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Conference Report

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The Moral Basis of Sustainability Science

Michael M. Crow

Welcome, everyone, to Arizona and to ASU. I thought I would begin your morning by offering you a fair amount of indigestion. So let me determine how I'm going to activate your digestive system. I'm first going to talk a bit about sustainability as a science and I'm going to try to compare it to other sciences and you're going to get a lot of indigestion, or at least some of you will.

At this institution, and I'm sure at others, some time ago we began the process of changing the evil ways of the past. And the evil ways of the past for universities were that we would do research and we would teach students and we would do science and hopefully somebody would do something with that. Hopefully it would have some kind of impact. Hopefully the world would be a better place, but this was not something that we took direct responsibility for. Somebody else would take responsibility for that and somebody else would advance all of that. So, we decided that it was probably a moment in time when we should alter our knowledge trajectory such that sustainability for our institution would become something that I would refer to as a 'value.' Imagine a university that had a value other than valuing knowledge. The value of knowledge in and of itself is insufficient to solve the issues that are associated with sustainability as an outcome. So let me walk you through that and perhaps create a bit of indigestion.

So, how many of you think of yourself as scientists? Come on! Most of you, right? You think analytically. You set up hypotheses. You test these hypotheses. You evaluate things. You approach things from the development of theoretical understandings. You test your theories. Your theories either work or they don't work. If they don't work, you advance a new theory, or you hold onto your old one far too long and take it with you, arguing with everyone else that you're right and then eventually you go away and they move on.

So, most of us are scientists. We live in a scientifically driven culture in many ways—and I'm not talking about the broader culture. There are a few more problems in the broader culture relative to science: they don't believe it. Within the academic culture or academic institutions or knowledge enterprises, the scientific approach is a basic way to move forward. Now, science by itself and, in particular, natural science, which is the unraveling of nature through the scientific method to reduce it down to its basic fundamental principles and our basic fundamental understanding, is amoral.

I only speak English and can't translate the subtleties of the language that I'm about to use. So let me apologize ahead of time. There's a huge difference between 'immoral' and 'amoral,' a very subtle difference in the English language. Amoral can be defined as without external value. It contains a morality or a moral basis within the construct itself but with no connectivity to value-laden morals outside of the construct of science. It’s a complicated concept. Stay with me while I work through this. As you know, I can split the atom. If I can split the atom, that’s an amoral act. And then a moral, less or more, government can use that knowledge for immoral purposes. So I’m making subtle distinctions here. But science in the way we carry it out in universities, natural science in particular, is amoral. It is without value. I don’t mean value as in monetary value. I mean values, as in it has no specific objective other than itself. So science can be a self-contained box advancing insight and perspective relative to natural systems for the benefit of the box, the expansion of the box, the depth of the box, the understanding of the box, the beauty of the box. You’ll hear scientists talk about the elegance of our understanding within the box. It’s self-contained.

Sustainability as objective of science is not inside the box. Sustainability is a value. It is a selected outcome. It is moral. It has a moral basis. It has to do with the relationship among and between humans. It has to do with the relationship between the environment that we build and the natural system of the earth. It has a moral basis. I won’t take the time to walk through its moral basis. And I won’t tie that moral basis to any particular moral foundation other than to suggest that it is a value-laden objective: sustainability. Science by itself, natural science, does not produce sustainable outcomes. If I look at the outcomes of natural science in an amoral context, I would say right now that its outcomes relative to sustainability are slightly ahead of even: lots of positives that we’ve derived from science, lots of negatives that we’ve derived from science. Science itself doesn’t care. There are individuals that care but science itself doesn’t care.

Now, there are other kinds of sciences. Often ridiculed by ‘science.’ Often undermined by science and natural science, attacked by natural science, thought of as lesser by natural science. These are sciences called design sciences, where you’re using scientific methods, and scientific techniques, and scientific approaches, but you’re not attempting to understand, in an amoral way, how nature works. You actually are attempting to build something, to do something. I’m not talking about engineering although engineering is in broad concept a design science. I am talking about a differentiated form of science that actually has a moral foundation. If sustainability is an outcome that we are all working toward and it has a moral basis, and we’re carrying out a scientific agenda to advance toward that particular outcome, then what we think of as the curiosity-only driven, amoral, scientific basis of understanding nature is an important aspect of our body of knowledge or understanding, but it’s not what we’re doing. Sustainability scientists are actually doing science to produce an outcome. And in the case of sustainability science, they’re linking what we think of as natural science with social science, with physical science, with behavioral science, and a range of other areas attempting to derive a particular value-laden no longer amoral but now moral outcome.

Now, here comes the dilemma. If we are advancing in an institution, the university, which is founded on the fundamental principles of science in its present form, which it is, and if that is in fact an amoral thing, which it is: how do you advance in the same institution or the same construct, value-oriented, morally based design sciences? Well, not very easily as you can see.

Medicine is a design science, but the value is simpler than sustainability. Human health outcomes are the objective. Science doesn't care whether you live or die. Science doesn't care if something in your body works or doesn't work. It just doesn't work or it works, and scientists can explain to you why. Medicine, however, is different. It has an objective to keep you alive. Doctors have an oath. So the scientists who are called doctors have an oath that they take to pursue a moral objective, even to their own peril. Now, that area of design science, medicine, has evolved over the last few thousand years and particularly over the last 300 years. In the world that they evolved, how many medical schools are intimately engaged in and embedded within the science departments of the universities? How many chemistry departments are the homes of medical schools? How many biology departments are the homes of medical schools? Well, none. They had to build a separate world, a separate environment, a separate box, a separate place, a separate hierarchy, separate logic, separate oaths, separate methodology, separate cultures.

Sustainability science has the same challenge in a different era, a different point in time. *Sustainability Science*, Volume 7, Supplement 1, February 2012[1]—that tells me one thing: ain't been around for very long. This is a moral objective and it needs a construct within the institutions in which it evolves that can protect and sustain that. And it needs groups of individuals such as yourselves committed to facing this challenge.

I can't begin to tell you how many times I've heard the following sort of arguments: those ecologists—how many of you are ecologists or came up through an ecology background? Little do you know, biogeochemists think that you're all idiots; that, you can't actually do what you think you're trying to do because it's too mushy. What it really means to the biogeochemists—how many of you are biogeochemists?—what it means is that it's really too much for these guys to process. It's too complicated in the way that they approach it. The challenge is to find a way to advance and survive value-driven, morally-based, scientific undertakings with an objective. Sustainability is the objective; and, that, in fact, is the intellectual philosophical battle.

My daughter is working on her PhD in Geography at UCLA right now and she is looking at the South-North Water Transfer Project. It's a project that will take large amounts of water from southern China and move it to the north, up to Beijing and elsewhere. It is the largest, by a factor of 200, public works project ever undertaken. It will deliver one hundred times the water to northern China than is being delivered to Phoenix, just to give you some idea of the scale. Little did I know, until she told me just the other day, but one of the reasons that they have to

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[1] Dr. Crow made here reference to the recently published Special Issue of *Sustainability Science* on "Sustainability science: bridging the gap between science and society" (Volume 7, Supplement 1, February 2012). This Special Issue stems from and expands on the outcomes of the 2nd International Conference on Sustainability Science (ICSS 2010) that took place in Rome, Italy, June 23–25, 2010.

deliver the water is not just that there's a water shortage in northern China, given the number of people that are up there. It turns out that 80 percent of the water is uncleanable under any scenario, under any methodology, under any technology that exists for an economic price that anyone can afford to pay. So the water there is ruined. Not just dirty, but ruined. All that stuff in that water, where did it all come from? It came from the universities and the scientific labs that built the molecules, and all the heavy metals, and everything else that we use that get dumped in the water.

So, we are in a race. Can those that value sustainability as an objective put together a scientific underpinning and a scientific base quickly enough to outrace the amoral scientists who are just contributing to the knowledge that's allowing us to advance at will, but producing still at the moment a barely net positive outcome, but for which a net negative outcome might be possible? Let's say an 8-degree Celsius average temperature change on the planet in the next few hundred years or something like that—that could probably have some negative outcomes. And what did that come from? That came from no-value oriented science beating value oriented science for too long of a timeframe. So you are involved in critically important work advancing a morally based scientific undertaking. We're involved in that also. We're moving in the same race, and all I can do is wish you luck and say get at it, because we have got to get it done. Thank you.

Linking Knowledge to Action for a Transition to Sustainability

Pamela Matson

First of all, I'd like to thank the organizers for inviting me to participate in this meeting. I'm really looking forward to it because I can learn so much from all of the work that you've done and all the thinking that's going to go on at this meeting. I greatly appreciate that.

I was asked by the organizers to give a short vignette about my own research and my own cases studies. I am going to do that, but before I do, since we are talking about sustainability and linking knowledge and action for sustainability, I thought I'd start with my own definition of sustainability. I use the definition that was developed as part of the National Academy of Sciences work on sustainable development in the 1990s, published in the book "Our Common Journey" [US National Research Council, 1999. Our Common Journey. Washington, DC: National Academy Press]; it's the simple statement of a goal. Sustainability's goal is meeting the needs of people, our needs of energy and food and water and employment and education and so on, today and in the future, while at the same time sustaining the life support systems of the planet: our atmosphere and water systems, our climate system, and the species and ecosystems on land and in the ocean that provide so much of what we need and so much of what our future generations are going to need. It's a very simple statement, and there are huge opportunities in that goal.

As everyone here knows, it's also incredibly challenging. If we take it apart and look at the social issues, we see that's true. Around the world, some things have improved. Life spans are increasing. Infant mortality rates are in decline. More people have access to education and health care than ever before. And yet, there are billions of people who don't have their basic needs met. There are almost a billion people who go to bed hungry much of the time, and that's today, with our seven billion people. We are going to be adding a few more billion before our human population levels off in a century. So, we have challenges in terms of meeting the needs of people. At the same time, we have huge challenges on the life support system side. Again, I don't really need to tell this audience about this -- there are all kinds of global scale and local scale changes that are going to make it very challenging for future generations to meet their own needs.

Part of the problem has been that in our striving to meet the needs of people, we've also had a lot of negative consequences on the life support system. Our job for the future is to rethink how we do things so that we have a positive relationship between them. It's going to take major rethinking of our strategies for meeting the needs of people. As many of us would say, the job here is to meet needs while or perhaps by sustaining the life support systems of the planet: lots and lots of opportunities in that area. However, we don't know exactly what to do. We're all sort of grappling, trying different things on the ground and in the universities, exploring new ideas, looking for ways to meet needs and sustain life support systems at the same time, and we're going to have to learn by doing. We're making some mistakes. Hopefully we'll learn from those mistakes as well as the successes. So I like to think of this as a step-by-step process: we're in a transition to sustainability. It's not going to happen overnight, and we need to have a way of learning what works and what doesn't.

So what would a transition to sustainability take? It will obviously take new knowledge and tools and approaches, and many of the kinds that we in universities do work towards; but, really, and I think this is critical, it also will include making sure that we are linking that knowledge to action on the ground. That's going to be my focus today. Many other things are needed (for a transition to sustainability) that we in universities don't have special role in, which everyone on the planet has to engage in. But what I'm going to do is talk about the first two (referring to powerpoint – creating new knowledge and linking knowledge to action). Let me start really briefly with the first one: knowledge, tools and approaches. This is what we do right? This is what university academics really like to do, as President Crow said. We like to develop new ideas, new knowledge and tools. And thanks to this, we understand a whole lot about what's happening on the planet. That list of social woes and environmental woes that I started this talk with are thanks to the decades of research that we've been doing to understand what's going on.

Luckily, I think, recently there has been a call for a reorientation of our research, so that it's focused not just on understanding, but on helping to develop solutions that make sense for decision makers. We're focusing more and more on human-environment systems as coupled systems rather than some of us working over here on the social side and some over there on the biophysical side. These are really critical elements of what I think of as sustainability science: focus on solutions and focus on the coupled human environment system. We're beginning to see a lot of work come out in your Sustainability Science journal and the sustainability science section of the Proceedings of the National Academy of Sciences, which a number of us helped create. Again, we're talking now about research that isn't just about understanding – it's about solutions of challenges in coupled human environment systems.

There's an increasing call – if you look around the international community, and the EU, international programs in the US – for that kind of research. We recognize we need to mobilize the strengths of our universities and other research institutions to work on these issues. So all of that is good: that call for action, the "call to arms" for sustainability science, is really important because the bottom line is that though we have a lot of knowledge, it's not all relevant knowledge to decision-making; and, it's not evenly distributed across the challenges we have on the planet. But, I think even more importantly, and certainly in the context of this discussion it is really critical, is how we link that knowledge to action. Even the knowledge that we have right now often doesn't get used. It isn't in the form or shape that decision makers can use, and so it's not used to support decisions for sustainability.

[Insert Fig. 1 here!]

Here's the problem: a lot of us operate with this model in mind: the pipe model. We carry out our research. We think it's going to be really relevant to somebody. We publish it in a journal; and, there's the last paragraph in the journal that says "and therefore mangers should," and then we walk away. We think our new knowledge is going to come out on the other end of this pipe, that decision makers are going to pick it up and they're going to use it. But all too often, we've not got the question quite right. We're not addressing something that the decision makers really care about or need to know. Or, there's just one little piece of information missing and therefore the decision makers can't use it. Or, our concept of who the decision makers are is not realistic: there are different decision makers at the other end of the pipe. So the pipe model doesn't work, and there's a big gap in knowledge to action links because of that. So one of the things I've been very engaged in is asking "how can we most effectively link knowledge with decision-making for sustainability?" How can we take all this knowledge that we're creating now and actually make it useful and used?

In order to get at that question, we're doing research on it. We're asking: What works? What doesn't work? Why? Several groups that I've worked with have used a variety of case studies to begin to ask those questions. The Roundtable on Science and Technology for Sustainability (of the US National Academies) which I chaired for many years carried out work on this topic (which led to a production of a number of different documents like this one (picture shown), edited by Bill Clark). I've also been engaged, and lucky to be engaged, with an international group of scientists who have been funded by federal funds to actually figure out what works in knowledge systems that link knowledge with action. So I want to give you a little bit of the results from those case studies. The place that I've worked in Mexico (that I'm about to give you a little vignette about) was one of the case studies that helped us begin to understand what works and why.

This case study is based on research that I've done with a number of other people for about 20 years. It was started by me (by the way, I'm trained as a bio-geochemist and ecosystem ecologist), Roz Naylor who is an economist, and Ivan Ortiz Monasterio who is an agronomist who works for CIMMYT, the international maize and wheat research institute with its headquarters in Mexico. We began working in a place called the Yaqui Valley -- 250,000 hectares of irrigated wheat in the middle of the Sonoran desert, fed or watered by huge reservoirs. It's an interesting place for a couple of reasons. One is that it is located right on the Gulf of California. Some of you may know that for conservation organizations, both nationally and internationally, the Gulf of California is one of the world's biodiversity hotspots. Everybody is working there because they're trying to protect it. Here we have an agricultural region that is right on the Gulf of California. This is also a really interesting place because it's the birthplace of the Green Revolution. It's where Norman Borlaug and other researchers carried out the early research and trials that led to the development of improved, high-yielding varieties of wheat, which then spread throughout the developing world during the Green Revolution years: the 50s, 60s, 70s, and into the 80s. The valley itself is a focal point for Green Revolution technologies. It was purposefully developed to grow wheat. The farmers in the valley had access to all those new improved varieties, as well as all the fertilizer and irrigation, and everything else they needed to be successful. As you can see from that little graph there, the Yaqui Valley line has the highest yields of wheat. Farmers there have been very successful in increasing yields, thanks to those technologies. If you look at the place today, though, it has all kinds of sustainability challenges, a long list of them.

For example, they are overusing their water resources. They don't have sustainable water resource approaches or rules, so when they run into a severe drought, as they did in the late 90s and early 2,000s, they just simply put themselves out of business. They pumped their reservoirs dry because they didn't have, at that time, models for sustainable allocations of water resources. Second one on the list: agricultural systems are over fertilized. That's costing them a lot of money, making it very hard for them to make economic profits, and also having lots of environmental consequences.

Then there's a whole long list of other things. Shrimp aquaculture exploded unsustainably there. Increasing awareness of the vulnerability of their crops to climate change, drinking water and air pollution, and human health issues, and the list goes on. Our team, over the years, looked at many of these things. What we realized is that all of them interact with each other, or almost all of them do. They're all in some sense unintended consequences of those green revolution technologies that were focused, yes, on growing more food, but at any price. We've addressed many of them, but for my little vignette today, I'm going to just talk very quickly about one of the areas in which we worked. By the way, I should probably say here, one could say: "This place is a disaster. Let's just scrap agriculture as it is done today and start completely over. Obviously, it's not on a good trajectory." All of those things may be true, but if you're pragmatic, as we were about this, we wanted to move this area, this Green Revolution region, into sustainability thinking. So rather than trying to throw out what is one of the breadbaskets of Mexico, and a source of seeds and wheat around the world, we decided to work within it and see if we can shift what they're doing today.

[Insert Fig. 2 here!]

Fertilizer is incredibly overused. That's in part because it was heavily subsidized as part of the Green Revolution technologies. When they first started out in the 50s, very little fertilizer was applied. By 1981, they were applying plenty of fertilizer, enough to maximize the yields of the wheat they were growing then. You can see between '81 and '97 they continued to increase the application rates of fertilizer, even while yields did not increase. Based on our own knowledge of biogeochemistry and fertilizer, we'd say this is a big problem. That excess nitrogen has to go somewhere. So we studied it: we tracked it, tried to figure out where the fertilizer was going in these systems. In the process of doing this, I might mention, we made some really interesting discoveries about biogeochemistry. But what was really interesting was all the pathways of nitrogen losses: into the atmosphere in the form of air pollutants that affected downwind systems and in the form of nitrous oxide, a greenhouse gas; leaching of nitrate through soils into ground water or into surface water, with human health consequences; solution losses of ammonium with the tail water of irrigation. All of these things were happening in the system. Some of that nitrogen was then moving through surface and ground water systems out into the Gulf of California where it was causing huge phytoplankton blooms that swirled across the Gulf and landed in the protected marine systems on the other side. Some of the pollutants were going into the atmosphere, driving on-going air pollution events in the cities during parts of the year. Probably some of the nitrogen was being deposited downwind, affecting natural ecosystems there, although that wasn't something we were able to study. So there were regional scale impacts of the fertilizer decisions that farmers were making in their fields.

At the same time we were asking: "Why are they doing what they're doing?" Through surveys, interviews, and analysis of documents, we found that, until the mid-1990s, fertilizers were incredibly cheap. In the mid-90s, Mexico liberalized a whole bunch of their agricultural policies and fertilizer became expensive. By the late 90s, our analysis told us it was the most important cost in farm budgets. But that was a recent change and perhaps farmers hadn't caught up with the fact that the costs were so high. Farmers also said that they were adding most of their fertilizer well before they planted because of labor and machinery constraints (although a few farmers had overcome those constraints through machinery modifications).. They also talked about their concern for getting enough fertilizer on there early, to optimize yields should they have a really good year in terms of weather. And, they said that their experience suggests that it works.

At the same time, we were asking: "Okay, given these challenges, environmental and economic and logistical, are there some win-win opportunities here for the farmers with respect to fertilizer management?"

We carried out field experiments, and developed and ran agronomic and biogeochemical models and economic analyses, and found that yes, there are some really great win-win opportunities. If farmers would apply less fertilizer but time it more carefully to crop demand, they will be able to maintain yields, actually increase grain quality (the nitrogen content of grain), reduce all of those nutrient loss pathways tenfold or more, and save 12-to-18% of after tax profit. That's a win-win! So we published a paper on that in Nature, and we said, basically: "therefore farmers should…." But because our team cared about the people in this place, we also did our best to linking that knowledge to what farmers were actually doing on the ground. We did that through on-farm trials with many of the most innovative farmers in the valley, farmer workshops, discussions groups, and so forth. And we found that win-win options were working for those who tried it in their fields. So we basically said: "Okay we've done our job. We expect this is going to be spread throughout the valley because everybody is going to think it's a great idea." But then we made the "mistake" of going back a few years later and looking to see what was actually happening.

[Insert Fig. 3 here!]

What we found was that farmers were actually using more fertilizer, not less. Despite the win-win opportunity, and the economic benefits of using less, they were using more. So clearly, we didn't understand something. We were not being very effective linking knowledge and action here. So we stepped back and tried to understand exactly what was going on in the decision-making system in this valley. We studied the "knowledge system" -- the network of actors and organizations that were producing and integrating and using information and knowledge and knowhow in decision-making. This (powerpoint slide, upper left third) is the knowledge system we thought we had when we started -- our university working with really key individuals like Ivan Ortiz Monasterio in CYMMIT and also folks in the national extension groups, along with innovative farmers. We thought those were the really critical pieces of this knowledge system. But when we analyzed it carefully, we found it was a lot more complicated than we had supposed. There are many other players in this, including some should have been but were not linked into the decision-making framework. For example, the secretary of health and the secretary of natural resources were in the knowledge system but not influential players, despite the fact that there were all kinds of human health issues related to agriculture in this region.

The most critical players, we discovered, were the credit unions. These are farmer associations; farmers pay to belong to them. They are respected and trusted organizations. The credit unions provide credit for seeds and fertilizer and so forth. They provide access to markets. They provide advice. But in this case, their advice had strings attached. They were basically telling farmers, "apply a lot of fertilizer or we might not lend you credit. You won't get our help." So why were they doing that? Well, of course, there is economic incentive for a credit union to get its members to buy a lot of materials; but also, the unions were forced to focus on the fact that life is uncertain out there. There is a lot of variability from farm to farm, from soil to soil, farmer to farmer, year to year. So the credit union's advice was designed to get around uncertainty and variability: if everybody puts on as much as they can, everybody is going to do okay…that is, if you don't consider the environmental issues related with over-fertilization.

[Insert Fig. 4 here!]

So we recognized that we needed to change the way we were working here, if we wanted to see action on the ground. We needed to think more carefully about reducing that uncertainty. So we developed, in partnership with others, a hand-held remote sensing system -- a radiometer that could be used to tell farmers how much fertilizer their crop needed at any given time in a particular year on a particular soil, much more in tune with real-time decision -making. And one key here was that we worked with farmers and the credit unions to test this method and to spread its use. The credit unions were really important in scaling up, because they have many members. Their engagement meant that many, many more people were using the technology. It's actually working pretty well right now, spreading around this valley, and spreading into other parts of wheat growing areas, thanks especially to Ivan Ortiz Monasterio's work.

That story and many others are told in this book: Seeds of Sustainability. I won't tell the other stories, but instead want to step back and talk about what we learned from this case in comparison with many other cases developed via team research efforts in which I was involved. (By the way, Jim Buizer was one of the leaders of the case comparisons.) I should mention these were natural resource cases, agronomic cases, climate services cases, and they included also some medical and corporate ones. Among the things we learned from the case comparisons is that there are a number of very critical barriers that get in the way of linking knowledge with action on the ground. Three were most critical; they showed up in many, many of our cases. I want to talk about each one of these and give just an example from the Yaqui case.

The first is mutual miscomprehension between scientists and decision makers. Guess what: we don't always talk very well. We're from different cultures, with different concerns, and very often, we scientists are not asking the right questions from a decision-maker point-of-view. There is also distrust from the decision maker point-of-view. Are we really credible and legitimate? If we swoop in with ideas and walk away, should they trust us? The answer is probably not. So one of the things we realized is that we need to reject this pipeline model of knowledge to decision-making transfers. We need to promote multidirectional flow of information and communication so we actually understand each other. Many universities, like this one (Arizona State) and mine at Stanford University, are developing ways to do that -- ways to have on-going "uncommon" dialogues between decision makers and researchers. We need to promote collaborative production of information, and participatory research can be a part of that. Stakeholders really need to know that they can trust what is being developed, and if they are participants in it, they are more likely to feel so. If we go back to the Yaqui Valley vignette again, there are a range of collaborations between scientists, innovative farmers and the credit unions. It's a good example of collaborative production of knowledge, which then has the credibility needed for extension to other farmers.

We also realize that there is a critical role played by boundary organizations, individuals or objects. Boundary organizations or individuals have one foot in the research world and one foot in the decision-making world, and are trusted by both, and help make that communication and translation work better. In the Yaqui case, Ivan Ortiz Monasterio, our agronomist colleague who lives there, was a key boundary individual trusted by both sides; he is known well by the farmers and also a trusted member of the research community: a really key individual. But the credit unions were also boundary organizations, a fact that we didn't realize initially. They were gathering and integrating information, advising farmers, and the farmers trusted them and used their information. When we figured out their role, we knew we needed to link more effectively to them, not just farmers, to enable a much more effective translation of knowledge to decision making. And boundary objects like maps of crop yields as they're related to climate were very helpful in engaging farmers in understanding their resilience and vulnerabilities to climate change. This graphic —where we put dollar signs on the red phytoplankton blooms of the Gulf and began to talk about money being flushed down the drain in this system – was also effective for boundary spanning conversations.

[Insert Fig. 5 here!]

Another critical barrier is fragmentation of information. Let me explain that a little bit. If you think about the knowledge to action link as a chain or maybe even a network, lots of different pieces have to be in place in order for it to work. In sustainability challenges, we found that nobody is paying attention to whether all of those pieces are in place so that the new knowledge is actually useful and used. Nobody is taking responsibility to make sure that this supply chain of knowledge is complete. That's one of the things we have to find among our own organizations, our universities, foundations, government agencies. We need to make sure that all the links are in place in that supply chain of knowledge to action.

And finally, inflexibility: what we found across the case studies is that in places where the organizations and their roles in that knowledge system are static, the system as a whole is not able to keep up with the changes in the world around them and thus can't continue to meet the needs of the decision makers. To really be effective as learning systems for sustainability, they needed to be able to evolve. So, using the Yaqui Valley as an example again, we were able to go back in time and look at how it changed over time. The players were pretty much the same during most of the last thirty years. Innovative farmers have always been really important players. What we found, however, was a shifting of responsibility among the different players in this knowledge system. For example, the linking or boundary role that credit unions are now playing used to played by government extension or farmer groups. We also learned that this system was changing over time in terms of the importance of the different players. I mentioned before that the secretary of health and secretary of natural resources weren't influential players up through the end of the 90s or early 2000s, but now they're stepping up. There are new air quality rules that farmers have to respond to, and some water quality issues are now being addressed with regulation. These secretariats therefore are becoming much more important players in that knowledge system, much more influential.

Finally, one of the things we've learned is something we should all be thinking about: how our own actions can change the agenda of a place. We've realized that in working in the Yaqui Valley for 15 plus years that our influence, and the influence from funding organizations that supported us, shifted the dialog in the valley from one that was focused on increasing agricultural yields, to one that was focused on sustainability challenges. Our presence there, being part of the dialog, helped make that change happen. So did the emergence of civic organizations that were worrying about the future of this region and imagining long-term sustainability visions.

There's a lot more to say about this, but I'm going to end here. I think one of the most important things we can do at this point is learn from all the experience that is present in this room. Your case studies are going to be incredibly important for us to learn from; I'd like to ask what can be learned from the comparison of these cases. I notice in your agenda there is only about 45 minutes for a synthesis, yet a synthesis across these case studies might be the most important thing you can do in this meeting. So what else can be learned from these case studies? Is there anything that can be generalized across the case studies? How can that help us both improve our understanding and also improve our ability to take knowledge to action on the ground for sustainable development. So with that, I will say thank you and good luck and have a wonderful week. I'll be here for part of it. Thank you. Do we have questions?

*Olaf Webe*r, University of Waterloo: You mentioned the diffusion of the cases. That's quite interesting. The question is how to do it? You know, it's an interesting case, and what's interesting for me, I'm in environmental finance, and, the role of the credit unions of course is very interesting. You have the same on global issues as well, the influence of financial players. But how do you…

Matson: How do you extend that?

Weber: How do you extend this quite specific example in Mexico that is interesting. How do you expand it to global problems?

Matson: Right. Well, very good question. It's one our team has been asked all the time we've worked there. We went into this place, not just because we wanted to help fix the problems in this place, but because we were searching for general knowledge and understanding that could be used elsewhere. So, many of the approaches, the tools, we have models of agricultural sustainability, basically. We have allocation models and rules for water resources. All of those things we developed in the area are useful and are being used in the other areas. So from a scientific point-of-view, we can learn a lot and we can use it elsewhere. We also worked very hard to try to extend the knowledge we gained there more broadly in Mexico. So for example, we created a set of water management rules for sustainability that, because of our team, was able to move up to the national level. So it's not just local.

Then the other thing I think is that it is so important to have people like our collaborator Ivan Ortiz Monasterio. His job is basically, with CYMMIT, an international agricultural research unit, is to just reach out across the world and work with people in wheat systems. So he's carrying those approaches and technologies. So I would say there are contributions both to the science of sustainability and of linking knowledge and action, but also tools and approaches that were useful there can be useful in a lot of other places. But you're absolutely right. I think this is our biggest challenge. If we use place based approaches, how do we know that what we're learning there can be useful beyond the place?

Masaru Yarime, University of Tokyo: I'm very impressed by the case study in the Mexico, and I just wondered that you mentioned an issue that is important to this case comparison is the fragmentation of knowledge. I assume that there are different kinds of knowledge possessed and maintained by different kinds of actors. I just wonder through this the dynamic process of interaction how knowledge merged or changed or transformed by having this interaction of different kinds of actors and then how that influenced the outcome or process. Do you have that kind of analysis?

Matson: Yes. Well I can give you a very specific example of that from the Yaqui Valley. The control of everything was around green revolution agriculture in that valley. So those same innovative farmers, very smart people, became governors of the state, became leaders of the funding and foundation type organizations that fund research, and on and on. It's very possible for there to be just an internal focus, so that all of those pieces in the knowledge systems are all about their agenda. Their agenda was increasing yields, basically. So when we became players in this, and other groups as well, we began to shift the agenda because we were bringing new knowledge into the system. So nobody in Mexico at the time was funding research on losses of fertilizer, on water quality, on air quality issues. We, because of our research, brought new information into the system. In some ways, that forced a change in the agenda. It forced a change in the chain of knowledge that people were dealing with. It gave a voice to issues and people that didn't have a voice before in that agenda. So that's what I think.

In this case, if you go back to that supply chain of knowledge, we were actually looking at that on purpose, and the foundations that were funding us, and some of the US agencies that were funding us ultimately helped fill the gaps in that knowledge chain under that new agenda of sustainability versus just agricultural productivity. That's my biggest concern because I don't think there are enough organizations out there who are willing to support filling in the missing pieces in a chain for sustainability. So that's an interesting issue that we could look at with your case studies. Where are those pieces being filled, who's looking holistically at it for sustainability? I'm not sure if that answers your question but it's interesting.

Charles Redman, Arizona State University: Pam, the Yaqui Valley is one of the great paradigms of sustainability success or on course to success. But a lot of what I heard would be what I would call different end of the pipe solutions, a regulation, better sensing so you can be more efficient. This sounds like a lot of sustainability solutions today. Can I challenge you or the other case studies during the week to look upstream? Can we go way back in the process and convert what's going on so we don't have to rely on regulation output or efficiency from better sensing?

Matson: Right. No, it's an excellent question. We look at this region and recognize that there are totally different ways of doing things here. I mean, they probably shouldn't be growing wheat to begin with. They probably shouldn't be growing much of anything. But there is an opportunity for this to be a productive agricultural region with diversified crops, higher value crops, things that make more sense to use all of that irrigation water on, much more efficient use of irrigation, all of those things. You can imagine different ways that this place could still exist as a productive agricultural system. What we found is that there's no knowledge system to help them do that. So I showed how that knowledge system evolved over time, but I think we're coming to the end of the road on that. If they were going to diversify into high value crops they'd need different kinds of knowledge than they have right now. If they were going to rethink how they do agriculture altogether they'd need different sources of information than they have there. So it's really challenging to figure out how to change a place. I guess maybe it's an excuse and we see this as a failure in a sense. We couldn't change that place completely, but we changed the agenda, we changed the conversation, we and others, no, not just us. The question now is: "Does that set them up for a different future?" Now that they're talking, you know the last big public meeting we held was called a transition into sustainably in the Yaqui Valley. Does that change and conversation set them up for a major shift in how they do business in the future? I don't know. But that's about all we could do I think in this case.

Peter Edwards, ETH Zurich: Which means very often you might start off with a wish to sustain focus but it runs into trouble.

Matson: Yes, it's so true. I don't know if you all heard, but he was making the point, really excellent point, that this required a long-term look, a long-term engagement in this place. If we had just worked for three years, we wouldn't have gotten the answers at all right, actually. So there's so many complication to long-term engagement in a place. Funding changes, we had to grapple for funding through this whole thing. People pieced pieces of funding together for the project. People's interests come and go. They refocus on other things. Yeah it was a challenge for us. I think, to me, this is the argument for capacity building. The goal has to be. Not that this team was going to stay together forever, but that we're going to have so many more people who care about this, some of whom live in that region, who can continue that. That needs to be a really purposeful part of that, because these are not short term fixes. It's a big problem.

Steven Mannell, Dalhousie University: To address the problem of the short-term fix and three-year funding cycle, we've all, I think, faced this one. Year one you make a lot of mistakes. Year two you begin to figure out what you're doing. Year three you're out of money. So, that we've all had. In our particular case, same experience you've had, you need to have a long contact in the community to get things done, to make it work. What we've discovered is if we go for education funding, projects come and go, but education goes on forever. In doing this, we stumbled backwards into the realization that getting involved with the local school system and engaging with education, engaging with institutions in the local area, turned out to be the best thing we could do. That has been very effective in Iceland and the Caribbean. So we did it by accident, and I have to say we did it mainly to keep the funds coming.

Matson: Yep. But, that's excellent. That's a really important learning from your work, and it makes a great strategy. I guess maybe for all of us, a challenge is to find the strategies that allow that continuation of what I think of as matrix funding for the research, as well as for the action and education to occur on. In our case, we didn't use that strategy. I wish we had, or I wish there were funds for it. But, we did find foundations who were really interested in the integrating of information for sustainability. They provided low levels of funding, but consistently over a long time to help us do those three year cycles. This is actually a really good point for the conference to address directly. What does it take and what are the strategies that have been developed to continue that long term?

Mannell: So education for sustainability and sustainability science are really joined at the hip in a very important way in terms of funding?

Matson: Mmhmm, good, agreed. Any other comments?

Nick Brown, Arizona State University: You mentioned maps as boundary tools or boundary objects, which I find really fascinating. They sort of connect science with probable outcomes and help sustainable outcomes. What other kinds of tools could we think of as boundary objects or tools?

Matson: Well, I think models in some environments, mathematical models. Simulation tools that really allow people to see their future have been very effective. Scenarios, I've got colleagues who work on a natural capital project trying to engage decision makers and stakeholders in different options for their future, use of their land or water systems. They do scenarios and they engage the community in thinking about different directions, different scenarios for the future. Anything that basically gets people talking together and begins to see other options are great boundary. Probably others in this room have other examples.

Steven Mannell, Dalhousie University: I wanted to add another, what we found a very effective boundary tool is storytelling, oral history. We found it at all levels. The most surprising use was actually when we were developing our sustainability program at the university. We spent half a day doing narrative oral history with people at the workshop as a way of understanding what were the things that people saw as the tradition and history of the place. What did they see as the failures of the past? Out of that you also learn some things that might help people avoid taking what might seem to an outsider the obvious step, but that's kind of culturally indicated in that scenario. So that kind of story, I know one example, which isn't directly related to my experience but research I've done: the 1970s, adoption of sustainable building technology. Couple of architects went to Prince Edward Island with toilets and tried to get everyone on the island to go with composting toilets. It took them five years before someone finally said to them, look we just got rid of outhouses 10 years ago. So there was a whole cultural taboo around this thing, plus they had just invested. So the history, this kind of narrative is a way of engagement, but it's also at least as important as any other kind of information you're going to get as to what the landscape is. But it also builds the collaborative engagement of people around them. If you spend the first part of your time listening to people rather than telling people, they're already caught in.

Matson: Yeah. I couldn't agree more and actually, we didn't do enough of that. The only area we really focused on storytelling among the stakeholders was in the coastal zone issues that we worked on. We finally had gotten smarter at that point and did it. I think that's an excellent idea. We talked yesterday, among some of us, about how important storytelling is. About a way of communicating what's important to individuals and to the world. So it's a really good point.

James Buizer, University of Arizona: I just wanted to add to the question about boundary objects. We found that one of the critical ingredients is that the object itself, and it can be a movie, it can be a map, it can be a report, but that it be coproduced. Because then, both parties own the object and that is the beginning of a communication. Then they feel like they own that process, rather than have something handed to them.

Matson: Right. No it's really important.

Barry Ness, Lund University: In terms of the barriers to understanding about the ideas of time, because I think for many of these issues of sustainability getting that longer-term perspective is important. I think when you talk to people about time, scientists often have a very different view of timescales than other people do. I suppose it's more of a general comment, but did you find this question about time being one of the issues? You get time as seen by scientists, and time as seen by other people.

Matson: Yeah. It's a really good point. I think I could give you lots and lots of different examples of how that played in. You know time and history was incredibly important to the farmers we worked with. In Mexico, there is a whole set of history about land and tenure rights and reshuffling of land ownership and so forth that it figured very heavily, even though it happened 20 years ago to their fathers or whatever. It really figured in their minds. It influenced their minds about thinking about sustainability. It took us a while to figure that out. They had a much longer-term view of agricultural innovation and sustainability issues. I think there's also, and maybe I alluded to it a little bit, I think scientists, and by scientist I mean social and biophysical scientists in this community I was in, expect things to happen pretty quickly. Sometimes they do, probably not thanks to us but just because they do. We really did not understand how long it would take for change to be made. It's partly because I think we were thinking at the time, now this is in the mid-1990s, that economics was more important than it actually is. That there would be a very quick change just on the basis of cost. Only later did we realize lots of other things were coming into it. So yeah, our vision of the timing of this was much different than what really happened and for a lot of different reasons. But yeah, it's so true. I guess another important thing to think about is we focus our attention on actually hoping to have our knowledge be used and useful. Well thank you very much. Have a good evening.

Case Studies in Solution-Oriented Sustainability Science

Arnim Wiek, Robert Kutter, John Harlow

This section presents three case studies of sustainability science in practice based on presentations, panel discussions, and supporting documents. The cases differ in many ways (e.g., geographical focus, topic, institutional setting, development stage), but they all illustrate on-the-ground efforts to conduct problem-driven and solution-oriented sustainability science research. The three case studies are at different stages of development. In the Japanese case ("Rebuilding from the Great Eastern Japan Earthquake"), sustainability efforts are in the initial stages as the base for long-term recovery is still under development. In the African biofuels case ("Bioenergy and Sustainability in Africa"), a great deal of progress toward the project's goals has been made, but there is not yet a thriving biofuels sector in Sub-Saharan Africa. In the San Francisco case ("Precautionary Purchasing in San Francisco"), the city has successfully implemented its precautionary purchasing ordinance and is now maintaining the program. The three case studies describe and reflect on rich examples of sustainability science projects and thereby add important insights to the ongoing discourse on progress and quality standards in sustainability science (Siebenhüner, 2004; Blackstock and Carter, 2007; Lang et al., 2012; Wiek et al., 2012; Clark et al., in press). Thereby, they offer vital ground for exploring new directions for sustainability science in the future.

Each case study is structured into three sub-sections. We first briefly characterize the sustainability challenge addressed; then outline solution options, realized and potential ones, to which sustainability science aspire to contribute; and conclude with open issues that need to be considered when moving forward on mitigating or resolving those challenges.

Rebuilding from the 2011 Great Eastern Japan Earthquake

This case study aims to show how sustainability science can help rebuilding the areas affected by the 2011 Great Eastern Japan Earthquake. Lessons from this case can help decision- and policy-makers around the world prepare for and react to large-scale disasters.

The Sustainability Challenge

On March 11, 2011, a 9.0 magnitude earthquake struck northeastern Japan. It was the most powerful recorded earthquake to hit Japan ("Tsunami After Massive Japan Quake," 2011) and caused a tsunami that damaged over 600km of coastline in the region (Mimura et al, 2011; Supprasi et al., in press).

Direct impacts of the earthquake and the triggered tsunami were casualties in the thousands, destroyed property, disrupted basic services, damaged environment, and ruined livelihoods (Mimura et al., 2011). One conference presenter, Makoto Hatakeyama, was at sea fishing when the tsunami struck, and he called the following ten days "hell on earth." Agricultural, fishing, and tourism industries in the disaster areas were severely damaged (Reconstruction Design Council, 2011). The earthquake and resulting tsunami also caused a series of accidents at a nuclear power plant in Fukushima, already one of the hardest hit areas (Dauer et al., 2011). Radiation leaked from the plant forcing thousands to evacuate. In total, roughly half a million people were displaced by the earthquake, tsunami, and nuclear disasters (Mimura et al., 2011). This triple disaster will likely be the costliest in Japan's history with long lasting financial impacts (Matanle, 2011; Shaw, 2011). From this brief account, one recognizes the key features of a sustainability problem being present in the Great Eastern Japan Earthquake case, including complex and long-lasting impacts that threaten the integrity of the regional society, economy, and environment, and urgently require sophisticated responses, which need to match the complexity of the problem itself (Wiek et al., 2012b). The nuclear accidents add a new dimension to the disaster (Perrow, 1984, 2011), which leaves the Fukushima region and residents in critical condition despite all preceding disaster preparedness efforts (Wiek, 2011).

Nonetheless, a great deal of responses to the Great Eastern Japan Earthquake have benefited from precautionary measures (Source on preparedness). High-speed trains, for example, were designed to shut down automatically during earthquakes and did so during this one (Mimura et al., 2011). As a result of this and other features, the high-speed rail was quickly back in service. Japanese people responded in an orderly way even though they faced tremendously chaotic situations after the disasters (Gilligan, 2011). However, the nuclear disaster at Fukushima showed flaws in Japan's anticipatory governance of nuclear power. Scientists believed a tsunami as large as the one on March 11 was possible, but the nuclear community ignored this information (Davis et al., in press). Also, Japan's regulators often relied on nuclear power companies to voluntarily comply with safety guidelines, but nuclear power companies did not always comply voluntarily. In summary, government and business could have done more to prevent such serious accidents through regulation, design, training, and mindfulness (Perrow, 2011).

Post-disaster studies have provided ample evidence for secondary adverse impacts that result from insufficient responses to a disaster and can amplify the direct impacts of a disaster (Gotham & Greenberg, 2008; Chamlee-Wright and Storr, 2010; Wiek et al., 2010). This affects particularly vulnerable populations such as women, children, and minorities, who are usually hit hardest in disasters and flawed recovery processes (Edwards, 2009; Abramson et al., 2010; Awotona, 2010). Several insufficient responses to the Great Eastern Japan Earthquake have put additional pressure on the affected populations and hindered the initialization of a speedy recovery. They included the dominance of partial interest groups, paucity of coordination, inadequate communication, lack of stakeholder engagement, incompetence, and so forth (Park et al., 2011). A prominent and well-documented problem of post-disaster emergency response and recovery is the ineffective and inefficient use of aid funds (Wiek et al., 2010; Dong, 2011; Dovers and Handmer, 2012). In the Great Eastern Japan Earthquake case, problems with assistance have appeared in short-, medium- and long-term recovery efforts. One of the case presenters, Makoto Hatakeyama, described many problems with the response to the disaster. There was more than enough emergency aid, but governmental and non-governmental agencies struggled to use it effectively due to a lack of coordination and proper delivery structures. Some people continued receiving instant meals long after they were not needed. Local governments were also overwhelmed. In medium-term recovery efforts, local governments struggled to find local people with the necessary administrative skills. Outsiders who volunteered had administrative skills but were unfamiliar with the local context. Some medium-term problems could become long-term problems. Fish farmers receive large subsidies from the central government and are therefore unmotivated to work. Much of the financial investment for rebuilding goes to people and organizations that need it the least rather than those who need it the most. These insufficient responses trigger adversarial developments. Because of problems managing the response to the disaster, many Japanese lost trust in the government's ability to respond to large natural disasters in general. Another example for impact amplification due to insufficient responses is the fear that radiation contaminated large regions, which continues to damage farming and fishing industries across the country (Takahashi, 2011; Kurihara et al., 2012).

Resilience is the ability of a system to withstand disturbances and continue to function (Folke, 2006). A resilient society can withstand even major disturbances like the Great Eastern Japan Earthquake. On a more structural base, it is therefore important to reflect on the specific vulnerabilities that put this particular region and populations at risk. The earthquake and tsunami represent strong disturbances that overwhelmed some of Japan's social, technological and natural systems, i.e., some of these systems moved from stable functioning to non-functioning systems. Much of northeastern Japan's infrastructure, including nuclear power generation at Fukushima, was destroyed. More resilient technological systems might have withstood the disasters (Park et al., 2011). But a resilient society displays more critical features than resilient infrastructures (Tweed and Walker, 2011). In fact, technological systems' resilience depends on robust social systems and human-nature relationships. Fisheries and rural communities, which were weak before, were severely damaged or destroyed by the impacts of the earthquake and tsunami. Insufficient job and business opportunities in eastern Japan had been causing depopulation and social disintegration for years before the earthquake, reducing the region's resilience and response capabilities of the people (Matanle, 2011).

Solution Options

If well designed, sustainability science research can play an important role in understanding the disaster in its complexity and developing solution options for a sustainable recovery from the Great Eastern Japan Earthquake. It seems that a transformational sustainability science research agenda would be most suitable for guiding such efforts (Wiek et al., 2012b; Matson, 2012 [Keynote in this Report]). Key aspects of such a transformational approach would be to shift emphasis from understanding the disaster to the development and testing of viable solution options; to closely collaborate with stakeholders and the public on solution options to create ownership and encourage implementation; to link research with evaluation and teaching efforts to continuously enhance capacity among stakeholders, the public, as well as sustainability scientists.

The participatory feature of transformational sustainability science is critical in this case. Sustainability scientists need to enable and collaborate with local communities in designing and selecting sustainable solutions (Talwar et al., 2011; Lang et al., 2012). In this process, local communities should carefully consider who benefits from the proposed solution. In complex cases such as this, winners and losers are inevitable. Complex solution options often display a high degree of uncertainty and might result in unintended consequences. When exploring solutions, communities therefore need to consider future developments, such as how demographics may change or the impacts of climate change. Communities should set clear success criteria for each solution proposal. Communities need to know when proposed activities have been successful, so they can devote their resources to new initiatives. Solving problems also requires resources, so sustainability scientists and communities need to determine how costly each solution option is and compare the cost to available resources. Unfortunately, well-organized aid from the central government was lacking for several months following the disaster, and many communities relied on grassroots efforts of NGOs and religious organizations (Fisker-Nielsen, 2012).

A key component of transformational sustainability research is a creative, structured, and participatory visioning process that generates systemic and shared future visions for the recovery (Wiek and Iwaniec, in review). A great deal of reconstruction efforts is path dependent aiming to restore the pre-disaster conditions and modes of operation. Progress towards sustainability, however, requires overcoming those path dependencies and significantly changing the ways communities are perceived and valued, as well as built, governed, and operated (Han et al., 2012). Considering the inertia that keep most communities on unsustainable pathways, disasters present a unique opportunity to disrupt these pathways and change the course of operation towards sustainability (Berke et al., 1993; Birkmann et al., 2010; White, 2010; Wiek et al., 2010). For example, the national government plans to increase the proportion of Japan's energy that is generated from renewable sources to 20% (Matanle, 2011).

Resilience could be used as a key principle for such visioning processes, if considered from a systemic perspective (Tweed and Walker, 2011). Recent studies support the emphasis put on rebuilding more resilient communities with a stronger social capital base and with stronger ties to each other (Aldrich, 2011). Stronger ties between urban and rural communities seem to be critical for strengthening resilience of the rural areas. Preserving and promoting the diversity of the region could enhance its attractiveness. The robustness of the regional economy is a key factor in this process. Rebuilding agricultural, fishing, and tourism industries and the villages that support them is imperative as their revival can lead the way for the recovery of the region

(Reconstruction Design Council, 2011). The area could become a real-world laboratory for sustainability-oriented economic and community development. One proposal is to create a new national park in the damaged area to restore biodiversity and stimulate tourism (Takeuchi, 2011). Trained fishers may need to switch to clam fishing, which uses a similar set of skills. Communities may also need to reform economic relationships. One proposal is to transfer fishing rights from cooperatives to private companies to stimulate new investments in the fishing industry (Reconstruction Design Council, 2011). The region's resilience also depends on governance of local and global commons. Reconstructing wetlands along the coast would increase resilience (buffering zones) and stimulate tourism. Communities can use the concepts of satoyama and satoumi to rebuild and manage ecosystems (Takeuchi, 2011). Satoyama and satoumi refer to community-based management of forests and coastal ecosystems, respectively. Both are informed by traditional knowledge about managing ecosystems. The affected areas contain many regions suitable for satoyama and satoumi. Much of the Sanriku coast has national, quasi-national and prefectural natural parks that could incorporate satoyama and satoumi or expand into new areas that do. Japan could create a "Sanriku Geopark" to memorialize the earthquake and tsunami and educate visitors about geology and geography. Wind, geothermal, and other renewable energy could be developed from national parks, while continuing to conserve them.

Traditional planning and risk management failed to prevent severe damage from the Great Eastern Japan Earthquake. Traditional planning and risk management seems weakest when addressing events that have a low probability of occurring but very high impact when they do, as it is the case of the Great Eastern Japan Earthquake and the nuclear disaster it triggered (Park et al., 2011; Perrow, 2011). But apart from new governance regimes for energy technology (and other high-risk technologies), there seems to be room for improving planning and governance in a more general sense. To support rebuilding efforts, Japan's government largely responded through conventional mechanisms such as special economic and tax regulations. However, community restoration will need innovative planning and governance approaches, including sustainability-oriented planning and anticipatory governance (Guston, 2008; Quay, 2010; Wiek et al., 2010). New zoning laws can help by making towns more compact and restricting them to higher ground (Reconstruction Design Council, 2011). A bottom-up approach, in which citizens participate in planning and governance through a proactive lens, seems to be a critical component of such an innovative regime (Matanle, 2011). While there have been grassroots recovery efforts (e.g., Fisker-Nielsen, 2012), Japan does not have the necessary civil society or institutional arrangements to accomplish reconstruction in a bottom-up manner (Matanle, 2011).

The Great Eastern Japan Earthquake has stimulated a broad public debate on climate and energy policy (Ogimoto and Yamaguchi, 2012). While the discussion has centered on energy technologies, the linkages to broader climate change issues have been recognized, too. This discourse has led to the prospect of a significant win-win situation. As Japan is reconsidering its energy system, anthropogenic greenhouse gas emissions continue to warm climates around the world – with Japan being one of the main contributors. Japan has now the opportunity to pursue resilience of its society through a sustainable energy transition that could reduce vulnerability to disasters and climate change (Barrett, 2012). One key element of this transition would be the phasing out of nuclear power generation, as it is underway in European countries such as Germany. Support for this audacious move comes from more then 25 years of research into high-risk technologies such as nuclear power. As Perrow (2011, p. 44) concludes: "Some complex systems with catastrophic potential are just too dangerous to exist, because they cannot be made safe, regardless of human effort".

A key component of the solutions portfolio is education in sustainable post-disaster reconstruction and recovery. Kazuhiko Takeuchi, one of the case presenters, relayed the University of Tokyo's plan to create new education programs to build capacity in decision-makers, stakeholders, and the public on how to rebuild and maintain sustainable, resilient communities.

Open Issues

Some of the proposed solution options will require substantial transformations as envisioned in the literature on sustainability transition processes (Loorbach, 2007). Part of this transition will extend to the change of basic consumer behavior and business practice. Such changes will likely encounter reluctance on the basic level as, for instance, fishers might oppose change of their fishing practices. While the described win-win situation of a sustainable energy transition sounds very promising, it faces strong resistance from players in power (nuclear industry). One of the obstacles to implementing a bottom-up approach to reconstruction is the entrenched "iron triangle" of elite political, bureaucratic, and corporate interests. Japan needs significant cultural and institutional changes if local people will shape the vision for and implementation of disaster recovery (Matanle, 2011). But at least one of the proposed solutions is already underway. Japan will create a new national park to restore biodiversity and increase tourism (IUCN, 2012).

Case Presenters and Panelists

The "Rebuilding from the 2011 Great Eastern Japan Earthquake" case study was presented by Kazuhiko Takeuchi from the United Nations University and the University of Tokyo, as well as by Matoko Hatakeyama from the Society to Protect Forest for Oysters. Comments on the case study were presented by the following panelists: Daniel Lang, University of Lüneburg; Hisashi Kurokura, the University of Tokyo; Hideaki Shiroyama, the University of Tokyo; and, Joseph Tainter from Utah State University.

Bioenergy and Sustainability in Africa

The Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems in Africa (COMPETE) project was an international biofuels initiative that addressed the interrelated problems of low quality of life, limited energy access, and lack of livelihood opportunities in rural Africa. The project was funded through the EU's 6th framework program and ran three years (2007-2009). It involved 44 partners, including scientists, practitioners, companies and policy-makers from Europe, Africa, Brazil, India, and Mexico. This case study illustrates how sustainability science has been used to address complex international development problems (Wiek et al., 2012b).

The Sustainability Challenge

Roughly half of the people in sub-Saharan Africans live on less than one dollar (USD) per day (Woods et al., 2007) with many in rural Africa relying on subsistence farming for their livelihoods. Low levels of development, especially widespread hunger, constrain farmers' ability to effectively cultivate their land, even though there is a great deal of productive land in rural Africa. Additionally, small-scale farmers receive little outside investment, so they have few opportunities to improve or change their livelihoods. Farmers also have to contend with negative effects of global warming on their yields. These factors contribute to farmers' unsustainable land-use practices that, in turn, degrade arid and semi-arid ecosystems. Getting affordable, clean energy is another problem for people living in rural sub-Saharan Africa. Most people use biomass, like charcoal and firewood, because they cannot afford fossil fuels or renewable energy (Taele et al., 2012). Without alternatives to biomass, increasing energy demand will increase pressure on African ecosystems. Increasing demand for food and energy will further strain the land that supports rural farmers' livelihood (Amigun et al., 2011).

The sustainability problem constellation outlined above entails many more facets and aspects, as indicated in the conceptual figure below.

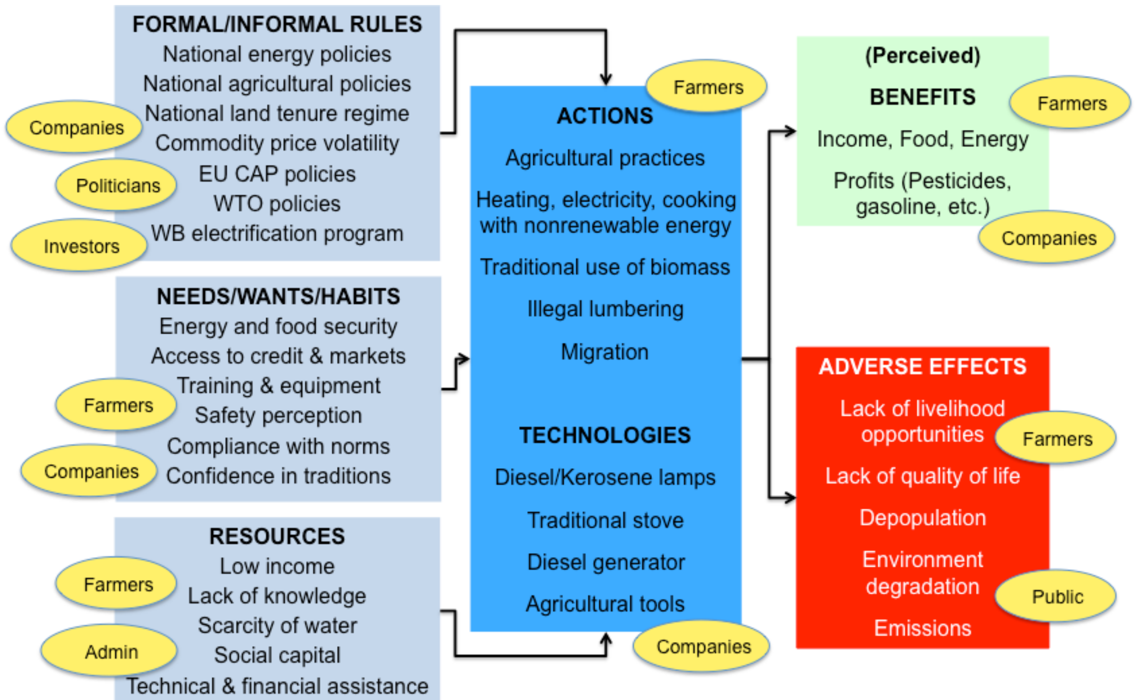

Figure X. Sustainability problem constellation addressed in the COMPETE project (the conceptual model is based on Wiek, 2009).

Solution Options

Cultivating crops for biofuels may help address these interrelated problems (Lynd and Woods, 2011). Bioenergy systems offer opportunities for investment and infrastructure improvements in agriculture with the promise to diversify agricultural production, stimulate socio-economic development, and provide sustainable energy for local needs (fuel, electricity, heating). However, even though studies show a significant potential for bioenergy development (Smeets et al., 2007; Hoogwijk et al., 2005), concerns exist that bioenergy production might have adverse effects, including negative impacts on biodiversity and natural resources access through increasing competition over land and water resources (Amigun et al., 2011). Adverse impacts need to be considered across the supply chain for biofuels production, which has three main stages. First, farmers grow and harvest the crop that will serve as the feedstock, such as sugar cane or soy (potential conflicts as indicated). The next process converts the feedstock into biodiesel (emissions, safety, job access). Finally, the biodiesel goes to market for distribution (market access, emissions). Depending on the intended use of the fuel, raw oil instead of biodiesel can be used. Biofuel production, processing, and distribution need to be tested and developed against potential backdrops to fully qualify for sustainable solution options.

COMPETE was an international partnership, including universities, research institutes and trade associations, that aimed to stimulate biofuels production in rural Africa through research and policy discussions. Specifically, COMPETE promoted decentralized, community-based biofuels production in rural Africa, focusing on eight countries: Botswana, Burkina Faso, Kenya, Mali, Senegal, South Africa, Tanzania, and Zambia. COMPETE also helped European and African countries exchange knowledge about biofuels policy and production. The project was structured into seven sub-projects (Janssen et al., 2009):

- Impacts of current land use
- Improved land use through energy crops and agriculture
- South-South and North-South cooperation
- Financing alternative land uses and international trade
- Policy development
- Cooperation and dissemination of results.

COMPETE conducted two types of research projects to achieve its goals. One type was research projects that aimed to create an enabling environment for biofuels production, using guidelines, policies, and social networks. Key activities for these projects were defining the scope of COMPETE in terms of goals and projects and mapping land use in the eight African countries. The second type of research project was on-the-ground cases that helped develop biofuels sectors in Leguruki, Tanzania and Kabwe, Zambia.

In October 2008, COMPETE published its "Declaration on Sustainable Bioenergy Development for Africa" (Yamba et al., 2008). The document was the result of a COMPETE conference attended by experts and decision makers in July of the same year. To create an enabling environment for biofuels production, it recommends policies and guidelines for biofuels development in Africa. It also recommends training schemes for local people, so they can comply with sustainability-oriented standards of biofuels production. The recommendations emphasize that policies should be designed in a way that local farmers benefit from biofuels production, which requires that policy makers and decision makers in related sectors need to coordinate their efforts. Several years later, the declaration still influences international dialogue, national and regional policy on biofuels (Wiek et al., 2012b).

Researchers used GIS to identify land in each country that is best suited for growing biofuels feedstock. In general, the assessment identified land that could be used for cultivating feedstock for biofuel with minimal environmental damage and minimal threat to existing livelihoods. The assessment excluded land that was unsuitable for production (such as deserts), had high biodiversity, or was used for agriculture. The assessment also incorporated research on traditional knowledge and land use practices. The GIS mapping exercise revealed there is a substantial amount of land in arid and semi-arid regions that could be used to cultivate biofuels (Watson & Diaz-Chavez, 2011).

The second type of project is an on-the-ground effort to develop biofuel as an industry. The potential for biofuel production using Jatropha Curcus as feedstock is considered significant for rural areas in Africa and COMPETE has explicitly explored the development of this industry (Romijn and Caniels, 2011). Case presenters reported on two local projects, both of which used

Jatropha Curcus as feedstock. Jatropha is a hardy plant with inedible oil seeds that grows on land unsuitable for food crops, and since the seed oil is inedible, it interferes less with agriculture for edible food than other biofuel feedstocks.

The first project was conducted by the private company Marli Investments Zambia Ltd. in Kabwe, Zambia (German et al., 2011; Farioli and Ippolito, 2012a). Marli contracts with farmers to grow Jatropha and then processes their harvested crops. Marli plants the Jatropha trees and then turns ownership over to the farmers. This arrangement is called an “outgrower” or “contract farming” model. At the time of the conference, there were roughly 25,000 participating farmers. Marli has adopted this model of distributed production to help farmers own their own land and improve the long-term prospects of the industry. Marli also employs outreach officers to teach farmers how to grow Jatropha. Farming methods are a combination of traditional and modern techniques. At the time of the conference, Marli was acquiring land that it planned to build a central processing facility on.

Marli’s efforts have been constrained by policy makers’ lack of attention and by poor infrastructure. Since biofuels are not a high priority, the industry receives less assistance from the government and less financing from international investors. In terms of infrastructure, poor roads, for example, make it difficult to transport feedstock to processing facilities and finished biofuels to market. Despite these challenges, Marli has helped farmers generate income. Biofuels production has also improved Zambia’s energy security, and Marli’s work informed Zambia’s energy policy.

The second project was conducted in Leguruki, Tanzania by TaTEDO, a Tanzanian development organization (Farioli and Ippolito, 2012b). Leguruki is a rural farming village that was not connected to the electricity grid. Popular crops are coffee, banana, beans, and corn, and villagers were already familiar with Jatropha. Before starting the project, some villagers used rows of Jatropha as fences and property markers. TaTEDO’s project aimed to electrify the village using diesel generators powered by Jatropha oil.

TaTEDO began the project with a participatory rural appraisal in May 2007. In participatory rural appraisal, project organizers and community members define problems and potential solutions together. TaTEDO also formed an “energy team” comprising villagers, government officials and TaTEDO staff to lead the project. TaTEDO selected villagers for the energy team based on their motivation, and TaTEDO also chose team members so the group as a whole would be representative of the village’s residents. At the end of this pilot project, TaTEDO and the energy team successfully installed a diesel generator powered by Jatropha oil. Farmers grew Jatropha with their regular crops by intercropping, or they grew it in their hedges. As a result, Jatropha did not compete with their food crops. Electricity from the generator went to a mini-electrical grid that powered residences and businesses in the evening. Children were able to study longer, and better street lighting improved safety. TaTEDO attributes the project’s success to participation by community members and cost-effectiveness of the diesel generator.

Researchers working with COMPETE evaluated the sustainability of these two on-the-ground projects. The Zambian central government has started to evaluate the potential of biofuels but has not yet started any biofuel initiatives. Therefore, community-based efforts, like Marli's, are more likely to succeed than initiatives that rely on government support. Biofuels have received more attention from Tanzania's central government than Zambia's. Tanzania's central government created a Biofuels Task Force in 2005, and the country has developed guidelines for the biofuels sector. The government is also supporting initiatives, like education on biofuels for government workers, to spur development of the biofuels sector (Janssen et al., 2009). With strong governance and incentives, the biofuels sector in Tanzania seems to have good prospects at least in the near future.

Open Issues

Biofuels have become more popular in developed countries over the past decade as a way to curb greenhouse gas emissions, especially from fossil-fuel-powered transportation. However, biofuels grown with fertilizer may not reduce greenhouse gas emissions. When farmers apply nitrogen fertilizer, some of the nitrogen in the fertilizer converts to nitrous oxide. Only small amounts of nitrous oxide are released, but it is a potent greenhouse gas, so even small amounts can outweigh the benefits of using biofuels. Researchers are still investigating whether biofuels reduce greenhouse gas emissions (Pearce & Aldhous, 2007). Developing countries may benefit economically from biofuels regardless of their global warming benefits. But if research shows they do not reduce greenhouse gas emissions, demand for biofuels in developed countries may collapse along with international investment in the sector.

Some opponents of biofuels argue that they compete with food crops and therefore reduce food security for subsistence farmers. Even though Jatropha is a hardy plant, it sometimes requires irrigation; in these cases, water that farmers use to irrigate Jatropha may take away from water that farmers can use to irrigate their food crops (Amigun et al., 2011). Biofuel crops can also compete with food crops for land. Biofuel supporters advocate using marginal land to grow biofuels to reduce competition with food crops. However, some conference participations pointed out that farmers can use even marginal lands to graze livestock, so biofuels still compete with subsistence farming to some extent.

Land is not merely a means for food production. Observers and activists worry that the spread of biofuels may exacerbate existing inequities in land access, compounded, of course, by land's historical, political, cultural, and spiritual value. Both Marli's and TaTEDO's projects seem to have avoided these problems, but both projects emphasized community involvement and ownership. It is not hard to imagine situations where large-scale projects funded by foreign companies could disproportionately reduce poor farmers' access to land.

Case Presenters and Panelists

The "Bioenergy and Sustainability in Africa (COMPETE)" case study was presented by Kamal Desai from Marli Investments, Ltd.; Francesca Farioli from Sapienza University of Rome; Jensen Shuma from the Centre for Sustainable Modern Energy Expertise; Helen Watson from the University of KwaZulu-Natal; and, Francis Yamba from the University of Zambia. Comments on the case study were presented by the following panelists: Shauna BurnSilver, Arizona State University; Barry Ness, Lund University; Petra Schweizer-Ries, the University of Applied Sciences in Bochum; and, Makoto Yokohari, the University of Tokyo.

Precautionary Purchasing in San Francisco

This case study provides an example of anticipatory governance for sustainability, specifically the 2005 precautionary purchasing ordinance in San Francisco (City of San Francisco, 2005). The ordinance was the result of a national multi-decade effort legislate the precautionary principle in the U.S. Because the principle was instantiated in purchasing, broad applications became available to the city.

The Sustainability Challenge

The central sustainability challenge in this case was the human health effects (Landrigan, 2002; Muir and Zegarac, 2001) of toxic chemicals dispersed into the environment. Of course, toxic chemicals have a wide range of other effects worth mitigating, such as animal health issues, environmental degradation, and uncertainty about the interactions of various chemicals, to name but a few. However, this case focused on human health effects, and specifically on those that were marketable and difficult to oppose. Strategically choosing which challenges, such as cancer and infant health, would foment legislation was a key factor in the city's success in passing the 2005 precautionary purchasing ordinance. The law has since become a foundation for addressing many ancillary sustainability challenges.

One implicit sustainability challenge within toxic chemical dispersion was the path dependence of risk assessment methodology. Traditionally, the risk associated with an event is the product of the probability it will occur and its impact when it does occur. A high impact and extremely improbable event would be considered low risk. A very low impact and frequent event would also have a low risk. In order to assess risk, both the impact and probability need to be known. Therefore, in traditional risk management, uncertainty about an event's impact or probability of occurring effectively lowers the risk.

Another methodological hurdle was building trust and coordination among stakeholders. Stakeholder participation is a central tenet of sustainability science, and though successful in this case, it was not an easy road. Initially, NGOs played their traditional role as antagonist, despite the city's willingness to pursue shared goals. Overcoming distrust required the city to build relationships with the NGOs over time.

On the resident side, the Department of the Environment held many open meetings to get input from residents on precautionary purchasing. However, few residents attended these meetings, which exemplifies a consistent problem in participatory sustainability science research: stakeholder recruitment. Even when stakeholders were identified and engaged, stakeholder groups had different priorities and vernaculars, making communication a challenge. For example,. researchers working for the Department of the Environment communicated about materials in terms of their toxicity. The city's purchasers focused on the costs of switching suppliers, and end-users were most concerned about whether new materials would match the performance of old materials. Finding solution options that meet the needs of researchers, purchasers, and end-users is no easy task, and takes significant effort on the part of everyone involved. It can be frustrating to bring together disparate actors in interconnected systems, but it is crucial for generating solution options for sustainability problems.

Solution Options

The Bay Area, and San Francisco especially, have a long history of environmental activism, from John Muir's protest against the Hetch Hetchy Dam starting in 1908 to the ongoing Save the Bay campaign. Citizens often advocate for pro-environmental policies and support programs that aim to increase pro-environmental consumer behavior. In many municipalities, businesses work against new regulations, but in the Bay Area, the business community supports progressive policies, such as pro-environmental building codes, recycling initiatives, and energy conservation measures. This agreeability is based on the city's mix of industries, including information technology, biotechnology, and banking and legal services, all of which are highly image conscious. In tandem, their highly-educated employees have progressive political views, and expect high quality-of-life amenities if they are to remain in the Bay Area.

The city benefited from its progressive enabling environment when establishing and implementing the precautionary principle in city purchases. This policy also benefited from a general feature of San Francisco's government: The city and county share the same boundaries, creating similar priorities and less bureaucratic territorialism. Also, the Department of Environment serves as the clearinghouse for all municipal sustainability initiatives. Since one agency is responsible for sustainability initiatives, there are fewer conflicts among government agencies, and less politicking intrudes on program development.

There was a new opportunity for legislating the precautionary principle in 2000, when San Francisco's city government created that Department of the Environment from existing departments. The Department of the Environment has several sections: Zero Waste; Toxics Reduction; Energy, Air Quality and Transportation; Green Building; Green Business Program; Urban Nature; and Environmental Justice. One of the department's initial tasks was writing an environmental code for the city. During this time, NGOs lobbied to include the precautionary principle in the city's environmental code and worked with city officials to draft an ordinance. They drew on existing city and state rules on environmentally responsible purchasing and drafted a city ordinance that would mandate the use of the precautionary principle in city purchasing. As the city spends more than $700 million on products and services (Raphael & Geiger, 2011), the ordinance could significantly influence suppliers. The final draft was complete in 2003, and in 2005, the city passed the ordinance.

The precautionary principle was a new approach to risk management. The precautionary principle treats uncertainty differently than the traditional risk assessment methodology. When information about impacts or probability is unavailable, instead of effectively lowering the risk, the precautionary principle assumes there will be risk, and opts instead for proven safe alternatives or reduced exposure until research can be done.

After the ordinance passed, NGOs gradually shifted their focus to state legislation, and city officials interpreted and implemented the ordinance. City employees initially viewed the ordinance as simply describing existing efforts in new language. That is, the new ordinance did not seem to substantively change their work. However, over time, as precautionary purchasing was championed within the Department of Environment, the ordinance revealed itself as a major shift. The question: "How much exposure to toxics is tolerable?" was gradually replaced with: "Is this exposure necessary?"

This shift in perspective led officials to research and evaluate alternatives to potentially hazardous materials. Department employees with scientific backgrounds and outside consultants were tasked with alternatives assessments that dealt with several criteria, such as performance, durability, and toxicity. Officials used the results to suggest changes in purchasing materials for the city, such as pesticides and cleaning supplies.

Raphael and Geiger (2011) offer many examples of solutions developed under the auspices of the precautionary purchasing ordinance. When data collection in city parks revealed toxics leaching from pressure-treated wood, often used in city playgrounds, the city had a framework in which to act. After conducting an alternatives assessment, the city found that treating the wood with different chemicals for parks led to less toxic leaching, while maintaining the same chemical produced less leaching in seawater. A second example is garment dry-cleaning. An alternatives assessment by city staff led to a capacity building partnership with the California Office of Environmental Health Hazard Assessment, and led to a robust multi-criteria analysis of alternatives to dry-cleaning chemicals. The preferred method became wet cleaning, and the city quickly began outreach and capacity building to dry-cleaners to market the new practice. Of course, the dry-cleaners were resistant to change, but city staff has continued to build trust with implementers, capacity, and comfort with the new technology, as well as again partnering with the state to offer grants of up to 50% of the cost of new wet-cleaning machinery.

The City of San Francisco has had a string of successes partnering with the state of California. In the instance of toxics (phthalates) in children's toys, the city was able to successfully ban the chemical based on similar European Union legislation. This led to a statewide ban shortly thereafter, and then, a national ban (Raphael and Geiger, 2011). The scalability of policy in this case might be based on the strategic marketing choice of unsafe children's toys, and the shame of larger governmental bodies when their subsidiaries outrun them, but it became national legislation nonetheless.

Because purchasing has such extensive reach, the scope of alternative assessments at the city level has expanded beyond ecotoxicology and begun to use life cycle assessment to consider more complicated issues. Life cycle assessment is a method for calculating the environment and social impacts of producing and consuming products and services. For example, the city considers carbon footprint, packaging, sustainable sourcing, and labor practices by vendors. The number of items that the city assesses has increased as well. Initially, the city evaluated low-hanging fruit such as paint, paper, and cleaning supplies. More recently, the city has begun to evaluate items that are more difficult to assess, such as food, vehicles, and city uniforms.

The department tracks purchasers' performance, so the green purchasing program can present annual awards and incentivize changes. These awards and incentives serve help businesses differentiate themselves in the market and improve the program's outcomes.

Open Issues

The most biting commentary on this case was that these are merely "first-world problems." Conference participants worried that this work was not as urgent as many other sustainability concerns in a global context. To the contrary, place-based sustainability science work will always deal with the problems at hand, and in the case of San Francisco, other Department of Environment programs, dealing with waste management and climate change, certainly have positive effects on global problems.

One aspect of this was the potential unintended consequence of the city's ordinance. The rule was a positive contribution municipally, regionally, and at the state level, but what effect might it have globally? If San Francisco's ordinance reduces demand for hazardous chemicals locally, it's reasonable to assume that the suppliers of these chemicals would seek new markets in areas with weaker governance and enforcement. This might mean that San Francisco has outsourced rather than solved its problem.

Lastly, because San Francisco has an especially conducive environment for initiatives such as this one, some conference participants doubted whether it could serve as a model for other cities. The city succeeded not only because of the policy itself, and the Department of the Environment, but also because of the strong support for pro-environmental policies from residents, civil society and businesses. These broader cultural factors are unlikely to be transferrable, and the city's relative wealth certainly makes policy goals more achievable. Yet, though the broader culture may not be portable, the institutional culture of the Department of Environment that embraces collaboration, permeability, and long-term capacity building could certainly be a model for institutions in other environs striving to begin sustainability transitions.

Case Presenters and Panelists

The “Precautionary Purchasing in San Francisco” case study was presented by Independent Consultant Ann Blake; Green Purchasing Programs Manager Chris Geiger from the City of San Francisco; and, Board Member Karen Pierce of the Bayview Hunter’s Point Community Advocates. Comments on the case study were presented by the following panelists: Luis Antonio Bojorquez-Tapia of the Universidad Nacional Autónoma de México; George Basile of Arizona State University; and Mikhail Chester of Arizona State University.

State and Future of Sustainability Science – Insights from Conference Panels and Workshops

John Harlow, Arnim Wiek

Based on the case presentations and panels, ICSS 2012 offered all conference participants to engage with the case studies more in-depth through facilitated breakout group discussions. The purpose of these small-group discussions was exchange and learning between conferees. The three case studies functioned as the platform for exchange, transfer, and learning about the current state and future directions of sustainability science. Facilitators and note-takers were prepared and coached to work with a set of relevant questions, derived from sustainability science literature prior to the conference. A broad set of more than 30 guiding questions were proposed and the facilitators were encouraged to flexibly use these questions depending on their group's experiences, competence, and interests.

The facilitated breakout group discussions were documented and later analyzed. We present here four brief synthesis essays on topics that were deemed by the conferees as particularly relevant to the current state and future of sustainability science. All essays are structured as follows: short justification of the importance of the issue; followed by summarizing deficits and challenges (with case examples); followed by reporting on innovative approaches that attempt to overcome the identified deficits and challenges; and concluded by outlining what remains to be done.

Developing and Implementing Sustainable Solutions through Collaboration between Sustainability Scientists and Society

Sustainability science is a problem-driven endeavor to support societies around the world faced with urgent problems that stretch across scales, sectors, domains, and actors. ICSS 2012 examined diverse cases, and brought some of their principal actors to the conference to directly address the role of sustainability science in their efforts to mitigate and resolve such problems. The cases brought forth a variety of sustainability challenges, including: degradation of socio-ecological systems in the Yaqui Valley, Mexico; primary and secondary disaster impacts on society, economy, and environment from the Great East Japan Earthquake, and resulting tsunami and nuclear meltdown; poverty, lack of quality of life, and environmental degradation in rural regions of Africa; and overuse of toxic chemicals in San Francisco. All of our cases showcase problems beyond the ken of a single discipline or organization. Solutions to these and other sustainability problems therefore require a suite of concerted efforts across disciplines and actors. Such collaborative efforts among sustainability scientists, stakeholders, and the public are considered critical for making progress in the transition to greater sustainability (Blackstock et al., 2007; Talwar et al., 2011; Lang et al., 2012; Clark et al., in press). In each case, solution options were the goal, but the cases were in different stages of collaboration and employed different participatory settings. The variety of stages and settings offered attendees the opportunity to examine and compare how different approaches pursue the development and implementation of solution options – and to tease out general factors of success and failure.

In the Yaqui Valley case, multi-decadal relationships between academics and stakeholders built the foundation for eventual success. The San Francisco case also displayed long-term relationship building between government, non-profits, businesses, and citizens [Raphael and Geiger, 2011]. In contrast, the Japan case is still transitioning from disaster relief to reconstruction and recovery, and just beginning to build relationships between academics, government, and local stakeholders in affected areas. In the COMPETE case, collaboration happened on multiple levels (from international to local); the collaboration between academics who identified appropriate areas for biofuel development and local implementers was most successful where local networks were ready to begin work right away. Solution-oriented sustainability science has begun to utilize such collaborative partnerships to move from science of problem identification and analysis toward a science of solution options that is motivated by eventual change towards sustainability. However, as Michael Crow pointed out in his keynote address and as discussed in the conference's workshop sessions, such a novel type of science that is based on a moral imperative that strives for real-world solutions faces many obstacles and barriers, including challenges of funding schemes, academic recognition, transferability, scalability, mistrust, and cultural sensitivity.

Financial support for this type of transformational research, for example, is still limited and does not follow traditional funding schemes. Pamela Matson's Yaqui Valley case study is a good example of this, as a web of funding from a variety of sources was required to continue the project over two decades. Sustainable solution options require implementer and stakeholder involvement throughout the research process from problem definition to methodology selection, research undertakings, and monitoring of implementation (Talwar et al., 2011). Such depth of relationship-building takes years, and the lack of financial support for this kind of work can make it unattractive to otherwise motivated researchers, in particular junior faculty. This is part of a greater challenge for academic research where tradition, reputation, and incentives do not encourage or even require academic pursuit of stakeholder engagement in solution-oriented sustainability research.

Another challenge is transferability of research results (solution options). In the case of San Francisco, a coalition of motivated stakeholders pushed toxic chemical policy at the city level with a progression of successes. However, the transferability of San Francisco's successes may be limited by the unique context, politics, and culture of the city, as well as its relative wealth. Similarly, scaling up creates significant challenges for certification, validation, policing, and enforcement, as regulatory and political environments can differ greatly. Sustainability science's place-based focus seems to limit transferability and may make it difficult to develop scalable and portable solution options (Lang et al., 2012).

The COMPETE case also offers a few instructive examples. Excellent GIS research took place in identifying areas for potential biofuel development. However, though the research was exemplary academic work (Wicke et al, 2011), Helen Watson showed clear evidence that the data analyzed was not complete (e.g., pastoral land-use not in the database) and not at a fine-enough grain to be entirely relevant. Biofuel development policy designed to support local initiatives was to comprise later stages of the COMPETE process, in order to spark new economic opportunity in many African countries. Yet, this top-down solution had low relevance to many potential implementers, because they lacked local knowledge and experience growing and processing biofuels, as well as the infrastructure to use biofuels (Romijn and Caniels, 2011). The alternative of development for export suffered from political influence on the dispersion of profits and benefits from implementation. This begs the question of whether top-down goals, such as European Union research designed to implement policy in Africa nations, will be as relevant and impactful as solutions at the community and household level where those policies are implemented.

In the Japan case, finally, the line between disaster relief, disaster research tourism, and sustainability science can, unfortunately, be grey, which might result in mistrust and resistance to collaborate. The research institutions and governments responsible for calculating risk levels for infrastructure and communities, in particular, may not be trusted, meaning that sustainability scientists must find more effective ways to communicate risk and uncertainty (Faulkner et al, 2007). Similarly, distant research institutions must build trust with people in affected areas, to ensure effective engagement, maximum transparency, and authentic cultural continuity of sustainable solution options.

These discussed obstacles for solution-oriented sustainability science are but a few of many. However, our conference cases also display innovative approaches to overcoming such barriers. In fact, many of the obstacles exemplified in one case are addressed well in another. The San Francisco case provides a useful instance of building trust within a participatory collaboration. The city administration was able to work with community groups, cancer-oriented non-profits, academics, and consultants over a decade to reduce toxic chemicals in the municipality (Raphael and Geiger, 2011). The non-profit and community groups began their involvement with the anti-toxic chemical movement because of their interest in fighting cancer. Their historical relationship with the city had adversarial and aggressively pushed policy reform. In this instance, however, the city was in agreement that toxic chemicals were undesirable. So, the first hurdle, which was time consuming, was to build trust between the city and new allies, a process that required in-depth stakeholder engagement. Once trust was built, the partners were able to move forward and select issues of common concern around which to build their case for using alternatives to toxics, instead of relying on communication of exposure risks.

Long-term funding, though a significant hurdle, may be available in the Japanese case based on the significance of the need. The University of Tokyo has plans for in-depth student sustainability science research on many of the reconstruction and recovery issues, and the government of Japan has expressed support for sustainability to be a primary design criterion in rebuilding affected areas. In other contexts, Steven Mannell from Dalhousie University suggested seeking funding for education, rather than specific projects, as education funding is long-term by its nature, and certainly can support a variety of sustainability science work under its auspices. In the San Francisco case, funding for the Department of Environment has been allocated from trash collection pricing, outside the politics of municipal budgets. This has provided a consistent and reliable budget for the department to take on multi-year projects. One result of this has been the ability of precautionary purchasing to generate alternatives assessments from academics and consultants, make sure the purchases work with the city's accounting and bottom line, and then ensure end-users of products (such as janitors with new cleaning supplies) are satisfied with product quality.

In the COMPETE case, biofuel development policy was the strategic goal throughout, leading to modular policy recommendations that were adapted for each national context, instead of repeating the core of the process. Transferability and scalability are essential factors to consider early in research design. Sophisticated collaborative schemes can help bring together local interests identified by stakeholders and the public, vis-à-vis general insights and broader applications pursued by academics (Lang et al., 2012). COMPETE also worked to scale projects, finding sufficient land and local expertise to develop jatropha at the necessary economies of scale to make export possible (Romijn and Caniels, 2011). Similarly, the Yaqui Valley case worked to scale best practice recommendations from academic work to Valley-wide standard procedures (McCullough and Matson, in press).

The case studies from ICSS 2012 exemplify the current state of solution-oriented sustainability science research, highlighting opportunities for improvement, and offering examples that might support such improvements. However, to produce and implement solution options to the problems societies face around the world is a massive task, and much remains to be done in the pursuit of research that is committed to developing solution options (and supporting their implementation), continuously builds researchers' and stakeholders' collaborative capacity, and is respectful and sensitive to cultural contexts.

Institutional Structures for Sustainability Science Research

With over 100 diverse researchers and practitioners present, ICSS 2012 engaged existing institutional constraints in sustainability science, outlining barriers to effective research and practice, as well as preferred structures and undertaken innovations for future work. Sustainability science has, thus far, happened within institutions (sets of rules) built for traditional research and pedagogy. With its innovative approaches it challenges established institutions (Wiek, 2008). Historically, academia has largely been oriented towards curiosity-driven, basic research (that claims value-neutrality); has rewarded knowledge production and publication with tenure and reputation; and has followed a unilateral educational model, in which students receive information as the primary mode of learning. In concert, funding bodies articulate their research framework programs within these dominant paradigms. These practices are deeply ingrained in the practice of higher education, and have proven resistant to change.

However, sustainability science purports to develop solution options to problems embedded in real-world practices and communities, and is therefore not well served by these institutional structures. In his opening keynote address at the ICSS 2012, Michael Crow identified a key mechanism of traditional academic work hardly conducive to sustainability science's solution orientation: "Universities […] would do research and we would teach students and we would do science and hopefully somebody would do something with that." Traditional academic structures and incentives produce research, students, and impacts, without explicit articulation and connection to solution options that are *actionable*. In a similar vein, Michael Crow identified sustainability science as a moral pursuit. Science with a normative aspect is in stark contrast to the objective pursuit of truth generally ascribed to science. Finally, sustainability science comes with strong participation and co-creation components, which means that students need to be learning skills in public communication, facilitation, and negotiation, as well as co-creating ideas, practices, and knowledge in real-world learning settings. Sustainability science connects research activities to real-world uses, brings values into scientific work, and asks professors to instill unfamiliar skills in students through collaborative and engaging pedagogies – and none of these innovations comply with current publication practices, tenure, and promotion criteria.

To build long-term relationships with stakeholders requires new commitments from academic institutions and funding bodies. Much like the diversity of funders exemplified in both the COMPETE and Yaqui Valley cases, a network of funding supporting various endeavors can sustain the long-term embedded work emblematic of sustainability science. Steven Mannell from Dalhouise University, a conference attendee, suggested connecting such funding directly to education, as that mission has more permanence than project-based funding. Connectivity between various institutional actors, funding bodies, and stakeholder representatives is the collaborative environment described in the field's literature, and sustaining such funding can provide more time and resources for collaboration. This is crucial, as time and capacity building for communication and synthesis across institutional and disciplinary boundaries is one of the primary means to pursue the ambitious goals of sustainability science research. However, when sustainability scientists have to create funding network, it requires heavy investment of time for application and reporting, as well as overlapping areas of investigation, or gaps in support where resources are most needed. Pamela Matson's case study in the Yaqui Valley is a successful example of the creation of a funding network, but one that that provided for multi-decadal work in three-year bursts. The uncertainty and patchiness of funding for sustainability science projects is a significant barrier to incentivizing faculty design and support of such projects.

Of particular interest at the conference, and in the context of the Japanese case study, was whether universities can be equally engaged in distant and local communities? Rural areas have fewer universities, and lower educational achievement, but this may not be the case in the future. Given emerging information technologies and rapid deployment of online education, knowledge systems in rural areas have opportunities to rapidly make up ground on urban areas. In Japanese reconstruction following the triple disaster, new infrastructure could leverage rural education opportunities with high speed internet, ongoing sustainability science project- and problem-based learning projects, and connectivity to urban areas that helps mitigate the rural-to-urban migration that siphons youth and education from rural communities. The sustainability science program at the University of Tokyo is investigating some of these solution options as well as studying the effects of the tragedy, in order to rebuild communities with greater resilience. However, there are major cultural differences between Tokyo and the affected communities, and the lack of local presence and embeddedness was highlighted by Mr. Hatakeyama during the breakout group session. When he was asked what he would do with reconstruction funding his reply was that he would bring everyone from the conference to the disaster site. This clearly indicates the strong conviction that real understanding is not possible without experiencing the place in person, which is well recognized in participatory research literature (Talwar et al, 2011; Lang et al., 2012). Of course, even researchers who do site visits can sully their names and the names of their institutions, if they go casually or without solution orientation and local collaboration. Sustainability science's clear focus on public participation and the development of solution options helps avoid research tourism, as well as ensures the provision of relevant knowledge. These factors will be crucial to the University of Tokyo's success in aiding with reconstruction, and Mr. Hatakeyama's presence at the conference to represent fishing communities helped identify what knowledge would be locally relevant, in particular expressing that radiation levels were a primary concern.

This begs the question: What institutional structures are needed for sustainability scientists to embed themselves in place-based contexts, equipped with participatory and solution-oriented research expertise? The sustainability programs at Arizona State University and Leuphana University of Lüneburg have begun to experiment with such settings, building connectivity to the surrounding communities and throughout the universities (Lang and Wiek, 2012). This too presents challenges, because so many actors and specific context components are relevant to sustainability that transferability can be very low. Sustainability science needs to continue identifying frameworks to evaluate sustainability science knowledge and skills, both to track student progress and to demonstrate the field's added value across relevant disciplines and communities of knowledge (Blackstock and Carter, 2007; Talwar et al., 2011; Wiek et al., 2011b). Within such frameworks, sustainability science can mature as a genuine field, add value to relevant disciplines as a focus area, and become a university-wide touch point. These various levels of engagement with the field could be predicated upon the degree of competency development, ranging from basic throughout a university, to technical in relevant disciplines, and holistic for majors and graduate degrees (Wiek et al., 2011a). The institutional structures necessary to build out this new type of sustainability literacy and expertise do not yet fully exist but are now continuously evolving (Ferrer-Balas et al., 2010; Whitmer et al., 2010; Yarime et al., 2012). Pedagogical techniques and incentives for initializing and maintaining advanced educational settings are still under development. These settings are critical for the embedded nature of sustainability science work, as well as for giving students opportunities to explore and expand their sustainability competencies and experiences.

Sustainability science education in particular bears significant opportunities for embedded project- and problem-based learning experiences (Brundiers and Wiek, 2012). Strong collaborative partnerships for sustainability research and education have been developed Between Arizona State University and the City of Phoenix as well as between Leuphana University of Lüneburg and the City of Lüneburg (Lang and Wiek, 2012). The University of Tokyo is creating opportunities for international graduate students to do work in disaster-affected areas through their International Intensive Program on Sustainability (Onuki and Mino, 2009). Stanford graduate students have worked in the Yaqui Valley for decades (McCullough and Matson, in press). The innovative approaches employed by these universities and others can be instructive for other academic institutions committed to sustainability and for future work.

Education in Sustainability Science

The pedagogies used in most academic settings are unilateral methods of delivering information from professors to students. Sustainability science, on the other hand, emphasizes collaborative efforts throughout the research process (Brundiers et al., 2010; Wiek et al., 2011a). This principle embraces close collaboration between professors and students, and can include curricula, syllabi, research design, and solution implementation (Yarime et al., 2012). It also implies a much more robust role for students in their own educations, and moves the pedagogy into a more experiential space (Sipos et al., 2008). Within that space, students are enabled to develop skills and competencies specific to solving sustainability problems, skills and competencies that academia has not traditionally focused on. Using different pedagogies to develop new abilities in students is critical to tackle problems that confound the scope, capacity, and descriptive-analytical purpose of traditional disciplinary research.

Taking a broad view of the academic experience of students, a solution focus is not overly present (Van der Leeuw et al., 2012; Yarime et al., 2012;). Students are primarily expected to process information that might enable them to better understand problems and systems – but not to envision changes and develop evidence-based solution strategies through rigorous research. But, sustainability scientists do not only research the change process. They try to be deeply embedded in the change process, collaborating to develop and implement solution options. These settings are most conducive to facilitate student participation in solution option development in increasing intensity throughout student education. However, for student participation to be meaningful, students must be prepared for success, which requires more than topical knowledge and general methodological familiarity. It requires specific competency development, and though researchers have identified relevant competencies (Wiek et al., 2011a), the pedagogies to deliver those competencies, as well as tools and frameworks to evaluate competency levels and development over time, are still lacking.

One significant departure from traditional academic settings implied by sustainability science is the adoption and further development of participatory and collaborative approaches (Robinson, 2008; Yarime et al., 2012). As an example, in the Japanese case, suicide became a significant issue after the triple disaster. Academia and sustainability science are historically ill equipped to recognize and/or address emotional problems, especially such a delicate and traumatic issue for the families. Clearly, working in distressed communities requires sensitive approaches that discover and acknowledge the importance of people's emotional states, as well as prepares researchers to empathize. To help traumatized communities, researchers must listen empathetically, share sustainability principles with cultural sensitivity, facilitate co-creation of lifestyle visions, and design and implement interventions that move toward those lifestyles in an iterative process. Though often considered "soft" skills, empathy, sensitivity, and facilitation are crucial to working with communities to solve problems.

A similar competency gap continues to exist in working across academic disciplines. In the COMPETE and Yaqui cases, international development was the paradigm for research. However, international development is rife with failure, and offers few transferrable successes. Would researchers have been better positioned with stronger anthropological, ethnographic, and historical analysis? Of course, these factors and many others were components within the Yaqui and COMPETE cases. However, the funding and time necessary to bring together disparate disciplinary experts into a high-functioning and effectively communicating team was difficult to acquire and sustain. Even when resources were available, the training of academicians makes communicating and collaborating across disciplines troublesome, due to differing epistemologies, methodologies, priorities, language, and definitions. To instill a greater facility for and interest in the interdisciplinary work expected of sustainability science requires a more sophisticated pedagogy of collaboration (Oberg, 2009).

The San Francisco case offers excellent examples of what could be very successful pedagogies for solutions. One of the main strengths of the city's sustainability work is the flexibility of the Department of Environment to take on a breadth of challenges, and the focus to attract appropriate resources to address those challenges. Academic work can be relatively broad, and tends to stop short of creating actionable knowledge. However, through academically trained consultants and scientists, San Francisco is able to efficiently marshal extremely specific research in order solve problems. If universities evolved institutions with similar flexibility in concert with focus and specificity, those institutions might be the perfect home to host action research that gives students experience with implementing solutions. A nascent example for such innovative academic institutions is the Walton Sustainability Solutions Initiative at Arizona State University (http://sustainability.asu.edu/walton/).

Of course, universities confront a host of other pedagogical challenges presented by sustainability science. One duality in the field is the tension between specialists who do topical or otherwise confined research, and generalists who connect research with users or link disparate disciplines. This issue has been the subject of bureaucratic experimentation. Mainly, universities have been distributing sustainability throughout curricula, as a minor, or addendum to an existing degree. However, in the universities partnering in the International Network of Programs in Sustainability (NEPS) that were all represented at the conference (see Appendix), sustainability has been centralized into central units with comprehensive sustainability programs and stand-alone degrees. There are other novel models such as the University of British Columbia's Center for Interactive Research on Sustainability (CIRS) (http://cirs.ubc.ca/). Obviously, centralization tends to produce generalists, while distributed sustainability tends to produce specialists. These two systems both have strengths and weaknesses, and should be used synergistically to create new pedagogies that help students to develop the individual and collective skills necessary to solve complex sustainability problems.

At the graduate level, students are often at the mercy of funding. That is, students choose their research based on what resources are available to support their work. In this model, there is no criterion aimed at putting the best students to work on our most urgent and difficult problems. Rather, the areas with political and financial support attract the best students. This is predicated on various funding streams being tied to specific outcomes and research agendas decided by funders. One alternative, carried forward at Lund University, is to fund all students equally without specifying their work. This structure gives students the chance to pursue the most pressing and relevant problems, by learning appropriate methods and content knowledge. In contrast, graduate methods training based on the predilection of funders can often track someone into an entire career not focused on urgent sustainability issues that demand evidence-based mitigation and solution strategies.

To solve our most time-sensitive sustainability problems, we could marshal the efforts of the entire education system (Crow, 2010). This would require linkages between various education levels, a culture of collaboration among disciplines, capacity building in interpersonal skills, and a pedagogy of experience that uses real-world sustainability problems as the setting for education (Rowe, 2007). This would be a major departure from the current educational model, and would encourage universities to build new centers to host such innovative work. In kind, funding for long-term work focused on solutions would have to be available to support student and faculty research in areas that may not be profitable financially. The pedagogies we need to solve problems leave behind unilateral lecture models and the trappings of historical funding bodies and academic institutional constraints. They are pedagogies of experience, collaboration, and communication. They prepare students to work with people, understanding history, culture, power, and emotions as tools to build trust, facilitate co-creation, and solve problems.

Politics and Power Dynamics in Sustainability Science Research

At ICSS 2012, Joseph Tainter from Utah State University framed sustainability with four questions: Sustain what? For whom? For how long? At what cost? (Tainter, 2003). These questions became a touch point throughout the conference, and are central to the politics and power dynamics of sustainability science research. Because what to sustain, for whom, for how long, and at what cost means choices, and there will be winners and losers (Talwar et al., 2011). Historically, the powerful and politically articulated interest groups have used their status to become and remain the beneficiaries of such choices. In many cases, this does not produce sustainable outcomes.

The Yaqui Valley case offers an example (McCullough and Matson, in press). Although credit unions held most of the financial power, it was initially unbeknownst to researchers that they used that power to influence the decision-making of farmers' fertilization practices. Researchers began capacity building with farmers to use fertilizer more strategically, in attempts to reduce overuse. However, credit unions advised farmers to apply increasing amounts of fertilizer in an attempt to minimize risk. Thus, what was sustained, fertilizer overuse, was determined by the power dynamics of the Yaqui agricultural system, and not by researchers, who, in the interest of the public and future generations, aimed at sustaining marine ecosystem and soil integrity, which had been suffering from excess nitrogen run-off.

Sustainability has often been discussed as having a "triple-bottom-line" of environment, society, and economy. The question "Sustain what?" creates obvious tensions and trade-off constellations between these three systems (Gibson, 2006), because the dominant answer historically has been prioritizing the economy. Michael Crow identified sustainability science as value laden, in this case, specifically elevating environment and society to equal status with the economy. Yet, this is insufficient to balance power. Cultural continuity should be a priority equal to economic, environmental, and social factors in sustainability science. In practice, this can become very complicated, especially because what is sustainable for society may not be sustainable for specific cultures.

In the COMPETE case, potential biofuel implementers worried that they would lose control of their culture if they switched their crops to an unfamiliar industrial system reliant on the vagaries of export markets. On the ground, such solutions can appear to be an exportation of Western forms, culture, and values. In the Japanese case, exported values came not from the West, but from the cities, where power, money, and decision-making is centered. Small rural communities with long, rich histories resisted relocation in the aftermath of the disaster because of the detrimental effects relocation would have on their cultures. Both of these examples showcase how what is "sustainable" for society at large, i.e., biofuels to substitute for fossil fuels and lower costs for relocation than rebuilding, are not how rural communities would answer: "Sustain what?" The San Francisco case offers nearly the opposite example. San Francisco has managed to achieve many successes in the reduction of toxics (and many other areas), but is this work transferable or relevant to less affluent places? These are the frontlines of the discussion of the role of culture in sustainability, especially because it is not explicit in the oft-touted triple-bottom-line. The key point to recognize is that, the world over, cultures without power are not merely subsumed into market-driven Western structures, but also fall prey to what is considered desirable to sustain by political actors and the powerful. Is sustainability doing enough to acknowledge and support cultural continuity? Is research in affluent places relevant to our most pressing problems? Are solutions aimed at global or national problems sustainable for localized and less powerful cultures?

One way to empower localized cultures is to begin sustainability science work from the bottom and work up (Smith et al., 2009; Lang et al., 2012). For example, stakeholder engagement and embedded research by the University of Tokyo in areas affected by the triple disaster has led to ideas the government might not have conceived on its own. In particular, finding out from fisherman what is most important to them (water radiation levels), learning how committed local villages are to their place-based culture, and considering semi-permanent university infrastructure on site has empowered localities to be meaningfully involved in reconstruction decision-making.

In the COMPETE case, local politics had the potential to impact biofuel crop siting, refinery and other processing facility ownership, and profit sharing between laborers and land-owners. Kamal Desai addressed many of these issues, describing the process that his business uses to develop biofuels. The former president of Zambia sits on the board of Marli Investments, lending creditability to the organization. This is crucial for outreach to tribal chieftains who singlehandedly decide whether to make suitable lands in the territory available for development. With trust based on Marli's successes, and the credibility of a former president, chieftains are willing to negotiate, and convert some land to biofuel production. Knowledge of local politics and power dynamics is the only reason that Marli Investments has been able to introduce new crops and refining infrastructure to villages unfamiliar with biofuel technology and its uses. While it may seem foreign to consult chieftains about economic development, it is culturally appropriate and effective in this context, and makes Marli Investments one of only a few successful biofuels projects coming from COMPETE's top-down policy development.

A critically important factor in understanding power and politics is time. Often, much political complexity lies beneath the surface that appears simple at first glance. In the Yaqui Valley case, decades of funding, academic work, and relationship building were necessary to determine the politics of the place and locate strategic intervention points where sustainability scientists could introduce best-practice for fertilizer conservation without resistance from the Valley's political and power structure. Even mapping the networks that influenced farmer's decision-making took years and multiple iterations, just to identify the stakeholders necessary to have at the table for effective solutions to be implemented.

In the San Francisco case, the city itself has political champions (mayors) of sustainability, and the liberal politics of the place have brought businesses willingly into the sustainability discourse. The city's Department of Environment is responsible for many of the city's successful sustainability initiatives, but ideas for those initiatives can come from the mayor, citizens, businesses, or within the department. Broad acceptance of sustainability goals and the permeability of the Department of Environment have created a flexible and innovative space for sustainability transitions. However, politics is ever a factor in city government. One key example of this is that funding for Department of Environment programs comes from specific taxes, such as a waste management pricing scheme that incentivizes diversion from landfill to recycling and composting waste. This funding is not annually subject to the city's political machinations, and this forethought has allowed for sustained funding that gives the Department of Environment the security to pursue long-term goals, such as zero-waste.

The ICSS 2012 cases all have various layers of politics and power. Academic work, especially problem identification and analysis, has often failed to adequately address power and how it contributes to problems (Jerneck, et al., 2011). This failure in problem definition constrains solution space, because if the true power behind a problem is not present in the definition of the problem, the solution will not address that power. Sustainability science must explicitly address power and politics in defining problems and developing solution options if those options are to be effective and relevant – and initial attempts have recently been undertaken (Jerneck and Olsson, 2011; Voß and Bornemann, 2011). In particular, the participatory component of sustainability science is only meaningful if the power dynamics between stakeholders and actors are explored and acknowledged. If sustainability science is going to solve problems, it must explore politics and power dynamics, and negotiate solution options that answer the questions: Sustain what? For whom? For how long? At what cost? not only on behalf of the powerful, but also on behalf of the marginalized.

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Appendix

Keynote Speakers

Case Presenters and Panelists

Conference Participants

Conference Organization

PhD Students Session

International Sustainability Programs

Videos