaging, never make it.

[68:03] And he thinks that Saudi Arabia for example, politically one thing they do to keep the citizens happy is maintaining low cost of their fuel.

[68:16] At the current rate of their growth in use of that fuel, they will not exporting beyond 2015.

[68:25] At last, they raised the price which then causes political problem.

[68:36] So where is the liquid fuel going to come from?

[68:35] In his point is biomass is the only choice that it has to be developed.

[68:43] Cellulose biomass to ethanol or butanol or some other products, because now, some of the jet-fuel products can also be produced by microbes will likely succeed to some level, and grown on non-food producing lands.

[69:02] I think that the U.S., the only thing it's talked about now is what is called marginal lands, not those lands which are very effective at food production.

[69:17] Water availability and nutrient supply will be the factors that limit production.

[69:26] And of course climate change has an impact on that in changing the especially the distribution and frequency of water.

[69:34] Drop in fuels and co-products will gain traction and be important economic viability of bio fuels.

[69:42] I will talk in the next hour more about some drop in fuels.

[69:50] Sustainability and its ecosystem services will be a key part of the bio fuel economy meaning the benefits from it.

[69:57] So that's what I have to say about to sustainability and bio fuel production.

[70:05] And if there are any comments, questions or discussion why don't we spend on few minutes on that now, and then we will take a break.

[70:28] So any bio fuel production in Korea?

[70:33] Probably not on whole land of area available for that.

[70:35] Maybe forest products but probably productive land will be for food production, is that right?

[70:58] So do you think the U.S. will make it by 2022 have 20 percent to 22 percent of its fuel from cellulose to ethanol and corn ethanol also?

[71:20] So I will talk more about scientific things in the next hour but I think I kind of deal with like the in the late 1980s that raise to put man on the moon that you could see how it could be done.

[71:45] You just needed to develop the particular components to make it work.

[71:50] So here, I think you can see all the steps to make it happen.

[71:54] You just needs to be worked out and optimized.

[71:59] But I think it will take longer actually then 10 more years.

[72:10] Okay. Let's take a break for 5 minutes.