The Circular Economy: Regulatory and Commercial Law Implications

Summary

Many have put forward a vision for a "circular economy" that would not only conserve and recycle materials, but also contribute to new technological, financial, and environmental innovations. As this circular economy approach gains traction, adjustments to our system of regulatory and commercial law will be needed. For lawyers and their clients, the circular economy represents a new and important thought construct that will lead to legal frameworks better adapted to the 21st century. On February 23, 2016, the Environmental Law Institute and the ABA Section of Environment, Energy, and Resources co-sponsored a day-long seminar that looked at the circular economy and how it is being applied at the intersection of energy, environment, and materials management. The panelists also discussed some of the specific regulatory, procurement, financial structuring, and other legal initiatives that are emerging to help actualize its objectives globally. Below, we present a partial transcript of the event, which has been edited for style, clarity, and space considerations.

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I. The "Circular Economy" Concept

Ira Feldman: Let's start with an overview summary. In response to resource constraints, environmental pressures, and economic barriers that characterize our take-and-dispose economy, many have put forward a vision for a circular economy that would not only conserve and recycle materials, but also contribute to new technological, financial, and environmental innovations. As the circular economy approach gains traction, with noteworthy advances in the European Union, China, and the United States, it is becoming increasingly clear that adjustments to our system of regulatory and commercial law will be needed to further progress.

This Dialogue acknowledges that the circular economy is not just another buzzword or slogan, but instead is a serious approach to supplant the way global production and energy systems operate. For lawyers and their clients, this represents a new and important thought construct that will lead to legal frameworks better adapted to the 21st century. The purpose of today's discussion is to explain the meaning of the circular economy and how it is being applied at the intersection of energy, environment, and materials management, and to present some of the specific regulatory procurement, financial structuring, and other legal initiatives that are emerging to help actualize its objectives globally.

I'm going to start with an overview, and then I will turn to Reid Lifset. Let me start with my perspective on the circular economy and a potential title for my presentation: "The Circular Economy Operationalizes Sustainability." For those who have been immersed in sustainability—and I am an environmental lawyer and a sustainability professional—sustainability is the integration of environmental protection, economic development, and social justice.

In the 15 years since the demise of the President's Council on Sustainable Development, there has been scattered progress in the United States through executive order, National Academy of Sciences reports, and the good work of the U.S. Environmental Protection Agency's (EPA's) Office of Research and Development. But it's been frustratingly slow progress for those of us who see sustainability as the organizing framework for the 21st century in law and policy. Perhaps the circular economy with its triple-bottom-line orientation can advance the sustainability state of play.

But, as a sustainability professional, I recognize that sustainability is not everyone's cup of tea. So, I offer another perspective and title for my presentation: "The Circular Economy Operationalizes Industrial Ecology." We're going to hear much more on industrial ecology from our other panelists, including Reid. What I have observed over the past few years is that, despite the good work by Reid and others, the reuse of waste resources championed by Andy Mangan of the U.S. Business Council, and EPA's embrace of materials management, industrial ecology has always been oddly disconnected from our legal and regulatory system. Perhaps the circular economy provides a path forward for utilizing the industrial ecology concept.

For those who were not excited by either of my first two suggestions, may I suggest: "The Circular Economy Operationalizes the Next Generation of Environmental Law and Policy." The Holy Grail for those of us in environmental law for the last 20 years has been the next generation of environmental law and policy. I don't think it's an overstatement to say that the circular economy has attracted a great deal of interest because, for those of us in the Environmental Law Institute and ABA-SEER orbit, the circular economy may be a way to achieve that Holy Grail. Again, there has been frustratingly little progress moving beyond our 1970s air, water, and waste framework of federal statutes. Perhaps the circular economy, with its systems approach, cross-media approach, and sector-specific approach, represents the path forward for the next generation of environmental law and policy.

To provide some context, I think we're all aware that our present state of play is a linear economy in which natural resources are extracted from the ground, made into products, used, and thrown away. This has been a highly successful approach for economic development during the 20th century, but in recent years, we've been looking for alternative approaches that can work in the long term because economic growth in "business-as-usual" mode is increasingly challenged. Some of the factors at play are not only environmental factors, as evidenced by the Millennium Ecosystem Assessment[1] and the Economics of Ecosystems and Biodiversity Initiative,[2] which have documented the accelerated depletion of ecosystems, but also the increasing demand for goods and services. The challenges of meeting the increasing demand for goods and services will be unprecedented with upward of nine billion people on the planet by 2030.

Another overlooked factor in the background context is the recent volatility in commodity prices, which can have a devastating impact on companies that, due to high fixed costs, rely on economies of scale. Commodity prices rose more than 150% in the eight years between 2002 and 2010, erasing average price declines over the past century.

To give credit where credit is due, a lot of the thought leadership on this issue derives from the work of the Ellen MacArthur Foundation, which has issued a series of reports on the circular economy starting in 2012. Earlier this year, they released another report providing a roadmap for the circular economy.[3] Some of their preliminary research shows that moving in the direction of a circular model could lead to significant economic benefits for specific industries. In particular, the circular economy approach can relieve some of the pressure on resource supply, commodity prices, and volatility while at the same time replenishing natural capital for the provision of food, feed, and fiber.

Why has the circular economy been gaining traction in recent years? Well, I think it's the combination of both the business benefits and the positive societal and environmental impacts. One could translate that to a triple-bottom-line approach. Many companies see the circular economy as a viable model to successfully tackle their sustainability challenges, to drive performance competitiveness and innovation, and to stimulate economic growth and development.

Figure 1, a graphic produced by the Ellen MacArthur Foundation and utilized in its reports, represents the circular economy model showing an industrial system restorative by design. Given the complexity of this so-called butterfly slide, we will hear more from other panelists on the various concepts and principles that are part and parcel of this circular economy graphic.

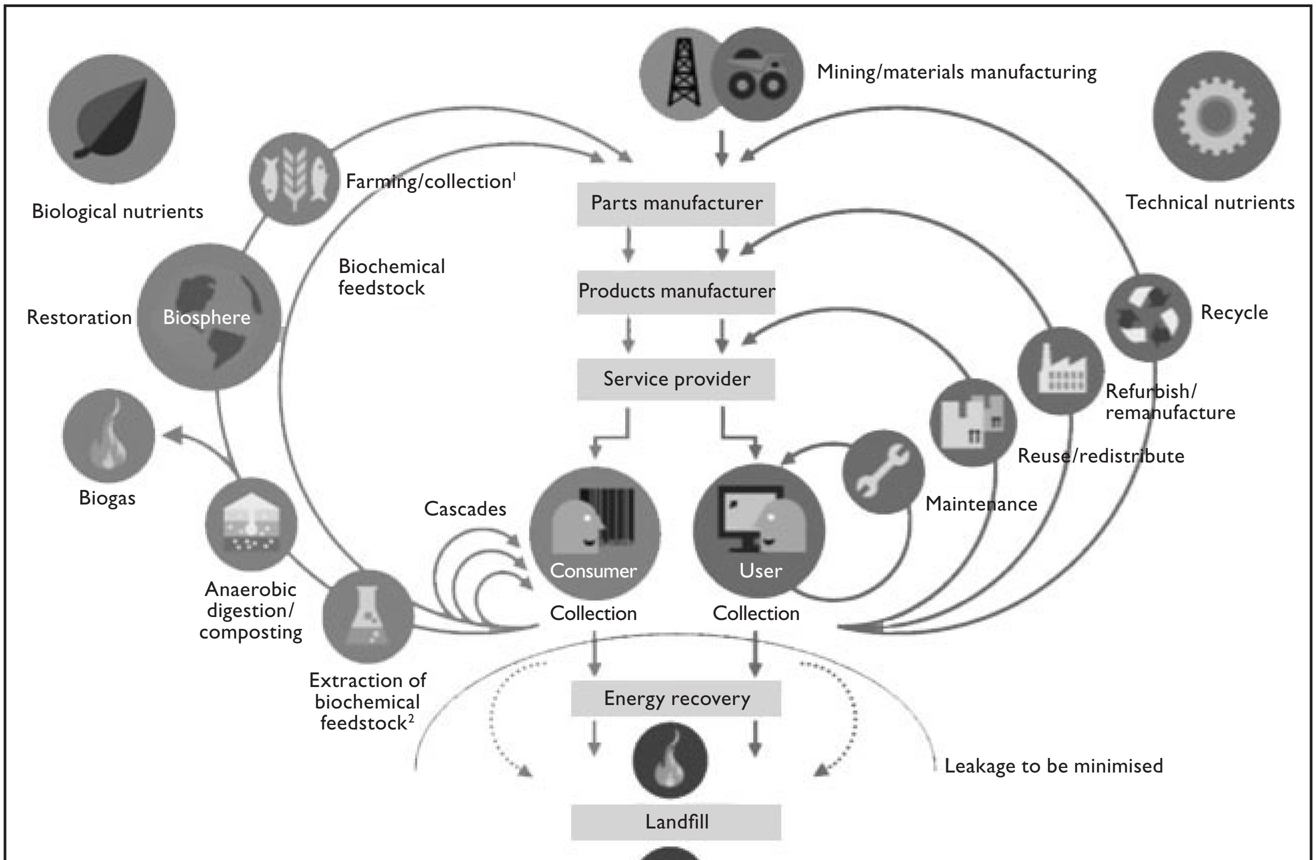
But for the basics, let me just start. The circular economy system is generally regarded as regenerative and restorative. It primarily relies on optimizing two distinct material flows: biological and technical. The products and services are designed to enable efficient circulation. Biological materials are returned to the food and farming system and rebuild natural capital. Technical materials are kept in production and use loops without the loss of quality. I always look for the shortest and most memorable definition for any new concept, and my suggestion for the definition of circular economy is this quote from Walter Stahel, who was the leader in the performance economy school of thought. For him, the circular model is "the goods of today become the resources of tomorrow at yesterday's prices." It's hard to beat that summary.

To take it a step further, the circular economy is restorative or regenerative by design, and the key principle is that products, components, and materials are kept at their highest value at all times. The system intentionally designs out waste to use as few resources as possible to begin with, to keep those resources in circulation for as long as possible, to extract as much value from those resources, and then to recover and regenerate those materials and products at the end of their useful life.

Taking it another step further—and I will not go into detail here, preferring to let my colleagues take on that task—the rule of optimization in moving from linear to circular approaches is that the tighter the reverse cycle, the less embedded energy and labor lost and the more materials preserved. Circular design, which many of us assume that we understand, when you break it down, really means using standardization, modularization, pure material flows, and design for easier disassembling. Another key concept

1. The Millennium Ecosystem Assessment was initiated in 2001 to assess the consequences of ecosystem change and the scientific basis for actions needed to restore or enhance the sustainable use of those systems and their contribution to human well-being. *See* http://www.millenniumassessment.org/en/index.html.
2. The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative designed to "mainstream the values of biodiversity and ecosystem services into decision-making at all levels," and to demonstrate how to value their benefits in economic terms. *See* http://www.teebweb.org/.
3. Ellen MacArthur Foundation and World Economic Forum, Intelligent Assets: Unlocking the Circular Economy Potential (Feb. 8, 2016), *at* https://www.ellenmacarthurfoundation.org/publications/intelligent-assets.

Figure 1: The Circular Economy



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input
Source: Ellen MacArthur Foundation circular economy team

that can help one appreciate the distinction between linear and circular approaches is understanding the distinction between "efficiency and effectiveness.".

So, let me start to sum up by saying that many people assume that the circular economy is the equivalent of recycling. Recycling is a fundamentally important concept, but that doesn't do justice to the circular economy concept. Circular economy is not recycling on steroids. The circular economy is lots of things, as we will learn in the course of today's discussions. There are these clusters of concepts and approaches such as sustainable business practices and corporate social responsibility, ecosystem services and natural capital, product takeback and designing for remanufacturing, the McDonough-Braungart cradle-to-cradle approach, and biomimicry.

There's been a long history of eco-industrial parks as part of the circular economy. We will hear more about industrial ecology and closed-loop manufacturing, a key component of the circular economy. But there are also newer approaches. Some of you may have heard of the sharing economy and product-service systems. All of this is being driven by advances in information technology and pervasive changes in consumer behavior.

I also want to flag the contribution of the U.S. Chamber of Commerce Foundation, which ran a major event last year and produced a significant report focusing on U.S. companies.[4] Many companies are actively pursuing models that decouple economic growth from resource constraints as alternative approaches to the linear take-make-waste model. The companies highlighted in the U.S. Chamber report included Hewlett-Packard, Philips, Tetra Pak, and SunPower. Going back to the Ellen MacArthur Foundation, their founding partners included corporate entities such as B&Q, British Telecom, Cisco, National Grid, and Renault.

Back to my theme of sustainability, the U.S. Chamber report showcased several companies that used sustainability terminology as equivalent to their commitment to the circular economy. These companies, such as Dell, Caterpillar, the city of Phoenix, Arizona State University, and Republic Services, did not shy away from the linkage between their existing sustainability initiatives and the circular economy.

As we talk about legal and policy implications, it's important to understand that the circular economy plays out at multiple levels: (1) the micro level, which covers single enterprises in high-resource-consumption and high-discharge industries and waste recycling enterprises; (2) the meso level represented by eco-industrial parks and symbiosis; and (3) the macro level involving cities and regions and even country-level poli-

4. U.S. Chamber of Commerce Foundation, Trash to Treasure: Changing Waste Streams to Profit Streams (2015), https://www.uschamberfoundation.org/reports/trash-treasure-changing-waste-streams-profit-streams.

cies. We'll hear later today about China's circular economy law. We'll also hear more about Europe's 2020 strategy and challenges in the U.S. market. Right now, our economy is locked into a system where everything from production economics and contracts to regulations and mindsets favors a linear model of production and consumption.

But the status quo is weakening under several disruptive trends, namely resource scarcity, tighter environmental standards, information technology, and changing consumer behavior. Obstacles remain, ranging from current product design, to cultural resistance, to subsidized commodity, and energy prices. Some of these barriers may fade on their own. Others will require a new framework in terms of corporate governance, cross-industry cooperation, new technology, and new approaches to law and regulation.

Let me end on an optimistic note. According to certain estimates, a shift toward the circular economy could generate by 2025 one trillion dollars annually in economic value, create more than one hundred thousand new jobs, and prevent one hundred million tons of waste within the next five years, while at the same time restoring natural capital and ecosystem services that are the foundation of healthy societies and economies globally. With that introduction, I'd like to turn the discussion over to Reid.

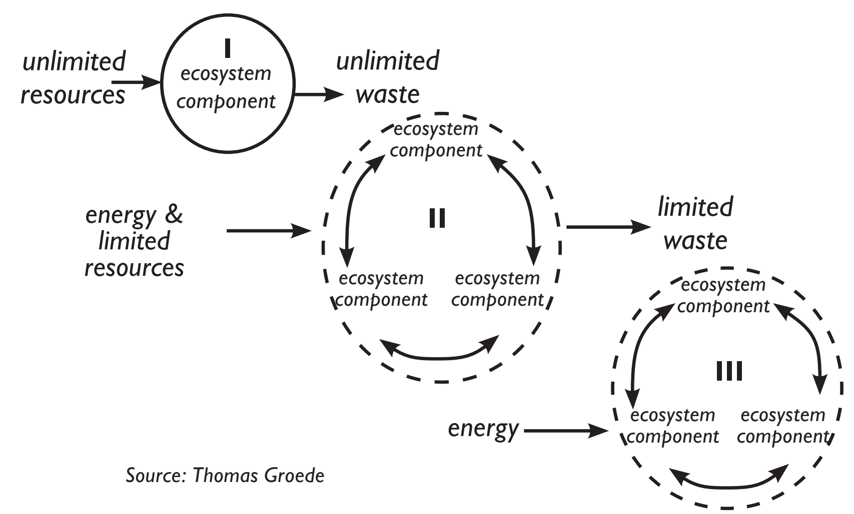
Reid Lifset: I'm going to give an all-too-quick, lightning-fast introduction to the circular economy and industrial ecology. I'm the editor-in-chief of the *Journal of Industrial Ecology,* a peer-reviewed international scientific publication owned by Yale, and I've been working in this area since the mid-1990s. My own research focuses on extended producer responsibility, the policy strategy where producers are required to manage their products and packages when they become waste. I also study the flow of metals through society and on resource availability, and I am a research scientist on the faculty of the Yale School of Forestry and Environmental Studies.

There are a multitude of concepts, frameworks, ideas, and terms that are offered as a way to grapple with issues related to the circular economy, such as sustainability, the green economy, cradle-to-cradle, Ecocycle, and so on. The question is: What are the circular economy and industrial ecology, and how do they differ? I'm not going to try and explain all the different terms, but we'll look at these and ask some questions about where they came from and where they're going.

At the core of the circular economy is an analogy to natural systems specifically taken from ecology, from the branch of ecology called ecosystem ecology. The central basis of the analogy is that nature is very resource-efficient. It cycles materials in ways that reduce both the need for new inputs and the amount of waste that is released into the larger environment. In Figure 2, you see at the top that when there is a small ecosystem relative to its larger environment, there is not as much cycling. You see more linear flows because, relative to the ecosystem, resources are abundant and the capacity of the environment to assimilate wastes is also large. Looking at a large ecosystem, what you see is more cycling in response to the limitations of those resources on one side and on the other what scientists would call "sinks for waste," the capacity of the environment to absorb those wastes. That's what is sometimes called a Type II ecosystem.

Then, if you move up to the planetary level, you see a somewhat closed system where the only major input into the system is energy from the sun. Over long time scales and spatial scales, we see a great deal of cycling of these resources. So, think of the word cycle and that's where the term "circular" comes from—the recognition that these resources are going around in a circle. In this context, the cycles are closed, and thus you will hear the terms "loop closing" or "closed-loop systems."

Figure 2: Moving From Linear to Circular Flows



Source: Thomas Groede

From there, an analogy for economies is drawn where we see resource cycling or loop closing in a variety of industrial sectors and human activities. There are small cycles. There are connections between the cycles. And depending on which part of society and which industry we're talking about, there is some limitation or constraint on the resources and on the capacity of the environment to deal with the wastes that are produced. This is the core idea that drives this notion of the circular economy.

Where did this idea come from? There's actually a long history. We could go back centuries, but we'll just look back a few decades. You may remember Kenneth Boulding, a prominent environmental economist, who talked about Spaceship Earth, a closed planetary system. And then there is Stahel, mentioned by Ira, who is one of the leaders in thinking about the shift from products to services. He variously has called this strategy the loop economy, the functional economy, and the performance economy.

One framework that I really want to highlight here is industrial ecology. The ideas underlying industrial ecology were first put forth in a prominent way in a seminal article by Robert Frosch and Nicholas Gallopoulos in 1989. Frosch was the head of global R&D for General Motors, former head of NASA, and former deputy head of the United Nations Environmental Programme, a man with a really interesting background. He explicitly talked about "industrial ecosystems," and drew the analogy between resource efficiency in the way that nature handles materials and the way that the economy might also handle its resources. That article, which was followed by a series of papers and books by the U.S. National Academy of Engineering, launched a global field that has been doing research in this area since then.

Following that, William McDonough and Michael Braungart developed the concept of "cradle-to-cradle," and offered related ideas. That term became a deliberate contrast to the notion of a "cradle-to-grave" life cycle. They used the term cradle-to-cradle to highlight the circling, the cycling, of resources. By the second half of the 1990s, countries in Northern Europe, notably Sweden and Germany, were overtly bringing these ideas into their environmental policy. By the 2000s, these ideas had moved pretty rapidly into East Asia, with Japan, Korea, and China adopting them under various labels, such as the resource-circulating society in Japan, the circular economy in China, or the green growth strategy in Korea.

Then, in 2010, the Ellen MacArthur Foundation was founded. Some of you may know that Ellen MacArthur holds the record for solo world circumnavigation in sailing. While on her boat, she came to an epiphany about the limited availability of resources because of the finite supplies on the boat. She came back from her trip, did some thinking and talking with people, and ended up forming this foundation that has brought together many of these ideas and giving them some push in larger society.

There are actually three developments that are giving momentum to the circular economy that brings us here today. As Ira mentioned, in China, there's actually a statutory and legal basis for it in the Law for the Promotion of the Circular Economy, enacted in 2008. It operates at three levels: enterprises with cleaner production; eco-industrial parks or zones; and integration of production and consumption at the city or province level. The major focus of this law is on pilot programs. Interestingly, the motivation was not environmental, but economic development. It was the NDRC—the National Development and Reform Commission—the high-level economic development agency in China, that pushed for the law.

And then we have the butterfly diagram that was introduced by Ira (see Figure 1). Let me take you a little further in this diagram. You can see on the left side the biological materials cycle at different levels. On the right are the technical materials with different types of loops, such as maintenance, reuse, remanufacturing, and recycling. As Ira noted, this is not simply recycling. Now, you might ask, well, is this just the three Rs on steroids rather than recycling on steroids? I would say it's more than that.

The left side of the diagram shows the biological or biogenic materials, what McDonough and Braungart called biological nutrients in contrast to the technical nutrients. With respect to these types of materials, they argue for cycling and cascading. A critical element of that is that these resources on the left should be benign and thus can be returned to the earth in agriculture and other uses without causing damage. They can move through a kind of cascade—moving from higher value uses to lower ones—if properly constituted. The materials on the right are ones that are not sufficiently benign to bring back into natural systems and, in the cradle-to-cradle framework, in one fashion or another, should cycle in the economy as long as possible and as separate from the biological cycles and natural systems as possible.

What is different here? Well, I would say that a key difference from the three Rs is this conceptualization of and distinction between the biological materials or biological nutrients and the technical nutrients. One of the provocative elements of the framework, as presented by McDonough and Braungart and to some extent by the Ellen MacArthur Foundation, is the notion that if we make the resources on the left side benign so they can flow through our use into agricultural systems and back into their natural environment and get the loops to work on the right side of the butterfly diagram, we can have a society of abundance. The idea is that there is not a constraint on resource use because cycles run indefinitely, and we don't have to worry about efficiency, materials availability, and toxicity. We can, as Ira mentioned, simply worry about effectiveness. That's a very interesting, and if we get to it, complicated claim.

So, there are ideas in the circular economy of priorities in material use, of making the circles tight, that are reminiscent of the solid waste management hierarchy; that the cycles should continue longer; and that there should be cascading uses. That is, materials should cascade from high-end uses to less valuable uses and so on so that resources are not used just once and then sent for disposal. A corollary is the concept of pure circles, that is, that the materials or resources should remain uncontaminated, and thus avoid problems in the subsequent uses arising from their diminution in quality or the impact of toxicity.

Another element of the circular economy that differs from the three Rs and from recycling is "service over product." This concept goes by many different names: product-to-service, service over product, servicizing, the functional economy, the performance economy, or product service systems. These terms are all more or less synonymous. I will give you an example of this concept from the Philips

Corporation. Philips is developing what they call "pay-per-lux," or what is called by others "lighting as a service." Philips makes, installs, maintains, and upgrades the lighting equipment for its customers and retains ownership of it. The customer, the building owner or the tenant, pays a service fee for a certain quality of lighting that is guaranteed by a performance contract.

When those windows, fixtures, equipment, or technology reach their end-of-life or become technologically dated, Philips, which still owns the equipment, takes them back for recycling and reuse. So, this is another variant of closing a loop. What the customer wants is the quality and adequacy of the lighting service. They don't really want to own the equipment that provides the service. Put another way, a customer's need is not defined as the physical artifact, the fixtures. So, in this case, a loop is closed because Philips maintains ownership. My favorite expression of this concept is that what we really want is a cold beer and not a refrigerator.

Moving on, the third element that's driving the emergence of the circular economy in circles like these is the work of the European Union (EU), which has made it a key element of its environmental policy. Last year, the EU issued an action plan for the circular economy with 51 distinct action items. So, we see these three developments that are giving momentum to this idea. The next step in the development of the circular economy is to take it to the next level, to grapple with the complications, and move from interesting ideas and exhortation to actually thinking about how it all works.

I'm going to give you one example here. One thing you may have picked up from my talk is that the circular economy is primarily focused on resource efficiency and resource conservation. In very simplistic terms, it is about resource preservation. There is not as much focus on the environmental dimensions such as minimizing environmental emissions or reducing environmental impacts.

Remanufacturing, for example, is very appealing and is being discussed a great deal in the circular economy context. The environmental benefits of remanufacturing stem not only from saving materials, but also from the reduction in environmental impacts. On the one hand, a new product need not be produced with all the attendant environmental impacts associated with that, nor do we have to face the disposal impacts of those products, at least in the short run. But if you think about products that run on electricity, the larger share of environmental impact often happens during the "use phase," that is, when the product is being used, rather than during its manufacture or disposal. This is because the use phase is when the most energy is being consumed, and environmental impact tends to correlate with energy usage.

So, in the case of a product such as a refrigerator, where new models are much more energy-efficient than existing products, that is, more efficient when in use, the impacts of the use phase outweigh dramatically the impact of both production and disposal. In fact, from an energy perspective, you will do better to buy a new refrigerator than to remanufacture the old one. Tim Gutowski at MIT has prepared an analysis of 25 different durable products and the relative savings in life-cycle energy, that is, energy used in production, use, and waste management, for remanufactured versus new goods. The point of this is that there's more to think about here: not only material resources be considered, but also energy use and, of course, the very important correlate, which is greenhouse gas emissions.

Where do we go from there? How do we take it to the next level? Well, this is the "back to industrial ecology" part of my talk. This oddly named field is the study of the flows of materials and energy in both industrial and in consumer activities, of the effects of these flows on the environment, and of the influences of economic, political, regulatory, and social factors on the flow, use, and transformation of resources. This is the field that grapples with the knotty problems, the real technical details of the circular economy. In fact, people are now calling it the science of the circular economy because the field has been dealing with these questions since the late 1980s.

It is primarily the Ellen MacArthur Foundation that has brought the loop-closing and the related ideas into the public domain and into policy discourse. Industrial ecology encompasses life-cycle assessment, carbon footprinting, and design for environment. It's these tools and concepts that I would like to see brought to bear on the circular economy as we attempt to take it to the next level to answer some key questions. For example, when does the circular economy produce desirable environmental outcomes and when does it not? When do we face the kind of problems presented by the remanufacturing issue I discussed before? How actually do we measure circularity in businesses and economies? How do we know when we're getting more circular? If we move back and forth between recycling and reuse, how do we know when we're making progress? And of course, what are the means of diffusion and adaption in different sectors of society, business, and government?

I haven't said anything about the regulatory implications of this. One of the reasons why I haven't is because, if you think back to that butterfly diagram, you realize that there are a lot of elements of the circular economy. As a result, there are also many disparate pieces to the regulatory implications of the circular economy. The implications are different for municipal solid waste recycling, for industrial recycling, for remanufacturing, for large-scale eco-industrial parks. It's not one question; it's a whole series of questions. To ask about the regulatory implications as though the circular economy were a monolithic thing, even if there is a unifying conceptual foundation, doesn't get to what's important.

II. The Circular Economy in Action: Energy, Renewables, and Other Materials Conversion Initiatives

A. *Batteries and the Circular Economy*

Timothy Ellis: There's been a lot of discussion of what the circular economy means as "an economy which balances economic development with environmental and resources protection." I think the lead industry is a really good example of a convergence of both the economic and environmental policies—we no longer have lead in dispersive uses such as paint or gasoline where it has caused big problems—and the fact that lead is thermodynamically easy to recycle has led us to an industry that's very acceptable, or at least has met all the metrics.

There are five major technological innovations that are serving the growing worldwide population and rising middle class: the Internet; the "Internet of things"; advanced materials; renewables; and energy storage. Each is important. All are interlinked. I think the one that's most important, however, is advanced materials. Everything is made of something. The world is made of stuff. All of us are made of recycled material. Every element on this planet gets recycled except one, helium, because it doesn't react with anything and eventually tends to exit at the top of the troposphere. So, everyone and everything is recycled.

The discussion right now in the circular economy is this: Do we recycle on a geological timescale or do we recycle on a timescale relevant to human beings in our emerging economy as we try to figure out how to feed, clothe, and bring calories of energy to 9 billion people over the next 15 to 20 years? How do we accomplish that?

Rechargeable batteries are needed more than ever for the growing worldwide population. The storage of electrons is growing in double digits. Each one of us in the United States and the western European economies owns over a hundred pounds of lead. It may not be in everyone's backyard, but it's in fork trucks at Walmart. It's in diesel engines. It's backing up cell phone towers. It's backing up computer systems. It's out there. But we need lots of different kinds of rechargeable energy technologies and that need is going to grow.

Lithium-ion is the latest, most popular battery in the world. Early on it was nickel-metal hydride, which is still the largest selling hybrid vehicle battery. Toyota Prius and Honda Civic still use nickel-metal hydride. Lead-acid batteries are still growing about 4 to 5 percent per year.

These battery technologies are, in varying degrees, complicated in microstructure and purity and there's a lot of value added above and beyond the simple elemental content. So, lower life-cycle cost is extremely important. No one wants to pay too much for a car. If we're going to expand the middle class in the rest of the world, we need technologies available worldwide. But, the biggest expansion of the middle class is happening between the Indus River and Japan because that's where most of the world's population is growing. They want their share of a better life as we in the western world have all come to expect and appreciate.

There's been a large amount of money spent on research and development of new materials, particularly for emerging battery technologies: nickel-metal hydride, lithium-ion, and sodium-sulfur. Why? Because they had to be proven in the laboratory before getting into products. Lead was already the dominant element of choice for batteries. Oddly, however, most of the people who are developing new electrochemical materials are spending no time figuring out what to do with these materials in the life cycle or how those materials can be recycled.

One of the problems in recycling is we have a very limited number of techniques to reclaim materials. We don't have an infinite suite of apps like you would expect on your phone. We have very simple processes, most of them based on mining, which are designed to be used with very high tonnages of materials. For instance, right now in copper mining, if you have 0.5 percent of copper in one ton of ore, you can make money processing that. But the mine is 25 miles long, 1,000 feet deep, and 5 miles wide. You take the rock, put it up on pads, put sulfuric acid over the top of it for three years to leach the copper out. You are not going to do that in downtown Washington, downtown Dallas, or even in the middle of Iowa. Those kinds of processes are not amenable to the way materials come back from their use in our economy. That's a problem.

In reality, there's a very active scrap-recycling business worldwide. Anybody who thinks materials aren't being recycled worldwide hasn't been out there. Our company has facilities in Africa, Europe, and in the United States. I've spent a lot of time in Asia and in South America. There's no excess scrap sitting any place out in the middle of the Congo. The Chinese and the Indian scrap dealers were there buying scrap and shipping it back to China and India because they see it as a low-cost source of material for manufacturing products. These countries are accumulating material, and it doesn't matter if the material is coming out of the dirt or coming out of the garbage can.

It's also important to understand that a plastic bucket we would throw away in the United States because it is not fashionable or the right color is a useful device in India. In the United States, we just throw it away. The other thing is that transportation is very, very cheap. There are a lot of freighters leaving the U.S. ports on the East and West Coasts carrying scrap. They carry not just scrap lead, but paper, plastic, steel, whatever material that is profitable depending on the universal prices, cost of transportation, and the differential between the Chinese yuan and the U.S. dollar or the Mexican peso.

These materials are moving all the time, so the market is a worldwide one. And for a lot of these metals, the pricing is set by commodity exchanges open contracts based on the London Metal Exchange and NYMEX. So, the pricing for those metals is known. For a lot of special materials such as very high-priced factory metals, that is not the case. Thus, there's a certain amount of dynamics and policy that could be developed around methods that actually would make trading and technology much more amenable for full life-cycle management.

Recycling in the lead industry is often not done by a company that buys scrap batteries, makes lead ingots from them, and then sells and ships to a new buyer. More often, the manufacturer of the lead batteries gets the scrap back itself, gives it to the recycler who acts as a laundry in converting it back to pure lead, and then the manufacturer gets it back. This way, the manufacturer isolates itself from the variability of the pricing based on the London Metal Exchange and the NYMEX prices. They see it as a natural hedge.

The same thing is true for some in the energy storage business. They need batteries for energy storage so they can move the nighttime power in a power station over to the middle of the day when people need it for air conditioning. They want to know what the salvage value is for batteries in the future. Why? Because it's a natural hedge and they would like to disconnect themselves from the variability in the markets. Anybody who has watched the commodity markets in the last couple of years has seen them go very, very high and then very, very low because they are actually not being driven extensively by the people who are using the material. They are being driven by financial instrumentation, people trying to figure out how to run this business profitably.

So, there are a lot of mechanisms at work that are motivating recycling in addition to the simple fact that we don't want to put things in landfills. Why? Because a landfill takes area and also has to be managed for a very long time. Our company has gone through Superfund sites and we know what it's like to manage legacy issues that are out there for a very long time well into the future.

So, how do we find the good model for the circular economy that shows that the system can work? That's a very difficult and complicated piece to work on, especially when you're also trying to understand how to support the world economy at the same time. Everybody knows the circular loop of the recycling symbol. In the closed loop of battery recycling, batteries are produced, sold, used, and collected at their end-of-life; recyclers separate and reprocess materials; and separated materials are recycled and sold to battery producers. The prices charged for recycled materials produced in this closed loop are competitive with primary or virgin materials and the cost of recycling is rolled into the retail battery price.

The EU Battery Directive over the years has come up with targets of materials to bring back into the system to be recycled. That's assuming there's someplace for those materials to go, and Europe is oddly becoming a net exporter of raw material. Otherwise, there's a cost for disposal. It's not a value-appreciation kind of thing, however, where you're trying to get value out of the materials that are in there because it turns out that a lot of materials are extremely inexpensive.

For example, a cell phone battery is usually made of lithium, cobalt, and nickel oxide materials. These batteries are recycled very effectively in Europe and one company already has a nickel and cobalt facility. They want the nickel and the cobalt because those materials are worth money. They know the prices on the London Metal Exchange. Let's look at lithium iron phosphate, which is a very good material for batteries, particularly in hybrid electric vehicles. The elemental value of iron and phosphorus in lithium is very, very low. But, why is a lithium-ion battery so expensive? Because by the time you make it in the right size and in the right purity, the value-add is the process of converting it into material that's good for the battery, but not the base element values. Smelter operators get paid on the base element value. While the elements are relatively inexpensive, it is the engineering required to design the batteries that accounts for their high cost.

I can't capture right now that form and function for the application value in recycling processes. But, does that mean I shouldn't work on it? No. We are working on it. If the batteries are based on cobalt, I'm not saying that we should go off and make a law to recycle. What I'm saying is people will try to get it because cobalt has a higher value per unit than iron and phosphorus. That actually would motivate me to get the batteries back, process them, and send the material back. That's why the lead-acid battery-recycling system works. Because we get batteries in a defined chunk—a nice big chunk of lead—from a very uniform source, such as a repair shop or a warranty depot for one of the auto companies. In contrast, driving a truck to pick up one AA cell battery at a time is not economically viable.

The other problem is that smelters are based on tons. If I make an investment in a facility that recycles lithium-ion batteries, for instance, or any battery chemistry, I have to know where the tons are because that's how smelters are paid. I also need to understand the regulatory environment in which I am building that facility. It's not just carbon dioxide we have to think about. We also have to think about the regulatory environment for nanoparticulates. Now, to put that in perspective, if you have a quartz crystal, it's not going to bother you much. But if you grind it up fine enough, you get silicosis. It's the same material.

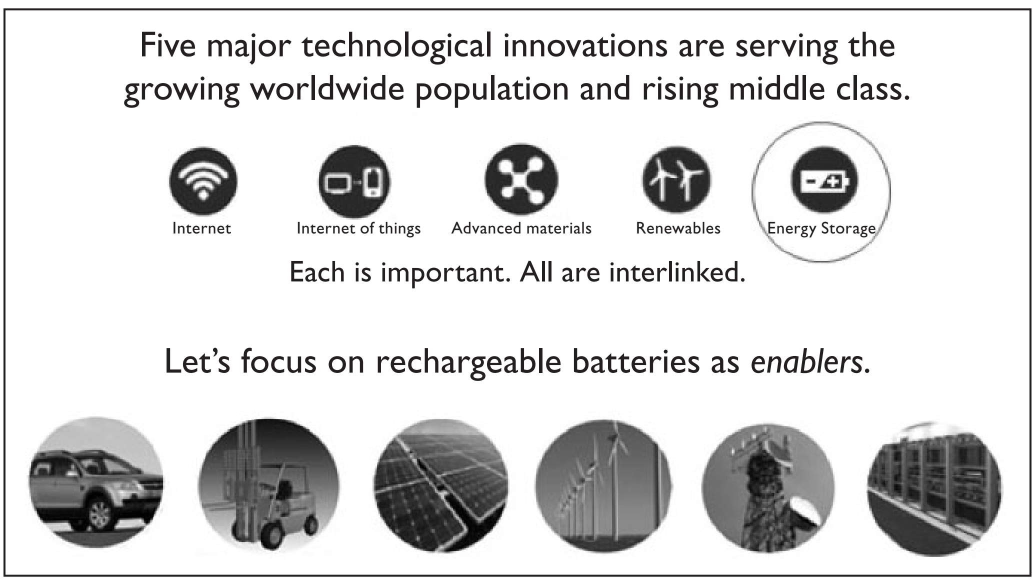
Product architecture is very, very important, but the hardest people to sell on the idea of the circular economy is, by far, product developers. They want the best of the best because their bosses will be all over them if the product isn't the absolute best sold in the market. So, somehow we've got to get around that mindset. How do you do that? It doesn't necessarily help to require a certain amount of recycled material to be used because you may not be able to build the chip the way you want or a battery the way you want.

I think it is probably commonly known that lead is the most recycled material in the world. The lead-acid battery recycling rate is 99%.

The next highest recycling rates are for corrugated boxes and steel cans. We use a lot of recycled iron. That's part of what we need as one of our reagents. We obtain the iron from post-manufacturing from other components, such as from the auto industry, even from the garbage dumps in some major metropolitan areas. Interestingly enough, we actually like to obtain the iron this way because we also get back other important elements of value for the products that we make—tin, antimony, bismuth. But getting the demographics right in this process is important. There are safety issues. For instance, taking various electrochemical cells that are not lead-acid and putting them in one of our furnaces can cause a lot of problems. And, by definition, if a lithium-ion battery or a sodium-sulfur battery crosses over our property line, it is now considered hazardous waste. We haven't done anything with it, but when it crosses over, its regulatory definition changes. Then, when we ship it to somebody else, that person has to have the right permits in order to accept it. So, these regulations sometimes make the opportunity for us to move materials out very difficult.

As an example, consider the shipment of hybrid vehicle batteries in a plywood box. What happens to the plywood box when it travels over our smelter line? It's now considered hazardous waste. It can't be burned in a furnace and cannot be buried because it's hazardous waste. If it's in a cardboard box and not a plywood box, nothing's really changed, but the designation is hazardous waste. So, those kinds of definitions actually can constrain what you could do in recycling. I'm not saying we should go make everything non-hazardous waste. But there are implications that have to be thought out very distinctly and succinctly in policy that can allow us actually to go forth and take advantage of the opportunities that we have the technology to do.

Figure 3: Can Batteries Meet the Circular Challenge?



Here's what the lead market has looked like over the last several years. Starting in about the late 1990s, secondary lead/recycled lead actually overtook primary lead in the market. There are a couple of reasons for that. First, I'm sure we have lead that we recycle right now that the Romans originally mined 2,000 years ago. The average lifespan of a battery out there right now is about five years, and then it comes back. So, if the battery was built in the 1950s, it has been through our recycling facilities four, five, six times already, not just in the United States, but everywhere else in the world.

The second reason lead recycling has succeeded is that, from an economics point of view, secondary materials are a natural hedge on prices. While some lead production from primary resources remains necessary to meet rising overall demand, recycling creates a second source of supply that helps stabilize the commodity price of lead. Some days, the primary guys make more money than the recyclers. Other days the secondary guys, the recyclers, make more money.

The point is that when you're looking at supplying materials or sourcing materials for the auto industry or for cell phone back-up towers, you have to look at the long-term economics. If you're going to invest four billion dollars in a new automotive platform, you've got to make sure that your material supplies are robust and that the pricing of those materials can be balanced out over time so you'll know your risk. There's nothing worse than investing in one thing and then finding out you can't get it or that the price just went crazy.

So, recycling as a natural hedge on prices is very, very good in lead-acid battery technology. It allows us to keep our cost down to about $150 per kilowatt-hour. Those prices will probably go down over time because we're becoming more efficient in the utilization of all the things that technologies do, but with a natural hedge built in. I think for the circular economy it is important to figure out mechanisms and ways the technology can permit us to continue to have those natural hedges that allows for the robustness of the products in the marketplace and people don't get some nasty price surprises.

The life-cycle costs of rechargeable batteries are important. The life-cycle cost of the lead-acid battery is low because the battery is simple and can be recycled easily. Nickel-metal hydride is more complicated. While the batteries are comprised mostly of nickel, the use of lanthanides, or rare earths, and other specialty elements adds complexity to the design. The reprocessing of these elements back into commercially usable metals is very difficult and expensive. Lithium-ion batteries are even more complicated. I don't mean to pick on lithium-ion, because they do things that you can't do with other battery chemistries. The only way to build a battery electric vehicle that's going to drive 250 miles is to use a lithium-ion battery so the car will be light enough to move.

The point is that there are a lot of engineering design trade offs that have to be figured out. Cost-effective recycling has generally not been factored into battery chemistry design. Those ideas need to be wired in from the beginning, not from the end. Sadly, the guy in the recycling bin or the guy in the scrapyard is the last guy anybody ever asks about what he wants. We're always the person saying, "Oh, that truck showed up; now what do you want in it?" So we're spending a lot of time right now trying to consolidate technical information documents to inform designers about opportunities to work on.

In general, there are three kinds of recycling. You can put the batteries in furnaces and melt them to recover metals. You can dissolve them in acid to aid separation. Usually, you have to do some of each. But the kind I particularly like is direct recycling. This is where you're actually going with physical separation processes to get materials back. We've done it for lithium-ions using magnetic separation. The problem is: Who is the last guy who would want to recycle material? The guy that just built the battery. He complains that it doesn't meet his metric or quality. If you ask if he would work on the design for the future so it would meet those standards, he says he is too busy trying to qualify for the next application. This is the place where I think policy can actually be useful.

If you are going to bring materials into the economy, you need to figure out what to do with those materials. Many of us remember Love Canal. Thinking about what you're going to do with materials after—rather than before—they are in the marketplace is a bad idea, particularly in these kinds of materials because you have nanoparticles and you have new chemistries. We need to figure out ahead of time what to do with the materials afterwards.

It is incredibly important to know and agree on those definitions upfront. If you don't have clear definitions, you can't build the environmental legislation and the environmental controls and everything surrounding that. There is no uniform set of definitions of even what you're allowed to bring into your facility or not bringing into your facility. Even the EU Battery Directive has definitions that disagree with each other.

If I'm going to build a facility to recycle anything, I've got to know what rules I'm playing by and where the rules may be going in the future. That seems very helpful for me because then it makes me decide which processes I'm actually going to try to use because I can't do every process.

Sadly, the way the system is set up and the way the economies are set up right now, it's a race to the bottom. Yes, pollution havens exist. The United States has a very stringent lead emission standard, and rightfully so. We should have a very stringent lead emission standard for all the right reasons. But many other countries are not keeping pace with U.S. standards. For example, the EPA lead ambient air emission standard is 0.15 micrograms per cubic meter ($\mu g/m^3$). Compare that to 0.5 $\mu g/m^3$ in the EU, 1.0 $\mu g/m^3$ in China, and 1.5 $\mu g/m^3$ in Mexico. U.S. battery recyclers pay more to comply with regulations, which undermines their ability to pay for scrap. Recyclers in poorly regulated countries can pay more for scrap because they have lower regulatory overhead. When other people don't have to pay those externalities, it allows them to come into our economy and buy scrap at higher prices than we can pay for it because we need a certain amount of margin or we can't keep those fans and scrubbers on. So, when people can literally go across the border and don't have to pay those externalities, it puts us at a natural disadvantage that we can't get around no matter what we try to do.

There has been a lot of discussion about how you bring those externalities into trade agreements, but the problem is that these technologies are expensive.

One of our new lead electrostatic precipitators allows us to emit less than eight pounds of lead emissions in a facility that processes over 100,000 tons. To put that in perspective, that's three times less than a 1957 Chevy on leaded gasoline would emit. That precipitator costs a better part of tens of millions of dollars. A guy in western Africa is not going to pay that, or can't pay that, or can't figure out how to get the scrap to a facility large enough to be able to pay for that. That's a problem. But frankly, the G7 nations buy a lot of materials, so we do have some leverage to help people bring the scrap to the United States or do things in a better way.

Hopefully, these countries can learn from the history of our lead industry so they don't have to revisit these issues or make the same mistakes.

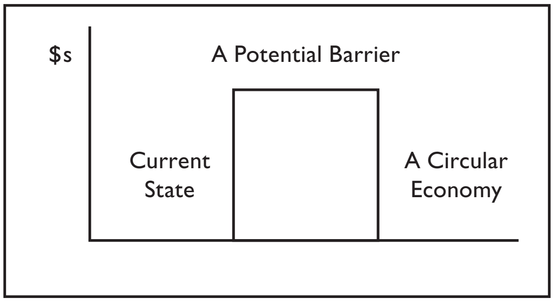
B. *Structuring Market Competition to Build a Circular Economy*

Wayne Rifer: My message today is how a structured market can be used to advance a circular economy. One tool for structuring that marketplace and catalyzing environmental leadership that I will be discussing today is EPEAT (www.epeat.net), which has provided a prerequisite structure for measuring and communicating environmental design and performance in the electronics industry over the last decade. EPEAT, the Electronic Product Environmental Assessment Tool, is a ranking system that helps purchasers evaluate and compare computers, monitors, televisions, and other electronic devices based on their environmental attributes covering the full product life cycle—including design, energy use, and recycling.

Second, I will talk about the challenges to the electronics industry to achieving a circular economy. A circular economy will require new technologies, markets, and business models. There is a "potential barrier"[5] (see Figure 4) that needs to be overcome. Now, those of you who have done a

5. In physics, a potential barrier is where a lower energy exists now, and it will exist in the future, but to get from here to there will require going through a higher energy state. Money can be substituted for energy to see my point here.

Figure 4: Potential Barrier



little reading in quantum mechanics know that there are ways to get through potential barriers if you operate on that scale. But for most of us who operate on the macro scale, a potential barrier means that you need investment to get from here to there. And maybe on the other side you've got a much more favorable environment that you're operating in, but to get there, you need to put some investment in. Which is to say that the lowest-cost approach in the present is not a driver for the transformational change that will lead us to the circular economy. After we accomplish certain things and get them done and put the investment in, maybe so. But we need entrepreneurs who have the vision and who will take the risk and invest in some of the things that we need for the circular economy, and programs like EPEAT can help us go that way.

As you all know, there are two basic tools that can drive investment in transformational change. There are laws and regulations by which we establish the baseline and get the bad actors to meet the baseline, or get out of the marketplace. And then there are incentives for going beyond that baseline. Now, we're all talking about value here. We've got to remember that value is driven and is created by values. Value isn't just dollars and cents. Value comes in a lot of other forms in our society. Policy is—hopefully—an expression of our values. Really, it's an expression of value to exceed the baseline. I'm referring to Tim Ellis' race to the top. What do you need for a race to the top? Well, first of all, you need a raceway, right? If you're going to have people racing to accomplish things, you need a raceway that defines superior environmental performance.

Actually, that takes me back to the very early days when I first brought up the idea of doing something like EPEAT. I asked the electronics industry: How can we build a tool that would use the marketplace to achieve superior environmental results? The answer came back from a brilliant guy at Intel who had a brilliant answer. It's simple, he said, all you need is a measuring stick for superior environmental performance. If it's credible and built well, you put it on the ground, and we will compete for that. That's all EPEAT really is, a measuring stick. You need that measure of superior environmental performance; you need to ensure that people are measuring accurately and credibly; and you need a reward. So, we're talking about marketplace rewards for achieving superior environmental performance to achieve a circular economy.

EPEAT in particular leverages the institutional purchaser. There's a vast difference between the way consumers purchase and the way institutions purchase. The difference is consumers shop based upon the offerings; institutional purchasers set the specifications. For environmental performance, multi-attributed environmental performance, institutional purchasers are driving the game. They say this is what I want to buy before they look at the price. The price is wrapped in. The offeror brings to the table what meets all the specifications that they put in, and it's very easy for institutional purchasers to put environmental specifications into a purchasing specification.

I guess we are now really examining the opportunity for EPEAT, which has been a great success in institutional purchasing, to encourage those high-value institutional requirements to trickle down to the consumer. Except for the Energy Star program, which allows purchasers to make decisions based on their pocketbook, I don't know that we or anybody else have figured out how to do that. I hope that does happen.

But EPEAT has been very successful in the institutional purchasing marketplace. The U.S. government buys 95 percent of its computer products off of our registry. It's required by regulation. So, this is not without law and regulation; this is one of the drivers behind EPEAT. More than 40 states require EPEAT. Many universities, health care institutions, and other large institutions of that sort are what really drive the manufacturers to our camp in our direction. EPEAT has grown over the years. It was first put in place in 2006. Although the standards had been developed before that, the registry and everything went on online in 2006. So, we've had about a decade of experience.

Now, an interesting fact is how the numbers of participating manufacturers rose and rose from 2006 to 2011, and then it flattened off. That's essentially because by 2011, all the major manufacturers, the biggies, that are selling into that institutional market, at least the biggies in the United States and in the European continent, were already in the program. We are now working very intensively with two other big markets, China and India.

I'm going to talk a little bit about the structure of EPEAT. It has three dimensions that are key elements of the program: (1) the standards that define superior environmental performance; (2) the registration, the process of getting the product recognized and verified; and (3) the registry, which is the product offering. I'm going to talk about those three.

I should mention that when we first developed the EPEAT system, everything about it was a stakeholder consensus process. The design, how it works, and all those things were built through a long process of stakeholder meetings. The industry was deeply involved and deeply supportive. The environmental community and the environmental advocates were there. The institutional purchasers, the government agencies, policy people, and recyclers were all a part of building the tools. So, at least all those who participated have an ownership interest in the process.

And I must say that the design that resulted from that huge committee process was really quite excellent. I've become a real believer in the democratic process for designing complex things so that they work well. Because not only does it work well, but it has all these supporters built in because they own a piece of the process.

We built the American national standards under ANSI-accredited processes. That's the American National Standard Institute. ANSI defines the rules for developing a voluntary consensus standard, which we are built on. What's in the standard is what the stakeholders, the environmental community, and government agencies think is important. These are standards that really address environmental impacts across a product's entire life cycle.

We have three standards that are currently being implemented on the registry now. One is for PCs and displays, the second one, a little bit more recent, covers imaging equipment, and the third is for televisions. We are in the final phase of developing a standard for servers, and Underwriters Laboratories is developing a standard for mobile devices that will then become a part of the EPEAT registry.

The structure that was devised by the stakeholders sets forth two kinds of environmental criteria: required and optional. Although it varies, there may be more than 60 criteria within a standard. In order to be registered at all, you've got to meet all of the required, or baseline, criteria. That earns you the bronze rating on the registry. Then, we have optional criteria. If you meet all of the required criteria and 50 percent of those optional criteria, you earn the designation of silver; 75 percent gets you gold. Actually, as it turns out, a little bit more than one-half of the criteria really are in the optional category.

The optional category is where government purchasers and environmental communities are able to express the kinds of things they would like to see in the product. It may not be on the market at the time the criteria are set, but the amazing thing is that products are soon developed to meet the criteria. For example, after we put the first standard into place for PCs and displays, it took one year before there was a single gold product, and then the number of gold products quickly started rising. Now, the problem is that almost all of the products are coming in as gold, which means it's time to raise the bar. It's time to revise the standard and that is what is happening.

I don't know how many of you have been involved in standards processes, but these things are not easy to change. They take a long time and are detailed because they're consensus agreements. You have the designers, you have the engineers, you have the environmental community, who come from totally different walks of life talking together and coming to an agreement. It's a multiyear process. Our standards set the base for what should be an environmentally preferable product. Now, we have to ask ourselves what a sustainable product is, the goal for an environmentally preferable product. The next questions are: What is sustainable and how can we get to a circular economy?

The environmental criteria categories in EPEAT standards most directly contributing to a circular economy are materials selection, product longevity, design for end-of-life, and end-of-life management. Materials selection includes things like the post-consumer recycle content and renewable bio-based materials. Product longevity refers to upgradability and durability. And those may be trade offs of each other. Those are some of the key trade off issues that you get into in an environmental standard.

For example, if you want a product that is truly upgradeable, it may have to be easily disassembled, which may make it a little more easily breakable. So, you have to figure out ways to get around that. This, by the way, is not fantasy. This is the main argument by manufacturers for not making their products very upgradable. Design for end-of-life, that's where you not only get into reusability, refurbishment, and remanufacturing, but you also get into recycling. How are the materials going to be liberated? And then we have requirements for the end-of-life system, how products are collected and how products are taken back. We heard about extended producer responsibility earlier today. Extended producer responsibility is where the producer pays for and manages the takeback system for their products, and it really is core in our standard. It's demanded as a base by the environmental community.

The EPEAT registry contains over 4,500 products that 55 manufacturers sell in 43 countries. We are a voluntary system. A manufacturer can choose to be on our registry. Many, if they want to sell to the federal government, they chose to be on our registry. When they look at a standard process, they're not thinking about what they could do. No. They're thinking what they have to do, whether they can do it, and whether they can do it and still make money on it.

The registry began expanding internationally several years ago. As we expand into other countries, we work to develop the interest of purchasers. Is there an interest of purchasers? What good is it to have EPEAT products available in a country if a purchaser isn't going to buy them? So, we have processes to develop the interest or see if there is a potential interest by purchasers, and we have processes to engage the interest of the manufacturers as well. We have a whole program for expanding the registry.

I was asked by EPA folks about how rigorous does the verification of manufacturers' claims need to be? I'm very strong on verification. We have done much verification of manufacturers' claims. We believe that the verification process needs to be quite rigorous. And when you're talking about electronics products, and you say there can be cadmium in an electronic product, where is the cadmium? It's in very small quantities and just in maybe a few components. It may be in components that the manufacturer had nothing to do with making because the companies we think of as the manufacturers—Dell, HP, Apple, and so on—they are actually the brands that we know and rely on their suppliers around the world. So, there's got to be a very rigorous verification process.

I did want to get to the key question here about what the electronics industry has ahead of it in terms of achieving the circular economy. Wouldn't we say the electronics industry should be a leader in achieving sustainability in the circular economy? They're a leader in so much of this world. But their challenges are great.

There are two major technology trends in electronic products. Number one is ultra-miniaturization. Number two is material composition. In the early days, when I first got involved in this field, there were at most 11 elements in your typical electronic product; now, there are about 60 elements in minute quantities per product. Vast numbers of products are being manufactured and sold, but there are only minute quantities of these elements that need to be recovered in each. And these products are, as was the point that was made earlier, distributed pretty evenly around the world. Minute quantities per product; huge number of products; spread around the world. That is the challenge: how to economically recover critical materials.

Think of the cell phone. Everybody has a cell phone now. And you've got to get all of those back. The current recycling rate for the most valuable metals in those electronics is very low—0-5% for platinum; 5-10% for palladium; 10-15% for gold and silver. Why is it so low? It is because throughout the chain, there are problems where products and materials are lost.

I said the first challenge is that we need investment in order to get us over this potential barrier that is now preventing us from being a circular economy, a sustainable economy. The second point is that it's a systems problem. It involves every step along that chain where there are different actors who operate by different motivations and there really is no institution or institutional process that brings them together. We need coordinated actions by many actors, including the manufacturers who design the products, the users, the first processor who sorts, separates, and accumulates the components, and the final processor who implements new recovery technologies. Again, I point you to voluntary consensus processes where people can see that they are in the process, that they have an interest, and that they can come together in an environment and work with others in that whole chain of commerce to deliver a more sustainable electronic system.

III. Growing the Circular Economy Through Legal Initiatives: Developing Laws to Facilitate a Circular Economy

Roger Feldman: This last panel is about the legal framework and laws in different countries that relate to the circular economy concepts we've heard. What's different is that there are either existing or formally applied laws that have to be used if there is going to be a so-called circular economy. When I first took on this assignment to talk about developing laws to facilitate a circular economy, I said, "I'm going to prove that I'm a circular economy lawyer." Then, Ira Feldman said to me: "There is no such thing. What are you talking about?"

I finally have gotten to the point where I understand that, but what I also understand is the following three points. First, we are *not* going to develop a new commercial law of supply chain transactions, but a law *can* facilitate new forms and more extensive collaboration among the parties in the supply chain so that sustainable closed-loop value chains can be formed. Second, we have had public-private partnerships for infrastructure development for a long time, and we are *not* going to develop new laws for the formation of those partnerships for the circular economy. But laws *can* involve embedding the explicit contemplation of overall closed-loop public-private value-chain collaboration in public procurement and regulatory direction of performance of services.

The third point relates to internalization of so-called external costs. We are *not* talking about creating a new law to mandate private internalization of "external costs" through public oversight of private linear commercial activities. The question we are talking about is how do you develop the right closed-loop sustainability-valuation metrics *to encourage* costs—and revenues—to be properly allocated so that people are willing and interested to invest in this closed-loop economy? In short, we are not talking about a new circular economy legal system, but discrete legal measures facilitating collaborations among parties that collaborate to create closed-loop systems that create value and contribute to long-term societal sustainability.

The development of law from this perspective has been the essence of what we talked about today. First, it is a way of improving and maximizing the use of natural resources through the economy. That's the stated moral and policy thesis for closed-loop economies. Second, you can in fact achieve sustainability objectives better—as has been inferred today—if you apply closed-loop thinking to how businesses are managed intelligently. Third, it is imperative to stress that there is no such thing as a single law of closed-loop economy, if for no other reason than that every governmental system of socioeconomic regulation must adapt to the conditions of its particular situation in terms of materials and in terms of requirements. If we try to say one size fits all because we have discovered the perfect closed-loop legal system, we're deceiving ourselves. Closed-loop collaborative arrangements must be introduced in a manner consistent with locally applicable political principles reflected in public governance institutional arrangements, methodologies for infrastructure acquisition and supervision, and the roles of the private and public sectors.

Technological innovation adds a whole new dimension to the way we can rationally approach these issues. It has taken us to a new ability to integrate value production activities, a new ability in 3D printing to design compatibly with reuse, a new ability to look at probabilities through big data analytics, and a new ability to communicate and tie together disparate activities. Things happen when they can happen, and what's really unusual about the time that we live in is that we now have these abilities to make it happen. So, we're not just talking principles: we're talking about applications of previously unforeseen possibilities. Framed from the formal legal perspective, these issues become analysis of issues related to property rights, governance, and finance.

First, from the perspective of property rights, we're talking about people sharing responsibilities and rights related to ownership and all of the issues that go with ownership in a commercial cycle—the internalization of costs, the sharing of created value in a value chain, the taxation of the value added in that value chain, and the structuring of joint ventures. We are also talking about risk-sharing: what existing and new risks are presented; how are we going to allocate them when we contract to collaborate—a term laden with different meanings for the different parties to every arrangement?

I think it's also very important to recognize the emergence of new intellectual property rights issues, precisely because we are in a new technical era where new things are possible. The meaning of intellectual property, and who has the rights to it, and who gets to benefit from it, are going to change. One narrow field where this is clear is in the delineation of wastes, byproducts, and new production inputs. As one example, what at one time was waste, such as food waste, is now somebody else's property because it has multiple types of purposing within the economic and the ecological system.

Governance in the circular economy presents new challenges. Government, after all, exists within the framework of an entire system or concept of how economies should operate: how collaboration will be enforced; how people will be forced or led by standards to do things; how a partially state-owned enterprise does or doesn't have to comply; or how a partially state-imposed process like an environmental impact statement will be imposed in the context of the application of the more encompassing life-cycle closed-loop concept. The extent of government intervention in transactional and manufacturing activities is an appropriate activity when it extends beyond health and safety to resource efficiency and different concepts of equity.

Governance entails direct legal responsibilities of public "managers" over property, regulatory systems, and natural systems resiliency protection. It's the job of government to protect property. It's the job of government to worry about the resiliency of infrastructure. It's the job of government to impose regulatory systems that provide an equal playing field between parties so that, for example, if you impose higher standards for performance evaluation (and cost), it does not also create a race to the bottom by those evading the standards; instead, it is a bottom that must have a floor provided by government, whether through procurement, formal prescription, or through some other legal mechanism that provides that floor.

I think this is very important. We in the United States and also in Europe through regimes for decarbonization have created new economic values related to the environmental process. An analytical question presented is: is the way we've created those environmental values and the way we've allocated them consistent with the process of adding or detracting other factors that may be critical to the overall circular economy value chain?

That is why a third and separate area of governance for examination involves performance and measurement indices as a key basis to the evaluation of the circular economy operations and finance. When is the circular economy functioning as a circular economy? When should there be new voluntary standards? When are scorecards workable? How can scorecards be voluntary and still be part of an effective system?

To do that in the carbon system, we have verification and measurement. It has taken us more than a decade to evolve our system of law that supports some measure of decarbonization. But in maximization of the value of the circular economy, we're talking about something that is not just decarbonization, but is focused on resource-efficient productivity as a more encompassing goal. It's focused on productivity as one of the highest and best goals of what an economic system is about. Most discussions of the circular economy emphasize intercorporate cooperation and optimum exchange of valuable materials ("trade," as it were) as being the driver for the circular economy. But absent legal guidance standards, measurements, and encouragement of types of trade, obsession with the fact of the economic cycle can be debilitating to the very objectives many of its proponents most value.

Similarly, with respect to developing the infrastructure of public-private partnerships with companies that either operate in government facilities or are the beneficiaries of fixing up government wastewater treatment facilities and similar types of installations, it's imperative to think in terms of a closed-loop cycle, e.g., taking the government wastewater treatment plants and making gas that can then be used for fuel in lieu of natural gas or improved to be a higher productive asset, i.e., creating corresponding private responsibilities of a public body to make available what can be closed-loop cycle assets.

It raises new globalization issues as well. Materials like precious metals are not evenly distributed throughout the world. How the availability of key recycled metals and how trading and markets are allowed to reallocate remarketed materials are extremely interesting, have huge potential monetary and social consequences, and raise difficult legal questions.

The finance area presents different questions regarding the opportunities and challenges of making the supply chain work, making different parties find it worth their while and not stressful—economically stressful or internal rate of return stressful—to work together. A very key aspect in this regard is risk and responsibility in allocation of risk. Lenders are looking for whether these projects have been de-risked sufficiently that they can take the chance of putting money on doing these things.

So, when you're integrating processes—or trying to insert beneficial new technologies into older systems of doing business or producing goods—new issues are presented. Financial institutions may have great difficulty in assessing present and future financial statements for asset-backed lending. There may be greater risk of undisclosed liabilities from other places on the supply chain or as a consequence of their operations. "Sharing" joint ventures or joint ownership presents new property rights and indemnification issues. New risk management and insurance products may have to be developed.

The central question remains: is the credit strength of the separate parts of the circular process going to be sufficient to support the needs of the individual financial instrument that are being issued to finance its operation? Are the government incentives and credits of the type we have had in the past when we have integrated companies putting together project financings still suitable when you enter these types of ventures? As we've seen in renewable energy, governments can incentivize the creation of collaborative arrangements in a satisfactory way when they are somewhat infant industries. Can this also be true in the circular economy area?

Credit evaluation of individual players in the circular economy comes down to cash flow, the cash flow coming to the parties who are the targets of the financing or who are asking for the financing. Are you going to have enough cash flow to pay for those circular economy bonds? It's coming back to the question of whether, if you have a tax system, you have a value-added tax system. How do you square that with the ability to have a workable economy of collaboration?

The bottom line is, when you look at a balance sheet in a circular flow economy, how do you know what is on the balance sheet? How do you know what the receivables are? How do you know what the payables are? How do you know that the assets and liabilities that they're showing on their books are theirs? Therefore, I think you're going to see an emphasis on trying to get new ways of financing the closed-loop cycle. You're going to see, for example, leasing of individual assets in the same way solar is tacked on to other kinds of buildings. You have a sharing issue when multiple parties are taking advantage of the same facility, but take a different value out of the facilities in terms of the cash flow than their customers get in terms of the contribution to the closed-loop economy.

I think you're going to see leasing affected. I do think you're going to see, as you see in energy now, pooling of multiple credits, including those of participants in the supply/service chain and those providing risk management.

The illustrative case for all of these issues is energy efficiency, which is really all about a closed-loop cycle of allocation of responsibility for production and for use. It relates to the proactive use of otherwise idle capacity. You see this on military bases. You see this in any case where you have storage, where you have grids that are designed for partial usage when the systems are cut off from the supplier. You see this in any kind of price evaluation of avoided expenditures such as demand-response savings. Demand-response is a way to create efficiency, but it also takes money away from the person who supplies the demand that no longer exists.

The key roles of regulation and finance in the circular economy are in the delineation of property rights, the delineation of who has responsibility, and the interests and roles of the different institutional providers. These developments are going to vary. We see that in the United States, even in the energy area where different states have treated renewables in different ways. The most recent example is how California is handling the treatment of disposable organics in landfills, which in turn has an effect on what the closed-loop cycle looks like to participants in different parts of it.

The United States has one perspective on the circular economy; it tends to think it has *the* perspective. But, in fact, for example, the EU is far ahead of America in thinking about these issues, and the Chinese People's Republic has actually passed a functioning law in this area. The use of different governmental systems does not change the underlying technological and equity issues. That is why the law of the circular economy, while nascent, will grow into an important factor integrating the traditional legal disciplines.