OIST OKINAWA INSTITUTE OF SCIENCE AND TECHNOLOGY GRADUATE UNIVERSITY
沖縄科学技術大学院大学

The Second International Symposium on Open Energy Systems

Organized by Okinawa Institute of Science and Technology Graduate University and Sony Computer Science Laboratories, Inc.

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**Seminar Room B250, OIST Center Bldg
OIST Campus, Okinawa, Japan**

Contents

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Dr. JONATHAN DORFAN
President of OIST

Organization Chair

Dr. ROBERT BAUGHMAN
Executive VP for Sustainable Development of Okinawa, OIST

Program Co-Chairs

Prof. HIROAKI KITANO
OIST Adjunct Professor and Sony CSL President and CEO

Dr. RONAN STEPHAN
Chief Innovation Officer, ALSTOM

Dr. MARIO TOKORO
Founder and Executive Advisor, Sony CSL

Organizers

Okinawa Institute of Science and Technology Graduate University
Sony Computer Science Laboratories, Inc.

Welcome Address

Dr. JONATHAN DORFAN

President of OIST

Welcome to OIST Graduate University and to the Second International Symposium on Open Energy Systems. Providing energy in this modern world is a challenge irrespective of location. Making energy sustainable, affordable, efficient, effective. Dealing with peak loads. There are many challenges. They are particularly acute in certain kinds of environments, such as small island communities.

The notion of a local grid, maybe a DC grid, that is sustainable on the basis of local supply, where the clients are inherently committed to an energy sharing model, is a very attractive one for such communities. We had an initial symposium last year, and were very surprised by how well it went, so a follow-up second meeting was suggested. Seeing so many illustrious people here today, I imagine it will be even more successful than last year.

This is a sustainable approach to maintaining our momentum. You will be touring the hillside housing system at OIST, which we continue to develop as a localized but important demonstration of the possibilities of a housing community running on solar with energy sharing.

Message from Organization Chair

Dr. ROBERT BAUGHMAN

Executive VP for Sustainable Development of Okinawa, OIST

Thank you all for coming to join us for this second symposium. Since last year, OIST has created a new office for the sustainable development of Okinawa, which addresses two kinds of sustainability. One is the kind addressed by our symposium today. Another is economically independent sustainable development. It's part of the mission of OIST not only to create a university and research foundation here in Okinawa, but also to contribute more broadly in Okinawa, Japan and around the world. As part of that we must successfully identify our intellectual property and make it available to the private sector and the public sector for development.

We're building on institutions we have already in place. A good working relationship with both the private sector and the public sector is key. This meeting today is an excellent example of this. We look forward very much to the further development of this critical field—broadly but also specifically for Okinawa and for OIST.

Session 1
OES Vision & Current Status

Speech 1

Open Energy Systems: Toward a Global Agenda Solution for Sustainability

Speaker: Prof. HIROAKI KITANO

OIST Adjunct Professor and Sony CSL President and CEO, Japan

Welcome to OIST, and to the Second International Symposium on Open Energy Systems.

We're all aware that if the IPCC's claims about the role of greenhouse gases in climate change are true, then fossil fuel use poses a serious threat to our civilization. Throughout history environmental mismanagement has caused the "collapse" of civilizations, as recounted by Professor Jared Diamond in his book of that name.

But a climate-change collapse would be on a global scale. We have to act. Meanwhile, emerging geopolitical risks in the Middle East and elsewhere are bringing the topic of energy security to the forefront. The changing price of oil is another important issue.

Last month we saw a dramatic fall in oil prices. Historically, it has been in the range of $20 per barrel on average over many years. The last 10 years saw oil prices soar, but they are now coming back down. The emerging consensus is that oil is not going to go back up to anything like $100 per barrel. It will stay at a relatively modest price.

This impacts the renewable energy cost equation. If oil prices remain high, then we can afford a somewhat higher cost of renewable energy, but if oil prices go down and stay low then we need really affordable renewable energy.

On the oil demand side, we see surprising improvement in vehicle efficiency globally. Increasing penetration of hybrid cars and electric vehicles actually reduces potential oil demand from the transportation sector, despite a global increase in automobiles. Then there is shale gas. In the US energy industry, most shale gas production is probably just about breaking even at current prices. But technology innovation is continuously pushing down the cost of shale gas and shale oil production.

Of course, something like a major political disturbance in the Middle East might push oil back up temporarily. But it is better to assume that oil prices will stay relatively modest in coming years, putting more pressure on the price equation for sustainable, alternative energy sources like solar, wind, and so on. Traditionally the perception was that these were expensive but good for the environment, so they would be subsidized even if their costs were higher.

But now the perception is that people will go for the sustainable energy option if they believe it will be more cost effective in the long run than conventional energy solutions. This perception is taking developed countries into a new era with a new kind of demand for renewable energy research and commercial deployment. I see this as a good thing, because we cannot subsidize alternative energy sources in perpetuity just because it is good for the environment; that is not economically sustainable.

On the other hand, the developing world continues to face the issue of energy access. Billions of people do not have access to electricity. I'm on the Future of Electricity Council of the World Economic Forum, which is putting together a proposed goal with renewable energy options, and one our tasks is to provide a proposal and documents for the next version of the United Nations Millennium Development Plan goals for the next five years. For people on many continents and in many countries who lack electricity, just three hours of electricity a night could completely change their lives. Today, we invited a few speakers from the Davos community in order to link discussions in this symposium with the World Economic Forum and possibly the UN Millennium Development Plan.

So we have diverging issues in developed and developing countries. Our solution is to go big in Open Energy Systems, hypothesizing that the same technology, with different implementations, will be able to solve these two diverging sets of problems.

We are working to come up with an Open Energy System which consists of distributed generation from a varied set of energy sources, predominantly renewable ones. We intend for the Open Energy System to gradually overtake the old system. *Open Energy System*s are distributed and open-ended so that everyone generates and everyone consumes—as opposed to closed systems, in which consumer and provider are sharply differentiated.

There are three criteria for an Open Energy System: first, it must support economic growth and development. The cost of electricity, as a major economic input, has to be affordable and economically feasible, not dependent on subsidies and donations. Second, energy security. The system has to be secure, resilient, reasonably stable and not susceptible to geopolitical risks. The third criterion is environmental sustainability.

In *Soft Energy Paths*, Amory Lovins discussed the importance of distributed renewable energy sources as a more democratic, safe and robust option than centralized energy distribution systems. Now, almost 30 years later, what he described has become technically feasible.

There are people now talking about smart grids, and I think that's a good thing, but at the same time, some smart grid concepts assume centralized power sources, while enhancing the grid with internet integration, deep demand control, etc. Let's make a distinction between the conventional smart grid idea and Open Energy Systems. A smart grid on top of the conventional system is still a closed system, just augmented by technologies for increasing efficiency of power distribution and taming fluctuations in the power supply and the upstream demand curve.

We want to go to a totally extreme solution: completely distributed energy generation, consumption and exchange. It's a paradigm of consumer-generated energy: in the future, everyone generates and distributes electricity. In many industries today we are seeing this paradigm of "mega transformation."

For example, consumer-generated media. Some statistics say youngsters are spending about three times as much time on YouTube and on Facebook as they are watching television, which is of course centrally created and distributed media. This same paradigm extends to service providers like hotel or taxi operators—now people are talking about Airbnb and Uber.

Think about that: people are providing hotel services in their apartments and taxi services with their cars. Extending this idea to energy, people can start providing electricity as well, creating the basis for a mega transformation of the industry structure.

There is evidence that, discounting storage costs, we are reaching parity for technological affordability of renewable energy distribution systems. Storage costs are now the issue; if we factor them in, we have not reached parity yet, making that the biggest obstacle. But there are major investments in research, and a lot of interest in batteries among companies in the US, Japan and Europe. So I expect that in the near future we are going to see a dramatic reduction in energy storage costs due to technology innovation.

A very interesting opportunity for the Open Energy System concept is in Australia, which is suffering from high grid-maintenance costs. A study looked at one scenario: how a third of Australian consumers going off the grid would reduce grid maintenance costs.

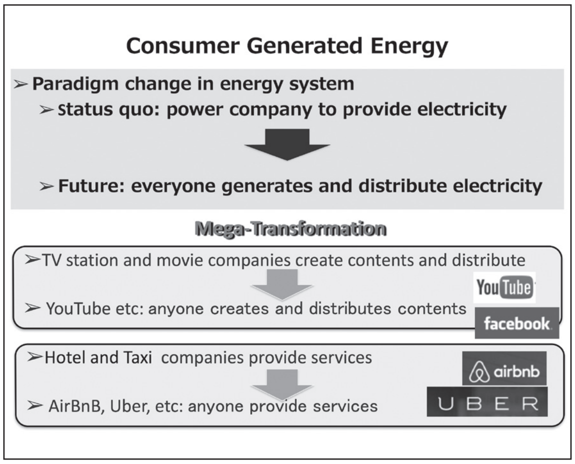
The concept of a completely renewable grid not only applies to developing countries where the conventional grid is not available, but also to developed countries suffering from grid maintenance. Particularly in countries that are so geographically diverse that maintaining the whole grid may not be economically feasible, people might decide to simply go off the grid.

The Global Agenda Council on the New Energy Architecture, in its “energy access for all” agenda, recommends Open Energy Systems as a leapfrog strategy, along with deep demand management. In areas of Africa, India and Southeast Asia where electricity from a fossil fuel-based energy supply is not available at present, providing renewable energy from day one would avoid many environmental issues. It requires a battery center that can distribute electricity effectively, which is exactly what we’re working on.

I think that our Open Energy Systems technology is flexible enough to allow the following: install systems one by one, simply connect them to create a small grid, then scale up. The same system Sony Computer Science Laboratories deployed in developing countries in Africa and Asia, with a slightly more advanced version of the technology, is already installed in 19 faculty houses at OIST, with families actually living in them. That is the power of Open Energy Systems: it can provide a single solution for divergent needs.

Scaled up to the regional or national level this would become like an energy cloud. I think that will be the vision everywhere for an affordable, sustainable and very robust system. At OIST we are trying to create a cluster of public-private partnerships and industry-academic partnerships to serve as an experimental proving ground for this kind of technology. Okinawa, as the southernmost major island in Japan, has similar climate conditions to Southeast Asia and other regions facing energy access issues. High humidity, salt issues and extreme weather such as typhoons disrupt the energy infrastructure frequently. So I believe that if we can successfully operate an Open Energy System in Okinawa, we can operate it in other places.

What are we trying to achieve with this symposium? We are now at an inflection point; things have changed dramatically since the last symposium a year ago. Now the time is ripe to come up with deployment strategies and form action plans. That requires bringing together all sorts of interested parties in academia, industries, governments, as well as in the global network of the Davos Community. The emerging community of this symposium can be the powerhouse of our initiative. I hope we can make a convincing case that Open Energy Systems are the way to go, and I hope that you will all want to join with us on this initiative. Together we want to change the world.



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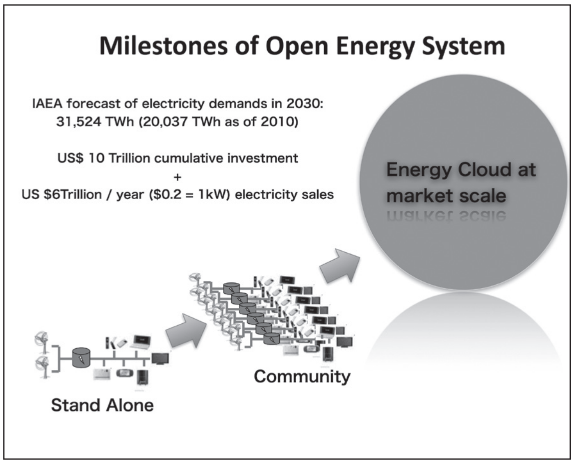

[Slide 21]

Speech 1: Prof. HIROAKI KITANO

Open Energy Systems: Toward a Global Agenda Solution for Sustainability

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Speech 2

From the Economy of Scale to the Economy of Choice

Speaker: Prof. PATRICK WHITNEY
Professor, Illinois Institute of Technology, USA

Good morning. I'm a professor and the dean of IIT Institute of Design (ID) in Chicago, where we focus on design methods that are more formal than those used in most companies.

Most companies use design to improve the appearance and ease of use of products and information. It is a direct process that defines a problem, selects a solution, and finds the optimal path to the answer. This direct approach is particularly useful when the producer is sure what the user needs and wants.

At ID we focus on what the offering should be before working on the appearance or user experience. Our process starts with, looking at the context bounded by strategic goals, user desires and capabilities for making offerings. Then, rather than going directly to the solution as done in direct design, we think of the problem as an abstraction [Slide 19]. Not an MP3 player, but enjoying music; not a car, but personal transportation when needed. Abstraction is frequently catalyzed by insights from user research. The user research and abstraction are core to what we call reframing or redefining the project. We then create many options, and develop a plan and a road map for moving into development. This approach is a new way of doing design that is gaining popularity with executives who are noticing that they almost always get an offering wrong when it is new. They find the time spent on abstraction and reframing is less than the time spent on redoing projects because of not understanding what people want.

I had a conversation a few months ago with John Rowe, at the time CEO of Exelon, the largest nuclear power provider in the United States. I asked him what was happening with the smart grid, and he said, “We know several different ways of creating the smart grid, but we don’t know which one people need. We don’t know what they want.”

Whether it is the smart grid or small appliances, companies face the ironic situation of knowing how to make anything but not knowing what to make. The problem of not knowing what people want did not afflict producers in the pre-industrial or early industrial eras. Before the processes and benefits of mass production economy of scale became common, most people did not have time-saving and life-enhancing products and services. When a company offered a new product at a low price, it was immediately bought with relatively little support from advertising or marketing. As consumers had more choices, the fields of advertising, retailing and marketing created ever more refined frameworks and methods of trying to predict what people want.

The dotted line [Slide 6] represents the path companies in the mid-20th century thought people were taking and the perception that consumers lived in market segments defined by income. Driven by the technology of the economy of scale, companies would sell stylish stuff to people who had more money and basic stuff to people who had less money. The solid line represents the path people actually took—through ever-fragmenting markets. In response, academics and executives invented new frameworks to deal with this fragmentation: focus groups, demographics, early prototype testing, market segmentation, etc. For example, in 1922 James O. McKinsey, an accounting professor at the University of Chicago, published a landmark book titled *Budgetary Management*. In it he outlined a three- part framework of the use of budgets:

1) Monitoring the operations of separate departments such as sales and production.

2) Coordinating the operations of departments into a whole business.

3) Noting future conditions and business cycles and shaping plans to meet these conditions that he called “forecasting” or “business predicting”.

McKinsey recognized that these activities were related and were already practiced in informal ways in various organizations. By noticing the patterns underlying these informal practices and developing a general framework that explained the patterns, he made it much easier for executives to lead organizations, students to learn new processes, and researchers to build upon the work of others. In particular, using the budget for "business predicting" captured the attention of executives whose demand for his services led to the creation of McKinsey & Company.

Their attraction to frameworks that let them understand and plan their future was understandable given the large, long-term bets that were inherent in the large and expensive production facilities that were core to their businesses.

The business methods and protocols created then are still the accepted way of managing a business today; they are the wrong way for the world that Professor Kitano described in his talk this morning. They were built to understand large-scale predictive systems instead of smaller-scale responsive systems.

Here are a few of the standard questions that those of you in the corporate world will recognize:

Which offerings are still selling well and have opportunities for line extensions?

What are competitors doing?

What do customers want?

These are all reasonable questions asked by managers responsible for step changes in established industries. This level of innovation offers high certainty that a project in the company will succeed, but they typically have growth rates that are too low to sustain the company. With step-change projects you know what you're planning on making, why you're planning on making it, how to make it, and who it's for. Those all become ambiguous when you move to leap-change projects. These are much more likely to fail, but when they succeed, they can lead to very high growth rates.

Henri Nestlé's infant formula. Sony's Walkman, which created the personal music business. Apple's iTunes, the first commercially successful software for organizing digital music. These are first-of-their-kind innovations. If these founders used the questions above as the criteria for those ideas, not one of the concepts would have been commercialized because they weren't based on any existing product, there were no competitors, there were no customers, and there was no shared margin to grow. The questions asked by Mr. Nestlé, Mr. Morita, and Mr. Jobs were much more basic—they are questions asked by successful entrepreneurs.

What should I make?

Who will want it?

Why will stakeholders find value in bringing it into life?

How do I make it happen?

They are also the questions asked by designers who focus on strategy. When compared to the standard managers' questions, these are more flexible; they offer more options. They are less reliant on the facts of what exists and more in line with "sketching" a vision of the future.

This is where design intersects with Open Energy Systems. We need to sketch not only what the technology and new uses might be but also sketch new business models and operating models.

Segmentation models are not as reliable as they used to be. Market segments are fictions of companies who intersect demographics with people's propensity to buy something. That works only when there's an economy of scale and people don't have much choice. When people have many choices, market segmentation starts to fail.

In the 20th century, companies were making big bets on operations because the way they competed was by having their functional silos operate more efficiently than the silos in other companies. Today it makes more sense to understand critical activities whether or not they are tied to a silo.

Navroze Godrej is the leader of innovation at Godrej & Boyce, a major Indian appliance manufacturer. He led their initiative to make a low-cost refrigerator for the 80% of people in India that can't afford refrigeration. In user testing they discovered there was a social problem of getting people to use Chotukool because in Indian villages, people didn't want cold food, they wanted food bought daily in the market to stay fresh for two days instead of one.

Keeping food fresh for one extra day changes the current daily trip to the market into a trip made every second or third day. Godrej discovered that a smaller, lower powered product that kept things fresh was more desirable than a conventional refrigerator. However, as they continued to observe daily life in the villages they had deeper insights about other opportunities. The real challenges, it turned out, were explaining the product and distributing it. For this, they turned to women's groups in the villages who created enterprises for marketing and distributing products. From Godrej's point of view, Chotukool is not just a business about selling refrigerators, it's a business about job creation in the bottom of the pyramid. This will help India by bringing people into the middle-class. And, of course, this helps them buy the range of products Godrej makes. The Godrej team was not concerned with functional silos but were very aware of the system of activities needed to bring Chotukool to life.

The power generation people at Godrej asked me how to get the bottom-of-the-pyramid population to buy a greater volume of reliable power from them. After talking for a while, we decided that was the wrong question.

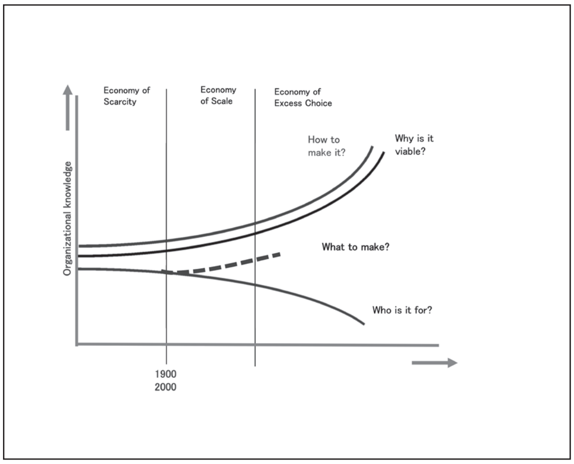
The right question is how to bring more people out of the base of the pyramid and into the lower middle class, which needs greater amounts of power in daily living. We are now exploring community centers in villages that help people who want to start or grow small companies. The centers may provide a range of services such as bookkeeping, reliable fax machines, and internet connections. The hope is to build an economy that will make bottom-of-the-pyramid people wealthier so they will buy more reliable power.

I'm very enthused by the more decentralized and flexible approaches described by Professor Kitano because certainty has gone away. We only had certainty when we didn't count intangible values and externalities. We only had certainty when we didn't know the real cost of things. We only had certainty when we pretended we had it. There is a growing recognition that for leap-change projects there is no certainty of outcomes, no matter how much executives and policymakers want it.

Remember the example of Professor McKinsey proposing the use of the budget to plan future activities? That was in an age when things were predictable and you could make ten-year bets. Clayton Christensen, the author of *The Innovator's Dilemma*, claims that financial projections for major innovation projects are either mistakes or lies. He says they're never right and we should stop doing them. Roger Martin, the dean of the Rotman School of Management at the University of Toronto, calls detailed financial projections for large-scale innovation delusional.

What if the maker movement, distributed flexible energy systems and production systems, and 3D printing as a production tool continue to expand? What if we find new business models that aren't tied to the economy of scale? Maybe we will move from an era of excess of choice to an era of sustainable choice. This would bring about fundamental changes as significant as those catalyzed by the Industrial Revolution. As an example, let's look at the size of companies. According to Ronald Coase, a Nobel-winning economist, the reason the economy of scale demanded the creation of big companies was to reduce the transaction costs and increase the trust between people. Now there are new ways for reducing friction and building trust. The World Wide Web, social media, and a company's choice of ecosystems shift the advantage from the biggest organization to the most flexible. It may be that the only big companies we need are insurance companies and infrastructure companies while every other organization benefits by getting smaller and responsive.

Responsive organizations decrease the need to know the result before we start the design. Designing for what we don't know yet is really important. We shouldn't be aiming at solutions—we should be designing platforms. If the maker movement takes off, people will make their own solutions. We need to create flexible systems that allow people to make things we haven't imagined yet. We are going to do some things wrong. Let's be wrong in a flexible way. It's faster, less expensive, and better to be roughly right rather than precisely wrong.



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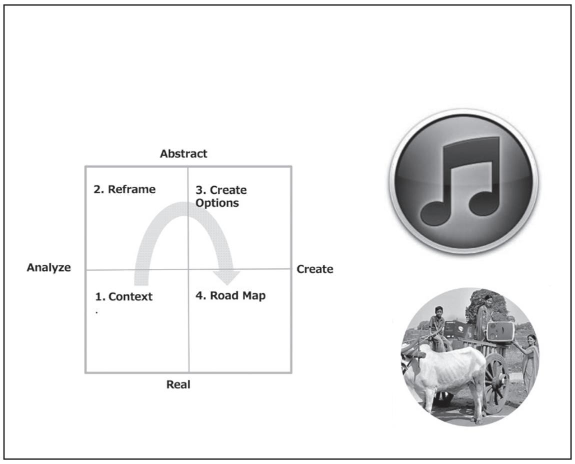

[Slide 19]

Speech 2: Prof. PATRICK WHITNEY

From the Economy of Scale to the Economy of Choice

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Speech 3

DCOES: DC-Based Bottom-Up Energy Exchange System for Community Grid

Speaker: Dr. MARIO TOKORO
Founder and Executive Advisor, Sony CSL, Japan

I'm going to talk about DCOES (pronounced "dee-coze"), which stands for DC-based Open Energy System. This bottom-up energy exchange system creates a community grid connecting 19 faculty houses at OIST, each of which has a solar panel and battery.

[Slide 3] The chart on the left shows the energy exchange being performed among houses. The amount of energy generated by the PV panel and retained in the battery of each house is shown by the size of the green rectangles. The chart on the right shows the history of energy produced, used, exchanged, and remaining in each battery.

We have algorithms that determine automatically, for example, that if one house's battery is above 70% charged, then it is ready to supply other houses. Another house where the battery is only 32% charged may request that energy be sent from the first house. Our algorithm specifies that if the battery charge drops below 30%, the house won't supply electricity, because this is the amount needed for the house itself. At night, the houses must buy energy from Okinawa Electrical Company.

This is the structure of the DCOES system [Slide 9]. It consists of a PV panel; charger; battery (at this time a 4.8 kilowatt-hour battery using four modules of 1.2 kilowatt-hour Sony lithium-ion batteries); energy system controller; bi-directional DC/DC converter; inverter; and AC switch so that DC energy can run AC appliances.

If there is no charge in the battery, power comes from Okinawa's electric utility. We call this part the Energy Server System. Nineteen of these ESSs connect on a DC grid equipped with various switches to isolate segments for maintenance or other purposes.

This system is not just experimental. It is in active use. Since mid-December residents have been using this energy system every day without our intervention. It is operating by itself very securely and reliably. There is some minor variation in equipment between houses; 2.8 kilowatt PV panels on some, 4.2 kilowatt on others. Some have two PV controllers. All the houses are equipped with 4.8 kilowatt hour batteries [Slide 12].

Along with the Energy Server System, a weather station and DCOES distribution board, separate from the regular distribution board, are installed. The privately owned DC grid is 350 volts; 380 would be the maximum because of device specifications.

On the conceptual side, our project goals are very simple but very important. The system must be sustainable, which means not passing on any liability to the next generation. The system must be dependable, keeping risk manageable. And the system must be accessible to everyone on Earth, that is, something everyone can afford. This leads us to renewable energy as a base energy source, a bottom-up architecture with an energy exchange system for dependability, and the possibility to start with a small investment for affordability.

We call this a community grid. There are two well-known topologies. One is distributed stand-alone systems. Each house buys a solar panel and uses it, and sells any excess energy produced to electric utilities. Then people start to install their own batteries because power companies do not want to buy any more energy. This is a bottom-up architecture implemented by individuals. If we look at these houses collectively, they may not be very energy efficient overall. The advantages, however, are that one failure cannot cause total system outage, and installations can happen one by one, keeping initial costs low.

The other topology is a centralized system. Earlier implementations would have been just the PV panels, but recently these systems have been installing batteries, which is a step forward. This is a top-town approach by a single entity, so overall efficiency is very good when serving a user base of known numbers and usage patterns. But since it is centralized, a single failure could cause a system outage. And it has a high initial cost.

In reality, batteries cannot store all the energy produced. By around noon, the batteries have become full. The PV panels can generate more energy, but since the batteries are full, they can't store any more of it. If there is nobody home and power usage is low at this time, then part of the energy is actually wasted.

The "standalone" topology has a low initial cost, is flexible in size and type of implementation, and offers independence from the grid. The "centralized" topology achieves improved efficiency, but with lower reliability and dependability. DCOES combines the advantages of both.

If we measure the self-sufficiency ratio over time [Slide 23], centralized PV has the best performance. The difference is substantial, especially if the PV panel produces a lot of energy. DCOES is in between the two, but closer to the top, to centralized. We collected real-world data from December 24 to January 23. In winter, standalone achieves a 43% self-sufficiency rate, DCOES 52% and centralized 56%.

Not very good figures, but in summer (according to our estimates, since real-world data is not available yet for that season) standalone reaches around 60%, DCOES 73%, and centralized 78%. In other words, DCOES will be able to replace 73% of power bought from the utility. Not bad. And if, hypothetically, we doubled the PV and battery capacities, according to our simulation, DCOES would achieve 95% self-sufficiency in summer and 82% in winter. And actually, it seems that we don't need to double the PVs—doubling the batteries alone really works very nicely. So we hope that the price of batteries will fall the way solar panel prices fell.

In summary, DCOES shows that with low initial cost and high flexibility we can have efficiency almost as high as a centralized system, along with very high dependability. On the technology side, we designed our electrical system with one voltage source and *n* current sources. A voltage source keeps the grid voltage at 350V. Current sources set the desired current.

We have software for robust and flexible distributed control. Each node has three modes: Waiting, constant voltage (CV) mode and constant current (CC) mode, which are computer-controlled over the network. A node in CV mode supplies 350V to the grid as a reference voltage. And then a second node signals to a third, "I'm sending energy." Those nodes are both set to CC mode, and a current of, for example, two amperes at 350V flows between them.

A second transfer can happen at the same time from yet another node to two more nodes. This is all negotiated across the network, schematically, since the actual current is not divided of course. How is the decision made to exchange power?

The simplest policy is based on capacity available for giving and capacity requests for receiving. A second kind of policy could be predictive, based on past usage patterns, and projected generation and consumption based on the weather forecast. A third policy could incorporate demand response levels. In the future we'd like to become a virtual energy provider by tailoring the policy mix to each community. A community that doesn't need to charge users for energy costs could prioritize maximal efficiency. One that does need to charge users some money could have a different policy.

The DCOES project is run by a research consortium, and supported by the Subtropical and Island Energy Infrastructure Technology Research Subsidy Program of Okinawa Prefecture through March 2015. We hope to extend that support for two more years. The aim is energy solutions and new energy business opportunities for Okinawa, island countries, and the world.

People from Sony CSL, OIST, Okisokou, Sony Businesses Operations Inc., Sony Energy Device Corporation and Sony Corporation have all made important contributions.

One acute need in Okinawa arises from being hit by typhoons three to five times a year. Rural areas of Okinawa can have power knocked out for two, three, even four days at a time. So there is an acute need for battery backup. Our system offers major advantages over oil-fired generators, which are very good systems, but are used only two or three times a year, while needing maintenance, operational drills and so on every month.

Our system, in contrast, can be used every day to reduce energy costs, and will make a big difference in an emergency. Smaller islands the world over face a similar situation to rural Okinawa, as do non-electrified communities in Asia and Africa, as well as very remote communities in places like Australia which are so isolated that they need to be able to survive on a standalone basis.

For the future, on the technology side, for now we only have this one tier of 350V exchange cable, but we could add a higher tier at 800V, and then another tier above that. If we could partner with an electric utility, we could connect with a centralized PV system. This type of hierarchical, hybrid installation is the dream.

And we would like to have all-DC houses. Daikin, one of the world's biggest air-conditioning companies, is collaborating with us on DC-powered air-conditioners. LED lights are basically DC. In general all appliances with a motor are now inverter based, making them very easy to modify for DC.

DCOES on the OIST campus, a proven real-world implementation, may be the only installation of its kind in the world at this moment. I hope that DCOES, as an architecture for a community grid for everyone, will contribute to humankind and to society.

Q: What does this architecture offer urban areas?

A: We are not in a rush to push our technology to urban areas for now, but this architecture can certainly be used there. If we start with the places or regions where residents really need electricity, and then produce so many units for that market that the unit price is driven down, it will then attract interest as an alternative in urban areas too. Then new buildings, new housing developments, could be equipped with a DCOES-type community grid. In five or 10 years, people may be thinking more about distributed, DC-based energy exchange rather than conventional distribution, so there are big possibilities.

Q: Can we depend on solar panels and batteries to replace conventional power plants?

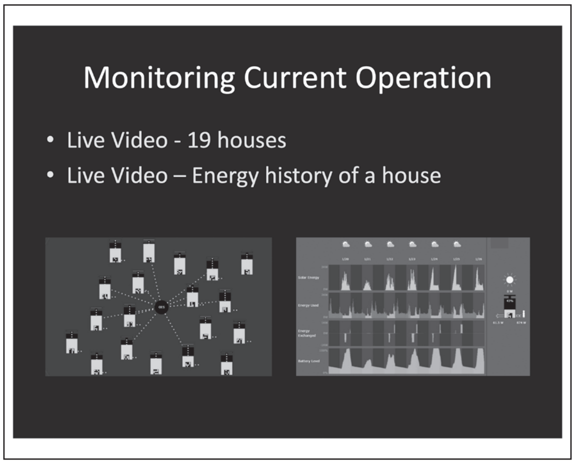
A: Yes, but we can also combine them with other sustainable energy sources, like biomass turbines, maybe hydrogen systems.

Q: Do residents know what's going on with the system? Do they make decisions about energy exchange? Are any power-hungry appliances like air-conditioners networked in to adjust how they operate depending on the system conditions?

A: Every house can see what's going on in the system as a whole, but only the residents of each house know what's going on in that house; not in their neighbors' houses. At this moment, we are not focusing on home energy management systems and don't have them installed. But we have started some research into incorporating home management systems, with their superior predictive operation, by collaborating with organizations that are developing them.

Q: What about communal dynamics? Is there any sense of consumers living in these houses feeling that their actions are impacting other people?

A: If you start bottom-up, with standalone systems, and then connect them to each other, you may get situations where people are saying, "Oh, my neighbor is always using more than I use, after I invested all this money!" But if right at the start of a community like this, everyone knows that they have to pay according to the amount they use regardless, then everyone is happy. And that is the model we are thinking of for the future.



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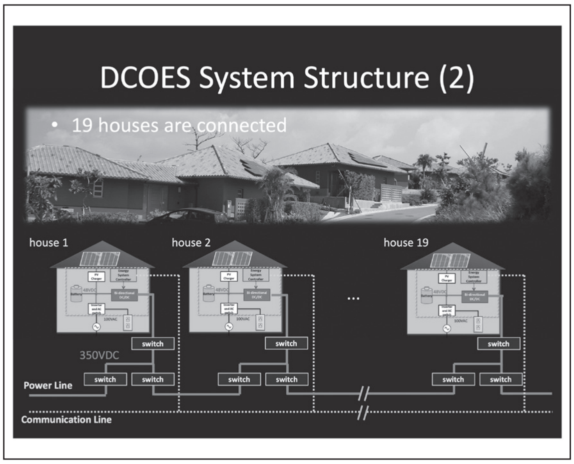

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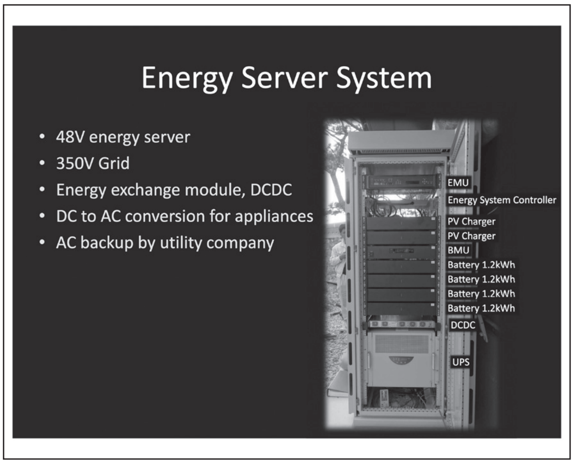

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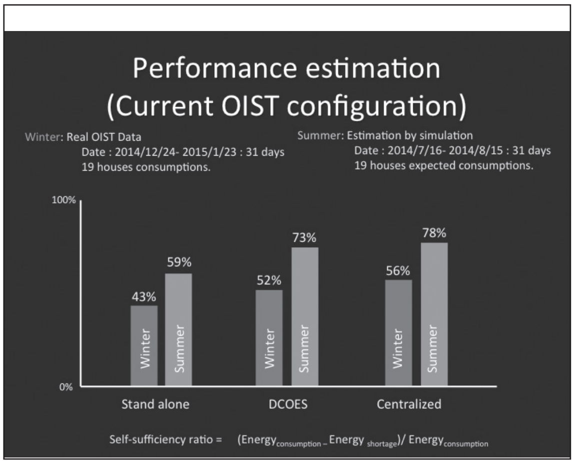


[Slide 23]

Speech 3: Dr. MARIO TOKORO

DCOES: DC-Based Bottom-Up Energy Exchange System for Community Grid

Download the presentation PDF: http://bit.ly/1BaNFYx

DCOES Tour

On the first day of the symposium, participants were invited to see for themselves the Sony CSL-OIST DC-based Open Energy System (DCOES) on the OIST campus. Prof. Hiroaki Kitano, Dr. Mario Tokoro and other members of the project took participants on a guided tour of 19 houses that are already demonstrating the practical value and future potential of this cutting-edge initiative.

Session 2

New Deployment for Energy Sustainability

Speech 4

Future of Electricity

Speaker: Mr. T. P. CHOPRA
President & CEO, Bharat Light & Power, India

I'd like to share with you my perspectives on what the new energy structure is going to look like for a country like India. Many new business models are likely to be adopted in places like India before they happen in the West. India is going to be one of the biggest laboratories in the world for testing out new business models and new technologies.

In India we still have somewhere between 300 million and 400 million people who lack electricity. We started Bharat Light & Power to try to provide solutions to this problem. Our focus is to improve the quality of life of people in India by providing clean energy at an affordable price. The key word here being affordable, because one of the biggest drivers in a place like India is the cost equation.

If we can succeed with technology at a cost point that works for India, we can do it anywhere in the world. Our strategy has four parts: first, building high-quality projects–wind and solar farms–with good returns. Second, driving growth by executing at the necessary scale. Third, building relationships. (Part of the reason I'm here is to meet other technology providers so BLP can bring the best technology back to India and implement it.) Fourth, innovating continuously. Our three key business segments are wind (we build and operate wind farms across India), solar and services. At this point in time our major focus is on the generation side. Slowly down the road we will start focusing on the consumption side in India as well.

Let me address the energy challenge. Why is it that we are all talking about distributed energy? Because we need to envision a paradigm for a whole new energy architecture. Why is that? One, global population growth as a whole. Two, growth of the middle class in Asia.

Today it numbers about 500 million people; by 2020, there will be 1.75 billion people in the middle class in Asia.

And that is going to be one of the most traumatic demographic shifts in the history of mankind. It means energy consumption is going increase dramatically. In 2010 in the United States, per-capita energy consumption was roughly 13,395 kilowatts per person per year. In China in 2010 the number was 2,944. In India in 2010 it was 626. Last year the United States was closer to 14,000, China was closer to 4,000 and in India we had 800. So think about the potential growth that's going to happen in places like India. Lastly, the emergence of mega-cities, which have populations of more than 15 million. Today we have 22, by 2025 we are going to have 35 megacities.

A combination of population growth and urbanization will result in dramatic changes in the way we consume energy and the demand for energy going forward. If we look at human development on the y-axis and the annual per-capital consumption on the x-axis, what stands out is that at 4,000 kilowatt hours per person per year, there is a dramatic improvement in the human development index [Slide 6]. And then it tapers off. In countries like China and South Africa and India and Nigeria we are going to see dramatic improvements in the quality of life as their energy consumption rises over the next few years. So energy demand is going to double by 2030.

As for carbon dioxide emissions, China's are actually greater than the United States and Canada combined. India is not very far behind. In 1978 China consumed 700 million tons of coal to produce thermal energy. Soon China will consume 4 billion tons of coal per year to produce thermal energy. 49% of all the coal in the world is being produced or consumed by China to produce thermal energy. But people in Beijing and Shanghai demand a change, because they can't endure the level of air pollution any longer. And resources, at some point, are going to run out: coal, uranium, and so on. If we don't start thinking about new business models and new technologies today, we will meet all sorts of problems down the road.

Speaking of resources, 50% of all the water consumed in the world is used by thermal electric power plants, while 30% of the world's population today is actually water constrained, rising to 60% by 2025. Considering that, which water use do you think is going to be impacted tomorrow when people can't get a glass of clean drinking water? These looming issues are the reason the world's technology companies need to solve the energy issue today. In India specifically, key drivers toward a new energy architecture are a growing population, dramatically increasing consumption, energy security (India imports nearly 70% of its oil), and huge production issues affecting gas and coal.

Along with environmental concerns, these present huge challenges to how to grow energy in India. So what will the future look like for India and the rest of the world? One key challenge is the tradeoff between economic growth and environmental sustainability. Will the Chinese government be willing to sacrifice GDP growth by shutting off thermal power plants in order to have cleaner air? That's going to be the ultimate question for a lot of us in this room and for a lot of governments and regulators around the world.

A critical need is for governments around the world to provide clear policies driving us toward a different future. Unless they start providing a clear mechanism for pricing carbon, it will be a struggle to scale up renewable energy plants adequately. And yet the amount of solar energy we get in one year is greater than the combined availability of all other resources.

Therefore I think that countries like India will make a huge push in solar. The government of India has announced that they want to get to 100 gigawatts by 2022. India today is the fifth-largest producer of wind energy in the world. Technological progress, such as the advent of 164-meter rotor diameter wind turbines, specifically designed for low-class wind speeds, will make wind power more economically viable in low-class wind speed countries like India.

In terms of solar PV panels, about five years ago the price was $6 per watt, a few years ago $3. Today's panels are closer to 53, 54 cents per watt. I don't think any of us could have predicted such a rapid decline in the cost of solar.

It's exciting to see the kind of technology that is being developed at Sony. Because the key change factor going forward is storage. Solar panels are now commoditized. I think it will be incredibly interesting over the next couple of years to see how we integrate new lower-cost solar panels with new storage technologies that are around the corner. All the analysis I've seen indicates a trend for investment in conventional energy to slow going forward. Whereas renewable energy investments will be growing dramatically over the next couple of years.

At BLP, we are leveraging big data, the cloud and analytics to improve efficiency. One area is reporting, actually providing people with the data that they need. Another is monitoring, ticketing and field operations. And then advanced analytics and forecasting. We collect all the data from power plants around the world. We are monitoring over 100 power meters live every second from every wind turbine via satellite on the cloud in Singapore. From Singapore the data is transferred to our control center in Bangalore where we do all the monitoring and ticketing, the reporting and the analytics and forecasting.

From there the information goes out to the engineer in the field who actually climbs up the turbine. He has access on an iPad to all the information from the time the turbine was installed until that very second he is up in the turbine. And ultimately we optimize the entire portfolio to improve the performance of the entire fleet. Our approach is all about data science: collecting the data and making sure we have the right data.

Then we apply our deep domain expertise to analyzing this data about the performance of the turbines. It also requires putting together the entire IT infrastructure that can offer security, stability and flexibility. We use all that to perform the right analytics to achieve the output of improved efficiency of our wind farms. We've developed what we call the Gamma approach: we gauge the information; address the information; map it; model it; and then automate it.

We use a couple of key tools. Visual analytics is key for understanding what is the right kind of data. We can predict very precisely that, say, 100 hours from now there will be a gearbox failure, so we can fix the problem before the failure happens. We rely heavily on cognitive approaches and automated rule-based alerts to do predictive intelligence. So we do three things: analyze the data, making extensive use of breakdown analysis and Pareto analysis; estimate what is going to happen; and forecast using all kinds of wind power forecasting and historical weather pattern data.

One use case is outlier analysis. At any point in time on a wind farm we see very wide variations in the performance of individual turbines. So we divide the entire farm into clusters to figure out why one cluster of turbines is performing better than another cluster in the same farm, and where limits are being breached. And we try to identify why one turbine is performing better than another. We look at different parameters of the turbine and analyze the performance of each of its components to come up with a score for the health index of each turbine. This visual diagnostic shows temperature measurements across different components of turbines. Each colored line signifies a particular turbine. We can see that a certain turbine is beyond the proper parameters compared to others at the same wind speed.

We do a lot of mean time between failure analysis of various components. It is critical to be able to know exactly when a problem is going to arise before it actually happens.

We aim to teach supercomputers how to do these analytics on an ongoing basis by developing algorithms. Now automated alerts are sent out whenever we have a problem at any of the turbines. Every second of the day we analyze the actual performance of the turbine relative to the theoretical maximum power curve.

We do a lot of benchmark analysis. We compare the performance of turbines among our wind farms. And we compare it to other companies' wind farms that we are monitoring for them. We study the performance of the turbines, even down to the level of specific turbine components.

For power forecasting, we use two models: a clear sky model and an adaptive linear time series model. This enables us to take historical weather pattern data and correlate it with data that we are collecting from each of the turbines. Power forecasting is going to become critical as smart grids develop and we integrate renewable energy into the grid.

Finally, met model validation. We continuously analyze the data to compare at any point in time how the model's forecast of the energy that would be generated matches up with the actual energy generated. Now we are working on how to correlate historic weather pattern data with actual data coming from the turbines to enable prediction of the weather. That will enable us to optimize the pitch and the yaw of these turbines to capture energy better, and change the way energy is produced going forward.

What about the consumption side? Can we take the same communication technologies that enable us to analyze power generation across the country and apply them to consumption as well? The next big wave of the new energy architecture will be all about energy efficiency. How do we become more energy efficient both on the generation side and the consumption side? Smart cities will be a great opportunity to implement all kinds of technologies. The Indian government has announced a program to build 100 smart cities India. There is going to be a dramatic shift in terms of large renewables, and in terms of small renewables. There is going to be a big push for clean air. Electric cars will help a lot in countries like in India and China.

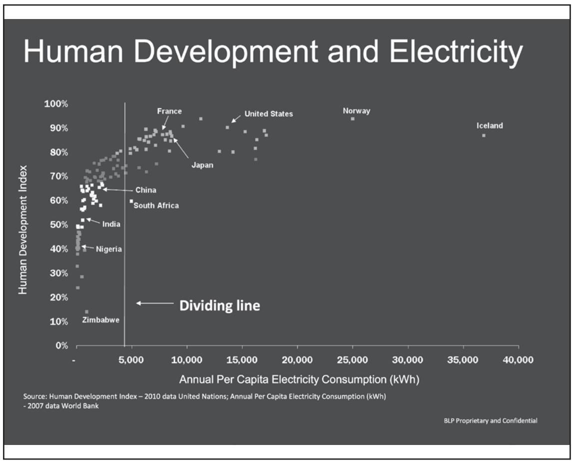
What about the centralized grid versus the decentralized grid? A persistent question is what the impact on utilities will be. Professor Kitano referred to the Uberization of energy. I know that if BLP moves toward decentralized solutions in India we will be stepping on the utilities' toes. They wouldn't like it if we started owning the consumer as well. But what if we can provide a distributed energy solution to a billion people? Can the government stop us if we go to peoples' homes and give them the solution? We are doing pilot programs in a few homes right now.

And finally, consumer versus prosumer. The game changers on this issue will be financing the delivery of the solution and getting the consumer more involved and actually understanding his energy bill.

The issue is how to develop a system that makes it easy for consumers to understand. We need to have an easy-to-use app that can give a billion people the ability to understand the way they consume energy and produce energy. That would transform how we actually produce energy around the world.

And if utilities don't adapt, newer players like BLP will claim the market. We don't have the legacy infrastructure; we have the latest in technology and flexibility. The system we designed uses the cloud so it can scale up very quickly. So we can move very quickly to adapt to the situation in India. What is going to happen in India in energy is exactly what happened in telecom. We have 900 million cellphone users today in India. Very few homes have landlines anymore.

The question is how long until we get the cost point down, until we get the financing and the business model right, to scale all this up India.



[Slide 6]

Speech 4: Mr. T. P. CHOPRA

Future of Electricity

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Speech 5

NANO-grid: Sustainable Green Energy Solution for Off-Grid

Speaker: Mr. DIDAR ISLAM
Managing Director & Founder, Solaric, Bangladesh

My name is Didar Islam, Managing Director and Founder of Solaric, a company in Bangladesh delivering affordable, proven solar technology on a commercially sustainable basis to provide electricity for household, community and agricultural use in off-grid areas.

Solaric's NANO-grid reduces end user cost by as much as 70% through innovative and appropriate technologies. Improved energy efficiency, modularized design, scalable system, pre-paid metering, and power line communication are the key attributes of the system. I doubt many of us sitting here really understand what living off-grid means. It means no electricity, no sanitation, no water, no banking, no government. Imagine that. That is 50% of the population in Bangladesh.

But in Bangladesh, 3.5 million people are using so-called solar home systems. A system with one panel, one battery, a couple of lights. All remote and off-grid. This 3.5 million number is more than the entire rest of the world combined. It was made possible through system development that combined financing, simple and appropriate technology, and an efficient way to deliver.

In 2009 I saw one home using such a solar home system. I asked, "Why are you using 12 volts?" Basically the system is a 12 volt battery and a 12 volt panel. And they said, "Well, this is what is available." I asked, "What if we can come up with something that gives you almost the same benefits of home electricity as being on the utility grid?"

But the question is not just the technology; it's whether you can deliver the product. There are three basic elements of a successful energy business off-grid. One is technical efficiency: your technology has to be efficient from generation all the way to the consumer. But more important than that is financial efficiency. Can you sell something in an off-grid area and bring back the monthly payment to your bank account?

They were selling systems on something like three years' credit, at a cost of between $150 and $400. A program supported by international donor agencies like the World Bank and others. It required going door to door to collect the equivalent of $5 every month. And that money had to go through all the layers back to their bank account, with lots of pilfering in the process. At the end of the day the whole system becomes very, very inefficient.

The third element is how to provide service. People are buying a product that they don't know how to service. So they are relying on somebody else to come to their home for servicing. But they are living in an off-grid area, far away from any resource center. So the cost of providing that service also goes up. System efficiency, payment collection efficiency and providing service to the end user, in combination present a big challenge.

The first system we developed was a 120 volt small solar system, one you can plug any appliance into. Built into that was a payment system. And that payment system was very simple. Because it is a product, not a utility or energy. So we implemented a fixed, monthly payment collection system paid by mobile phone. Whether they have electricity or not, people have mobile phones. They get a four-digit code in their mobile phone and use the TV remote to input that code into the device and they're on for one month. And that simple system was like dynamite. It changed the whole process. Now nobody needs to go door to door. No bad loans or collection and collection efficiency is 100%.

Next we came up with the NANO-grid. We talk about microgrids, mini-grids, those are in the 100kW, 50kW range. NANO-grid is a 3kW system. The same size as in the homes that are part of DCOES at OIST. But it's powering 50 homes in a neighborhood within a 2km radius. Each home consumes 50 watts, powering a TV, a fan, a couple of lights, mobile charging and a few gadgets. And the monthly payment is $5 a month, roughly; it can vary because it is meter-based.

We are now installing 10 of these grids every month. Within months we will ramp up to 100 systems per month and we are signed up with a company in the US to do 5,000 of these NANO-grids in the next three years. And that's just the beginning. Because Bangladesh alone needs 100,000 of these grids. There's a reason why they are so small. Because if the grid size is too big, utilization goes down. Because power needs in the beginning are very, very low in off-grid areas; people are switching over from kerosene lamps. We never get near 100% utilization, but if demand grows then it's very easy to scale up in terms of panels and batteries because it's a DC system. In only one place have we needed to scale up from 3kW to 5kW.

In the longer term, the world has 1.3 billion people living off-grid. In Africa it's 80% of the population. We are now operating in four countries other than Bangladesh: Tanzania, Nepal, Malaysia and India.

We founded the company in 2009, when we saw that the price of PV was coming down to the point where it would soon become commercially viable. Meaning, we wouldn't need any subsidies, or any donors. Our objective is to innovate appropriate technologies for the off-grid population. And that includes not only the generation but also the financial gateway.

In Bangladesh the cost of grid extension is around $400 on average per home. The cost of setting up the NANO-grid, inclusive, even the LED lamps in the house, is around half that. Because a 3kW system for 50 homes is around $10,000. That's $200 per home. Just 50% of the cost of grid extension by the government. This is a compelling argument for why many people in the world will never see the grid, just like they will probably never see a landline phone.

Small solar home systems are too expensive at around $8 per watt-peak for a small system with one panel and one battery. The monthly installment for lighting works out to around $2 per lamp per month. And the cost of revenue collection, which is the bulk of the operational cost, is very, very high for systems like that which are fully distributed at the home level.

Five dollars a month. That's the magic number. The percentage of the annual income spent on energy in off-grid areas is much more than urban areas: 15%+ compared to 3% to 4%. In Bangladesh, $5 per month is the number that the top 60% of the off-grid population can actually afford to pay. They are paying it either way: for kerosene or for a solar home system or for other alternatives.

With NANO-grid for the same cost per month, $5, they can now actually use lights, TV, fan and all the amenities. The system looks like this [Slide 8]. It's a 3kW system with a 36kWh battery. Plus an additional 5kW panel only for day use for seasonal irrigation purposes. We have a small generator as a backup, for bad weather conditions. For the electronics, other than the panel and the battery, the highest cost item is the inverter.

Solaric's innovative "Inverter-less" technology, by eliminating the inverter, has enabled us to bring the capital expenditure down to only $3 per watt-peak, less than 50% of solar home system products.

The system is 220 volt DC. The generation and the battery is all in one place and a 220-volt cable goes out to every home. The home only has one device, called the prepaid smart meter. It doubles as an energy meter and a fixed monthly payment gateway. An energy user can top up, just like with a pre-paid phone. But if he wants to buy an energy efficient appliance and pay on installments over six months, he can use the same gateway, make the monthly installments over the mobile phone, get a code, input it and his device works.

It's a complete ecosystem supporting the off-grid population. It can support rural economies by providing power for small-scale irrigation pumps and commercial or community establishments (such as tea shops and local government offices).

The payment system is centralized. In this NANO-grid system people are buying only energy, not a product. We call it a virtual utility company. In a country like Bangladesh where the population density is so high it is not hard to find sites.

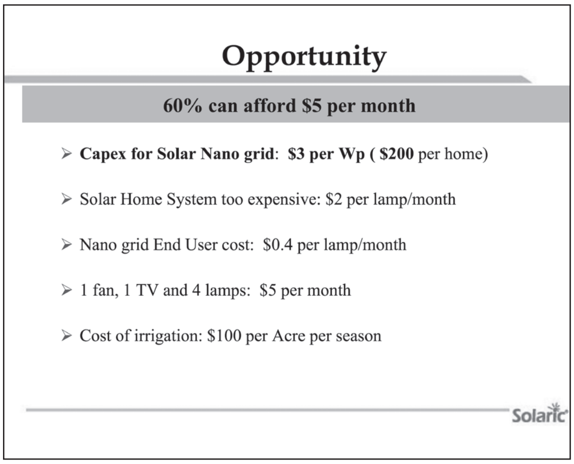
A local entrepreneur operates the NANO-grid system site as his own business, basically setting up their own retail energy organization. Finding the right people who can be trained and trusted to operate the NANO-grid is the difficult part. So we have a very elaborate screening process.

A NANO-grid costs around $10,000 per site. It is financed by every home paying a one-time $50 connection fee. From 50 homes that is $2,500. The entrepreneur pays $2,500 as a security deposit to us to start the business. He has to submit signed documents from 50 homes stating that they want to connect, and what appliances they want. Requiring entrepreneurs to complete those steps automatically mitigates some of the risk.

So we collect $5,000 up front. The remaining $5,000 we finance at a commercial rate through commercial banks. The entrepreneur gets his return back in 18 months. The bank gets its money back in four years at 9% interest, after which the entrepreneur owns the whole system in perpetuity. So it's commercially driven, at commercial rates, with no subsidy, significantly lower end user cost, and solar as the source.

The operator provides one service point for the 50 homes, which drastically diminishes the cost of providing service compared to one system per home. One employee paid $100 per month supports 10 NANO-grid sites, 500 homes. We have remote sensing via power line communication over the DC cables so we know how every NANO-grid is operating, how much energy each home is using, collecting all this data without having any internet or connectivity.

We can turn the NANO-grid on and off remotely. For example, if an operator is not cooperating or working right we can take over and charge meters directly.



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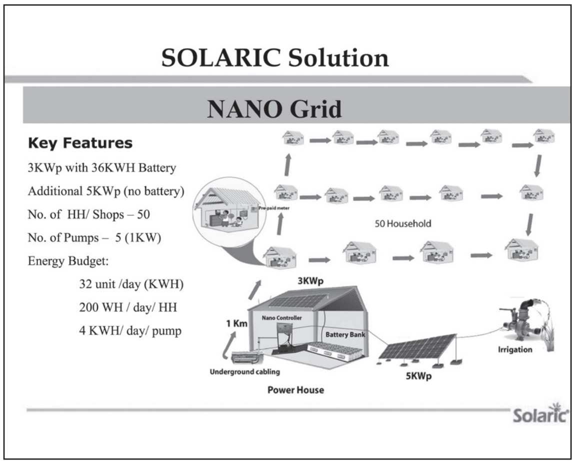

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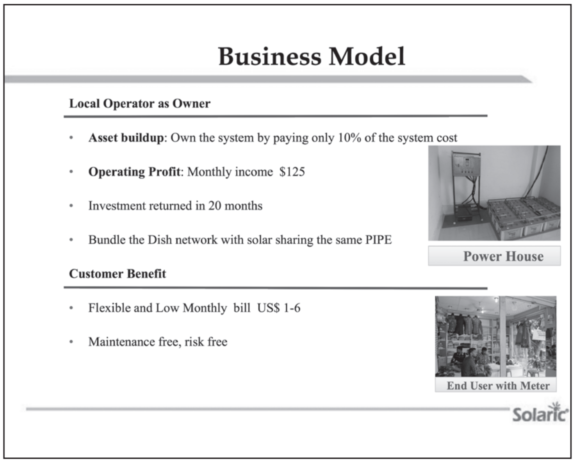

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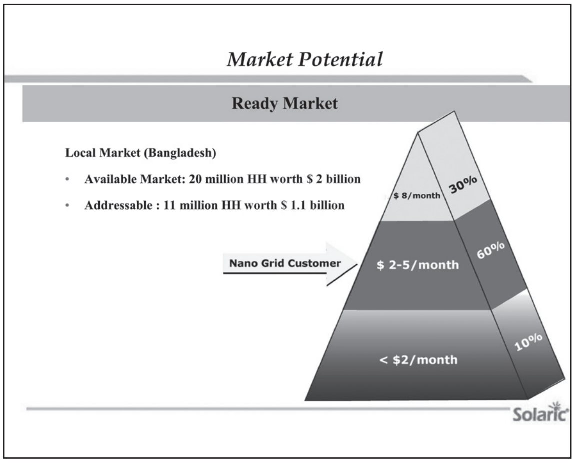

[Slide 12]

Speech 5: Mr. DIDAR ISLAM

NANO-grid: Sustainable Green Energy Solution for Off-Grid

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Speech 6

New Microgrid Architectures and Business Models

Speaker: Mr. LAURENT SCHMITT
Vice President for Smart Grid, ALSTOM, France

My name is Laurent Schmitt, Vice President for Smart Grid at ALSTOM in France.

At ALSTOM, new products means mostly smart grids. Smart grids are fundamental to transform today's electricity grids to address growing demand, renewable intermittent and distributed generation, and environmental pressures. It is very interesting to see how the top-down and bottom-up are converging on similar architectures.

My thinking is that smart grids will be both centralized and decentralized.

There won't be one control center controlling these millions of devices. We will need a multilayered architecture. Microgrids will be an integral part of that. The DCOES project Sony and its partners are doing is a good example of a layer below that. When we talk about microgrids at ALSTOM, we mean a range of 1 to 5 megawatts, and a mixture of B2B and B2C applications, not just residential.

Five years ago in Europe there was a lot being done around renewable integration. Three years ago in the US came the invention of a new model called demand-response, and load management, involving implementing new market mechanics for allowing real time pricing and demand response.

What we have seen very lately is a new area called smart cities.

It addresses how to attract the end user into the energy game. The demand response concept three years ago was mostly driven through a central utility environment. The smart city connects in the end user, who has his own Internet of Things around him, to induce him to think in a clever way from an energy system point of view while managing the complexity. It's all about how to make the interface and your apps as appealing as possible so that the end user can set personal targets which are easy to understand, immediately calculate savings, and transact with the rest of the community.

It would be a pity not to use legacy assets of traditional utilities, but there are a lot of things growing from the bottom up. One of the challenges is to interconnect these two elements.

What should the architecture be in order to have a stepwise control environment spanning layers that interconnect control centers for very large systems at a minimum of 50MW down to layers at the kilowatt level?

Meanwhile, renewables pose a problem for energy systems because they are highly intermittent. How can you balance renewables with storage, looking at the entire energy system, and how can you control the grid? There are a lot of governance issues.

A big question currently is how should the transmission companies and distribution companies better work together to address renewables in an integrated way for the system.

When you reach 20 to 25% of capacity from renewables, which Germany or Denmark has far exceeded already, the imbalance and instability associated with that become a huge issue. With deregulation, the balancing of electricity is essentially traded on a real-time basis. Traders decide strategically to dispatch energy depending on the scarcity of energy in real time.

In Europe, average costs have gone down very significantly because of renewables, while peak price has gotten higher due to situations where you have no renewable capacity and high load. Now a dispatcher who has a lot of renewable energy has to decide almost every night, depending on the amount of wind blowing in his system, whether to curtail it or not. And if he does curtail, it turns out as negative pricing because he has to pay for the renewable energy which is connected to the system.

On the consumer side, that means you can make money by consuming at home in the middle of the night. So if you happen to have a PV system with storage in your home, you could trigger charging of batteries at that time because you'll actually be paid for it.

Smart cities are about end-user expectations: First, quality of life, such as traffic congestion, electric vehicle deployment. Second, job creation. Last but not least, energy efficiency. Basically, constructing buildings which produce as much as they consume and making people aware of energy efficiency so that they become actors in building energy management [Slide 7].

Energy positive buildings will have micro-CHP in their basements, PV systems, etc., with the objective being to balance the amount of energy consumed by that building in terms of kilowatt-hours. The big problem is to achieve some form of kilowatt balancing as well, without burdening the grid. What kind of incentive would optimize the capacity of the grid for this type of building infrastructure?

Another factor is the spread of electric cars. The average charging pattern is extremely bad for the grid. People drive home and plug in just as the grid is at evening peak load condition already. And coordination with other transportation like trains makes people want to plug in their cars around train stations during the day, where it's already extremely congested and costs a fortune to add capacity to the grid. So schemes to displace the charging period are needed.

Last but not least is the advent of devices—internet TV boxes, apps in the cloud, smart thermostats—that can be used for informing consumers and "prosumers" about their energy habits so that they can have their own energy strategy. Not making them dispatchers, but using machine learning behind the scenes so the end-user just has to decide whether to keep the level of comfort at an optimized level or force a certain extra usage of energy under certain conditions for various reasons.

In developed economies we can't continue with grid planning that involves putting in more cables and copper wires in the center of the city. We simply cannot afford any more massive grid expansion in these extremely complex and congested environments. We need to build communities that enable people to agree on sharing the scarce capacity of the grid in the city environment. So what we see very clearly emerging is a highly decentralized Grid 2.0.

I really like the DCOES Project at OIST done by Sony and its partners because I think it's a mirror of the up-and-coming notion of peer-to-peer energy management. The fundamental question is how to build a system which can allow transactions among micro energy systems in the city environment, enabling some form of market. And how we are going to coordinate AC and DC if we connect both into the system, and how are we going to integrate micro grids into this environment.

Grid utilities are actually putting a lot of effort into adapting themselves and their technology. So the real reason for their inertia is that they are currently badly regulated against these new technological options, giving them no investment incentives in these areas. But distributed intelligence with local control, inside DC microgrids is a layer in which activity needs to be coordinated with these higher levels to the best degree possible, by a “brain behind the grid” [Slide 13].

At the high voltage transmission level, markets for energy have been created and begun to be interconnected with each other in Europe and the US. The next sub-layer is balancing the system at the country level, in European terms. And then an emerging platform for being able to balance the system at the level of the city, taking into account the constraint of what happens in the microgrid environment [Slide 15].

The multilayer architecture is all about getting the right price for flexibility. And to get the right price, you need to start at the top layer, because if you ignore that at the bottom layer, you totally disturb what happens at the top. The first step is smart regulation of transmission. How are we going to open up these markets so that they provide good price signals to the layers below?

It’s not a matter of pure mathematical optimization. In deregulated democracies, these layers are actually more matters of governance. It is a matter of how we adapt the optimization to the governance of our society.

As an example, we have a project called NiceGrid with France-based utility EDF. It features AC microgrids with a host of different PV and other generation, different storage, at the community level and micro-community or pico-grid level as well as the home level.

This project covers 10,500 inhabitants in an area which has a significant amount of solar PV, 1.8MW peak. The total peak capacity of that area is around 20MW [Slide 22 in PDF]. The system on the community level is a 400kV line connecting down to a 20kV substation. That feeds 88 substations at low voltage, and community energy management occurs on top of that system.

In developing a control mechanism allowing optimization of all these systems together, you start to realize there are different signals to be managed in parallel. One is a traditional demand-response signal, which is basically load and generation balancing based on signals coming through at the high voltage level from the total system perspective. Other types of signals are voltage constrained signals, simply because of the fact that if you take a certain feeder of low voltage, and start adding 60% more PV, this feeder is going to get congested itself.

So if you want to do co-optimization of all these elements, you cannot purely look at the high-voltage transmission level, you also need to look at the distribution level. Here the mechanism we used is a marketplace, simply because this system does intervene behind the meter and with the consumer. This is no longer about a utility issuing its own decision to a refrigerator or EV somewhere. It's about enabling the end user to decide the way he wants to control things, and informing and requesting and proposing the degree of flexibility of his control back to the energy system [Slide 21].

Apart from building a technological environment, what we ended up doing is building a community of people. We ended up having 550 customers with smart meters start to benchmark each other: how is my neighbor doing on efficiency compared to myself? To inform people of how the energy is being managed clearly requires building that consumer environment. Much like Mr. Islam's NANO-grid, I would say.

The city itself takes over that coordinator role, to market and explain energy efficiency to the citizens. That's what I call a smart city. Our software is called Network Energy Manager. It looks at PV production forecasts and load forecasts, calculating low voltage constraint valuation, and runs a mini-market, a trading platform which allows end users, whatever size of battery they have, wherever they are located, whether they are B2B or B2C, to trade and make offers for flexible services back into the system.

This is no longer a load leveling approach without economic thinking; instead there are people actually trying to trade with each other for peer to peer energy management. We still have the grids, but peer to peer energy management is a new way to transact energy through this environment.

A software layer manages at the city level. It shows the solar PV output and forecast, how much energy is stored where, and who is making which bid for what. One example is called a solar peak bid, which offers incentives for people to use as much energy as possible during this peak power capacity time. The architecture of the system has pico-grids each with their own storage and own inverter.

One of the challenges is to transmit data across these various infrastructure components. We are mostly using a broadband power line carrier down to each home for collecting real time data. Real time data is extremely important for several reasons. First, because PV is extremely intermittent and it's intermittent in real time.

Secondly, if you want the consumer to interact with the system, you must deliver them real-time information about exactly what's happening, so that he—or a machine learning system he lets control it—can be aware if he is interested in this information.

We are deploying a similar system in the French overseas islands, which have a similar situation to Okinawa. That system connects down to microgrids in very remote areas, lets the microgrids run as efficiently as possible, and resolves the issue of grid balancing.

I think the real challenge is to craft the business model. The problem we have is we think too much in silos with our offerings. But building microgrids enables you to tap multiple revenue streams, because you not only bring value to end users, but to the energy market.

You are flattening the volatility of the market, as the microgrid trades in the market. You also bring value into the grid, which is another very important element. The grid, to be able to operate, must be able to manage reserve. Once you control microgrids with demand response and so on, not only can you do load management of your grids, but if it happens that the grid has a big problem over a span of five to 10 minutes, microgrids can actually sell reserve services to the grid.

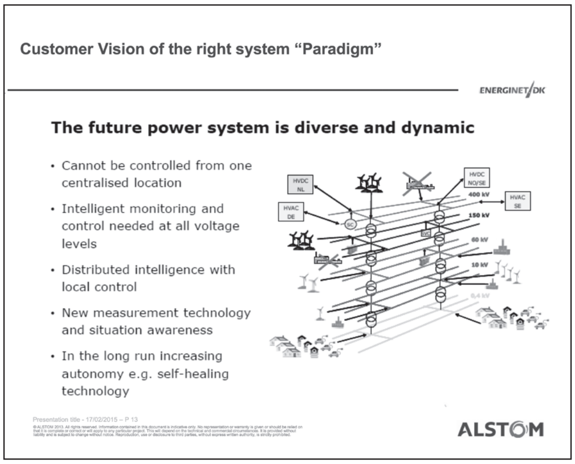
So that means the original revenue stream based on energy efficiency and load management can add one or two extra revenue streams. Deregulation is the only way to move forward, simply because we'll never get there in a vertically integrated model.

The hundred million euro question for the world is how are we going to price distribution grids in the context of a lot of distributed renewables? How are we going to make payments to those who connect to the grid for the short term, because the grid has value for certain short-term services, while still providing an incentive for them to use the grid as little as possible? And how are we going to rebalance the cost of the grid which is potentially not being subsidized as much as before by them? I don't think the model has really been found yet.

We are having interesting discussions with Sony about the need for open, flexible, interconnected and interactive models for bridging the two steps of the scale. There is absolutely no doubt that a microgrid coordination layer is fundamental to avoid overinvesting in infrastructure. But it has to be connected back with the grid system.

Even emerging economies, as they grow and develop industries, they will naturally have increasing power density, which I think will present a better business case for a grid. And when the grid does come, I think it will be important to have microgrids which can interconnect back with the main grid. They could start with pico-grids like SOLARIC's up to a point where the environment becomes sufficiently industrialized to interconnect back with the grid. That will save the utility capacity and capex expansion for base load generation. The question will be how to make use of those pico-grids from day one when the interconnection comes.

[Slide 7]



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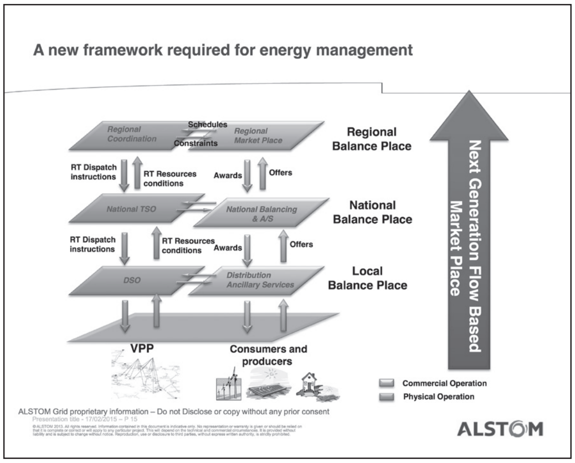

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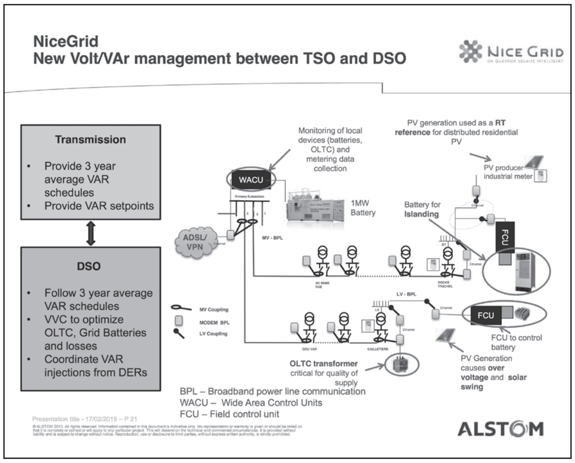

[Slide 21]

Speech 6: Mr. LAURENT SCHMITT

New Microgrid Architectures and Business Models

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Speech 7

Integrating Renewable Power Plants with Battery Storage

Speaker: Mr. RICCARDO AMOROSO
Chief Innovation Officer, ENEL Green Power, Italy

My name is Riccardo Amoroso. I am the Chief Innovation Officer of ENEL Green Power. I'd like to talk to you today about storage integration with renewable power plants and the pilot projects we are doing at ENEL Green Power to understand the business models.

ENEL is a very large power utility with almost 100 gigawatts in capacity worldwide, in 40 countries, serving more than 60 million customers. More than 60 percent of ENEL's revenue comes from outside Italy. ENEL Green Power is an IPP player with a focus on renewable power plants only, and more than 9 gigawatts of renewable capacity around the world.

We definitely are the most diversified, both in geographical and technological terms, among peer companies. We will be moving from the developed country environment into the emerging market environment. More than 80 percent of our capital expenditures goes into emerging countries, focusing on solar PV. We have more than 300 megawatts of PV plants in operation, almost 500 megawatts of PV plants in execution, and 4 gigawatts of short term pipeline, and another 3 gigawatts of long term pipeline.

We foresee that like the technological breakthrough of six or seven years ago in PV, we will see a similar pattern in storage. We are keenly focused on understanding the business model and economics of new business opportunities made possible by technological innovation in storage. Renewable is going to grow a lot over the next few years.

Solar and wind are going to drive most of the megawatt growth. Asia and other emerging markets are going to grow the most.

Here is some real case data from Italy about how significant the impact of renewables will be on the operation of the grid, and the challenges that it imposes on the system. In Italy in 2010, there were around 60 gigawatts of solar capacity, and since then 20 gigawatts have been added. Here you see how the amount of electricity circulating through the transmission lines has declined year after year. Minus 40 percent during the peak PV generation hours [Slide 9]. So PV is substantially changing the way a transmission system operator has to manage the in-flows and now out-flows.

You can see the challenges that an individual PV plant poses for the grid, both on clear sky days where the issue is forecasting, as well as cloudy days where in addition to forecasting, you need to manage the spikes that individual clouds will generate on the system. Imagine this on a scale of thousands of PV plants feeding into the grid [Slide 10]. You have the same issue with wind power: how to forecast the wind generation pattern, and how to manage the imbalances between anticipated wind production and actual wind production.

One major technology which is coming online to bridge these issues is storage, particularly battery storage. A number of services can be implemented by integrating storage into renewable plants, such as curtailment limitation and energy shifting, peak shaving, voltage regulation, frequency regulation, black start, and islanding [Slide 12 in PDF]. Existing power plants without storage basically do most of those things poorly or not at all. Applying storage opens up a number of energy shift options, and allows better regulation of the grid.

This has regulatory implications, because we are at the very beginning of a process of determining how to remunerate all these services and shape a different market. Some key facts about the storage market so far. For utility scale applications, roughly 100 megawatts commissioned in 2014, with more than 400 megawatts announced. Still a market very largely driven by policy in different markets.

Lithium-ion batteries are emerging as the clear winner in terms of technology, but a lot still needs to happen before we know what is going to be the winning technology when it comes to integration with renewable. We expect a huge cost reduction trend driven by electric vehicles. I think the driver will be the technology that wins the electric vehicle game, because that will drive volumes upward significantly. And there is the possibility of using those batteries, in cars up to 70% capability, and then redeploy them at a much lower cost in a stationary system application.

We'll see hybrid system renewable storage emerging as a clear solution, with demand growth starting from areas where there is grid limitation or in emerging markets.

There is wide consensus of spectacular growth in storage volumes in the coming years; it's likely to reach almost a gigawatt per year in the next eight years or so. Forecasts are always wrong in and always in one direction: they underestimate the cost reduction, and they underestimate the volume increase. We've been trying to map which applications of storage to renewable are using which technologies [Slide 16 in PDF]. And we are trying to map technologies to services [Slide 17 in PDF]. At ENEL Green Power we are now moving into the pilot project stage.

Now we are buying storage systems in the range of several megawatts/megawatt hours. We are coupling them with renewable plants, both PV and wind, to evaluate not only the technological challenges, but also the business challenges. We have technical partnership agreements with OEM, players like GE, Samsung, Toshiba, and Tesla.

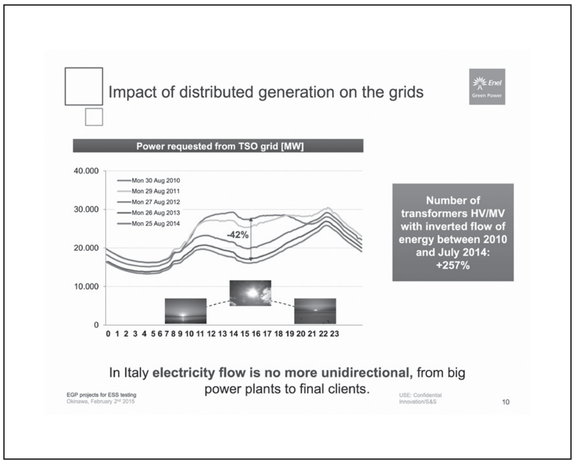
We are testing three main business models: ancillary services, energy shift, and imbalance reduction.

On-grid we have several projects in Italy [Slide 20]. Off-grid, we have this project in Chile. Chile today has enormous growth of PV deployment, thanks to the fact that it is very sunny, the LCOE, and the cost of production. Solar is actually in the money, lower than the wholesale price, but it's not dispatchable. So you need to couple it with storage, and the more storage you deploy, the higher the cost.

In Chile we are testing a smaller scale project. This one is a 200 kilowatt PV plant coupled with a 250 kilowatt to 520 kilowatt hour battery, along with a small 30 kilowatt wind turbine. With diesel generation as a backup, altogether serving an off-grid load of a local community [Slide 21].

In implementing storage you need to aim at having a wide array of services, coupling together frequency regulation, power regulation, energy shift, and price arbitrage. At ENEL Green Power we are working in 20 countries, monitoring all the different markets and finding which specific combinations of countries and services offer the best return on investment.

We are on the edge of commercial deployment of storage-integrated renewable. A lot has yet to happen in terms of regulatory framework definition by the various countries, but there is huge potential. We are using an open innovation approach at ENEL Green Power. We have a crowdsourcing initiative, so if you have an interesting innovative idea that you want to share with an innovative utility, you can go on our website and submit your idea, and we will consider it for a possible technological partnership agreement.



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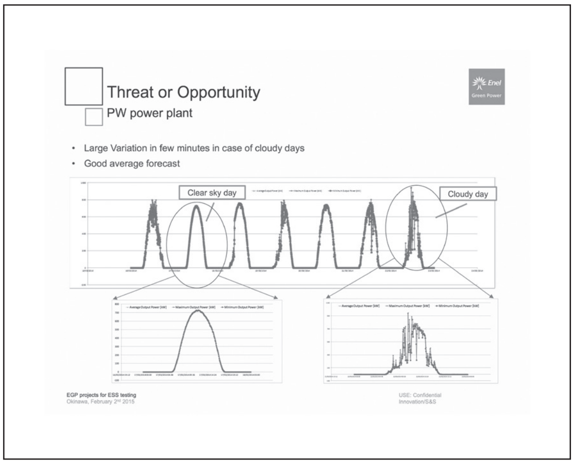

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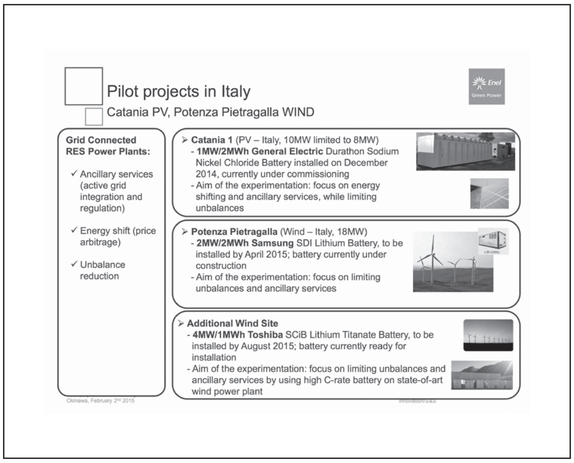

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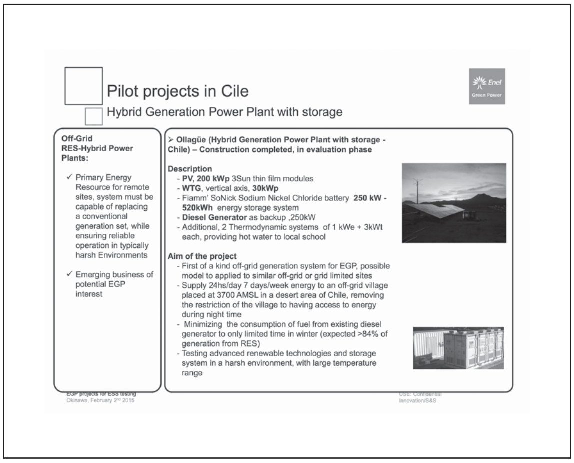

[Slide 21]

Speech 7: Mr. RICCARDO AMOROSO

Integrating Renewable Power Plants with Battery Storage

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Panel Discussion 1

Moderator:

Prof. HIROAKI KITANO
OIST / Sony CSL

Panelists:

Mr. T. P. CHOPRA
Mr. DIDAR ISLAM
Mr. LAURENT SCHMITT
Mr. RICCARDO AMOROSO

Prof. Hiroaki Kitano: Is the consensus at this moment that solar photovoltaic and wind turbines are the two major sources for the types of grid we have heard today, or are there any other possible resources to hook up?

Mr. T. P. Chopra: My initial thought four years ago was, Let me focus on the biomass side because India produces 540 million tons of biomass waste every year, which theoretically can produce 54 gigawatts of energy. India produces 200 gigawatts of energy, so nearly 25 percent of all India's requirement technically could come from biomass. The challenge I find with biomass is the supply chain—how do I get into a 20-year contract with a farmer to provide me the biomass, to provide me the cow dung on a reliable basis for 20 years?

With hydro, the execution risks have become very, very high and environmental risks have become very high. So net-net, when you look at the cost curves and economics of solar PV, wind and solar are beginning to differentiate themselves from other technologies in the clean energy space.

Nobody expected such a rapid decline in solar PV prices as the way it's happened.

The CEO of Trina Solar recently made a very dramatic statement that he expects a 50% reduction in solar PV prices over the next few years.

If we see a 50 percent reduction that immediately puts all the other technology generation platforms at risk, so in the longer term I think wind and solar will be the two clear winners.

Kitano: What about Bangladesh?

Mr. Didar Islam: What works is what is simple, and solar is the simplest solution. Just put it up, it works. Nothing gets simpler than this, and this is the reason why off-grid is dominated by solar.

Kitano: What's the situation in Europe?

Mr. Laurent Schmitt: We believe that it is going to be a portfolio mix issue and not a single silver bullet winning everything. What is clear is that PV is going to have a large share of it. We do see more and more products where we have heat networks sharing heat across several buildings. And we should not neglect fuel cells in electric cars, because that is going to resolve big problems in that space with that micro generation you can run at marginal costs.

Kitano: Will portfolios be implemented universally across regions?

Mr. Riccardo Amoroso: When we select new markets, there are three things we look for. One is the availability of world-class renewable resources, because in the end, that's the real driver of the economics in an unsubsidized environment. The second is a growth environment because that justifies adding capacity, so you're not going to replace existing capacity; you're going to meet new demand. That's very important to create upward pressure on wholesale prices of electricity. Third is a stable regulatory environment, not subsidies, but rules that are not going to change every other day. In countries that have all three of them, we're moving in with new investments.

Now when it comes to the technological choice, there's no single answer. There's going to be a mix. Renewable is going to play a very large part in terms of new capacity. Obviously for sure the largest share of new capacity. The numbers for wind we see are in the $50 to $60 per megawatt hour and in PV between $60 and $80 per megawatt hour. Both technologies are now competitive, wind more than PV at the moment, but PV has more potential for cost reduction in the future.

Chopra: In the off-grid area, in consideration of service costs and all these things, you don't want any moving parts. It has to be so simple that it's basically maintenance free.

Kitano: Although the wind has a slight cost-benefit edge at this moment, sooner than later PV will probably overtake it. But since PV can generate only in the daytime, it really comes down to the issue of storage. And we're in agreement that storage costs are going to go down. Do you think the best bet is to continue to expect improvement in lithium-ion? Do you have any new kinds of storage technology on your mind that might actually overtake lithium-ion in the mid-term?

Amoroso: It's really early to assess who's going to be the technological winner of this game.

Kitano: Is there a storage cost inflection point in India and Bangladesh? What would be your take on the target cost for the storage side?

Islam: For off-grid I can tell you that number. It's ten cents per watt-hour. This is the number that we are using for flooded lead acid battery technology. Now given the fact that lithium batteries are higher performing in terms of both discharging capacity and also longevity, the levelized cost turns out to mean that you can do thirty cents per watt hour and be equivalent to what we are using now. The price right now in the market is almost double that figure of 30 cents per watt hour. So if we hit 30 cents per watt hour today, we would be at par with the older lead acid batteries. The forecast is within two years we will hit lower than that.

Chopra: The exciting part about the battery storage technology is that the technology available today may not be the technology of tomorrow.

A lot of these cooler technologies are in pipelines in labs around the world that may really disrupt what there is today and put lithium-ion out of business. But other reasons may drive adoption of something that may not be the most economically or technologically advanced.

Kitano: So that's the good news, that we're going to have continuous reduction of PV costs and we're going to see dramatic innovations in storage. Now the struggle is to distribute and to provide the real consumer value. How do you actually save people money on the electricity bill, as a very obvious and tangible benefit? What will enable home energy management systems to penetrate the market?

Schmitt: They will have to get people excited about energy, so that potentially they devote as much attention to it as they do today to an iPhone. The question is whether we can deploy technology that can make a customer willing to pay more because it offers more services, as with an iPhone.

Home energy management is not a pure energy play. It's a lifestyle management play, connected with comfort, with security in your home, and so on. So how is the energy app going to pop up into a portfolio of apps to make your lifestyle and life better? A lot of home energy management technology is very old fashioned in the way it grabs data from the meter and so on. I want to know what I consume now and what I potentially can do now in my lifestyle, not what I did three days back.

How can you embed this into the lifestyle of people and make it fun for them to play with it? That trick has not been found yet by anyone.

Chopra: The success of home energy management will not come from giving me information. As a consumer I'm already overburdened with information. My simple request is that somebody in the world reduce my cost of energy. My bill was 35,000. Bring it down to 20,000. Figure it out. Don't bother me with it. I don't have time to keep looking at my voltage and my frequency every day. And I think if we can provide that service to consumers, that's when it'll really take off.

Kitano: After Japan's major earthquake, there was a quite substantial change in energy policy, and a lot of people tried to save energy, use less electricity. And people tried their best to get into a lower volume contract by switching off everything they could. So if you can dynamically adjust without undermining quality of life, then that could be interesting.

Some might say, what about gamification? But give me a break—people are not going to stare at their energy bill for more than two minutes per day. Probably not even two minutes. So, aside from cost reduction, any other ideas?

Schmitt: My view is yes, there will be new things created around some form of gamification. Each individual has a certain energy footprint which he can afford, and if someone can find a game approach which gets people to be aware of that and make an effort, I think that could work.

Islam: All this energy management service was more like an engineering solution shoved down your throat, rather than asking what is required. Now people pay for value, not only just cost. The iPhone is a good example. When we first developed this payment gateway, we shipped a remote control with it. We did that to make it simple, something to play with, just like a toy.

Everybody asked, why are you giving the end user a remote controller, which he only uses to pay you? That doesn't make any sense. So we give them a small switch on the remote. We call it a smart switch. All they can do with that switch is turn the light off and on, or dim the light. But that's play for them, a tool they can play with. It's value added to the system, instead of trying to force some solution.

Kitano: One of the reasons I raised the issue of home energy management is how we manage demand response. At the end of the day for end users, it's electricity just electrons coming in. That's it. It doesn't really matter what kind of power sources, what kind of architecture we're going to use, if you don't provide the value, like cost reductions, stability. Of course we can claim, this is sustainable, so you are doing a good thing. But at the end of the day it boils down to the really simple economics actually.

So we are actually seeing a big change in perception in terms of cost competitiveness of renewable energy. Last year, or the year before, when we were talking about renewable energy, it was, "Great, it's sustainable!" But the cost parity was not there so government subsidies and feed-in tariffs etc. was the focal point of the discussions. And now we are seeing that renewable is going to be competitive no matter what and, soon.

Amoroso: It's absolutely a major breakthrough. The costs of renewable is now in the money. Not in every market, no, there are specific markets where the resource is world class where this happens. But there are more and more markets like that, typically with a combination of world class resources and high growth, because high growth triggers the need for power and the need to pay for that power. That a pure wholesale price comparison is already in the money is of paramount importance.

And if you compare not only the wholesale price but the retail price including transmission and distribution, in the case of new capacity to be added to the grid, so new transmission lines to be added, new distribution lines to be added, then the equation is even more important, because renewable is the one that allows for distributed generation.

Of course you need to account for storage to make it fully predictable and uninterruptible. And that's where the game is going to be played now. Because storage is still not fully in the money. But the cost is going down so significantly that it's becoming in the money in a real short time.

Kitano: Let's say you were specifically going to deploy a DC, renewable micro grid with battery storage that is scalable, and can be independent, like the technology we have here at OIST. If you had to pick two major initial markets to enter in a developing country and a developed country, who are you going to pick?

Islam: I will say if it is off-grid, go to Africa. Where 80 percent are off-grid. Africa is so vast and so big in the sense that the regular grid will never reach there. So the market is just sitting there and waiting.

Chopra: I'm biased and I'd say India. In India, we have a new government that's pushing like crazy to get electricity for all. We have 300+ million people who don't even have electricity. Yet at the same time we have a fairly decent grid. The amount of money the government's going to be spending in T&D in India is going to be as much if not even more than generation because I think they see that as a huge opportunity for figuring out how to integrate exactly what you are doing, which is the large grid with the small microgrid. And how do you get the two systems to talk?

Schmitt: I would look at either the growing economies, in segments of users with a growing capability to invest, and B2B based communities into strengthening the quality of the grid through micro grids on the one side, and on the other side I would bet on the social aspect. In Europe and the US we are going towards a very distributed architecture, simply because people don't like nuclear any more. The complexity of the service is higher, which hopefully offers me the chance to better differentiate my service.

Amoroso: India for sure. It's going to be a key market. Not an easy market for a non-Indian but absolutely a key market. China is obviously the answer, but even more tough for non-Chinese. Other markets in Asia Pacific that may bring a lot of satisfaction in the future are the Philippines, Thailand and Indonesia. In Africa I would say for sure South Africa will keep on the path to being a major market in the future, with Morocco and Egypt, potentially two newcomers depending on the geopolitical situation. In Latin America, for sure Brazil will keep on being a strong market, also Mexico, and Chile I would say.

Whitney: What major disruptions and inventions and whole new categories of things do you imagine might occur if the cost gets low enough that we can give reliable power not to 2 billion people in the world but to 5 more billion people?

We increase the power to more than twice the number of people?

Islam: Now, 150 years after Thomas Edison, we are beginning to appreciate the value of DC. I think in our lifetime, all appliances will run from DC, and people will have a choice, either to use DC coming into their home, or AC coming into their home. So they will not be bound to one or the other and all appliances will run seamlessly whether you have DC or AC.

Amoroso: From the sustainability angle, imagining a world in which everybody has free, even green energy, but free, the push for trying to reach middle class status on a billion people level made me think about the challenges on planet earth's resources that would derive from having billions of vehicles, billions of TV sets, billions of you name it. That's scary to think about.

Schmitt: Whatever the costs of batteries and so on, we will end up with a system which will be much more strongly constrained. So the value of that constraint I think will drive us towards these micro transactions, and that goes also with a social aspect of our societies.

Chopra: I was trying to think about what is that one thing that might be the real game changer. I think it's all going to be about data. And about analytics because the guy who controls data, and the person who is able to analyze this data, understand it and provide a solution I think data is going to be really the key. I think we are entering an information age, which is going to be driving a lot of the energy systems as well.

Session 3
Smart Energy For Smart Cities

Speech 8

Infrastructure Disruption

Speaker: Mr. JON DOGTEROM
Venture Services Lead, MaRS, Canada

I will give a summary of some of the trends and changes we are seeing in the energy industry: how innovations behind the meter control and energy storage are set to disrupt the conventional operation and planning of energy infrastructure, and what that means for utilities. At MaRS, we work with entrepreneurs across a range of sectors, including energy, to help them to grow their businesses, and with venture capitalists or corporate investors to get capital into these companies.

We now have one of the world's largest innovation centers in Toronto's historic Discovery District, operated by a public private partnership.

A mix of entrepreneurs, law firms, and venture capital firms all in one place provide the ingredients to move innovation forward, with the goal of creating jobs. One partner calls it, "Silicon Valley with a roof over it." As the companies move through the stages of growth, we offer different services to them along the way. I work in Cleantech, one of our three main practices, which includes energy innovation.

About 50% of MaRS Cleantech innovation is energy related. Within MaRS Cleantech, we have three different entities: 1) Venture Services, working with the entrepreneurs to equip them with the market intelligence and education, skills and training that they need to move their businesses forward with mentorship and practical advice from the venture capital community and investors; 2) Arctern Ventures, a private venture capital fund with investments in about a dozen companies that we work with; and 3) the Advanced Energy Center, which works on systems change, trying to open up the sector to innovation by bringing utilities, regulators, and entrepreneurs together to try to solve problems, first in Ontario and then leveraging those successes in other markets.

Ontario's Feed-In-Tariff Program for solar and wind led to more manufacturing activity in the area. Because having local manufacturing boosts innovation, Ontario has outsized energy innovation for a region of our size.

Ontario also rolled out 7.6 million smart meters to reduce the cost of meter reading and to allow energy prices to vary by time of day. It only reduced peak load by about 2-3%. But the data from the smart meters is collected in a central database every 15 minutes. And we started to make a lot of interesting discoveries from that data depository. For example, we started combining the smart meter data with other data sets, such as municipal property tax data (size of the home, age of home, number of occupants). So far, we are just scratching the surface; there is much more to discover.

We also launched an access-to-data program that allows the ratepayer to securely share his data with a third party company that might come back with an app or suggestions to reduce energy consumption. We have also started to do some energy storage procurement. 50 megawatts is not a big number but as we go through the process we are starting to see the regulatory issues you come up against. [Slide 17] shows categories in the Cleantech practice and the amount of capital raised in each sector over the last four years. Energy categories dominate with IT smart grid and energy storage the most interesting for future job creation.

Many MaRS affiliated companies are based around home automation; for example, chips enabling appliances to communicate within the home, and programmable thermostats similar to Nest. We believe the five biggest drivers of change are low cost distributed generation; customer control behind the meter; energy storage innovation; new business models; and utilities facing aging infrastructure and decreasing revenues. Utilities in Ontario are somewhat in panic mode right now as they begin to realize that the sector is changing dramatically.

Behind-the-meter control is taking off. The energy segment of the Internet of Things market will grow from 2.25 billion in 2012 to 8.61 billion by 2020. Consumers can save energy and control energy with smart appliances. Appliance manufacturers can bid into the capacity-based electricity markets. With more and more connected devices, consumers now have control over what's going on inside the home. Nest was bought by Google for $3.2 billion not because of their attractive, smart thermostat, but because they have a plan for getting into the electricity market.

Nest has a question on the warranty card: "Do you want to participate in demand response?" When Nest has enough thermostats within a region, they will bid into the capacity market. They will be able to shut your air conditioner down and reduce peak load. The thermostat owner could receive a check from Nest in the future for the portion of the capacity market that Nest bid into with your appliance. Utilities are taken aback because they didn't realize that gas plants used for peak power production might be competing with a thermostat that actually has no real cost to bid in—someone already paid for the thermostat.

Nest is taking the consumer relationship away from the utilities and putting it into the hands of someone else. Instead of paying your utility bill, imagine getting an energy check from an appliance manufacturer.

We're seeing some really interesting innovations in energy storage. One of the most potentially disruptive to the energy industry overall is power-to-gas energy storage: using an electrolyzer to produce hydrogen, a fuel that can be dumped right into the natural gas system, or combined with CO2 to make natural gas, or saved for vehicle fueling. I believe that energy storage is going to change the game for hydrogen, providing a window for selling units for energy storage purposes until the number of fuel cell vehicles is sufficient to justify hydrogen infrastructure.

Integrating power-to-gas with wind power will provide a useful buffer for excess power instead of having to curtail the load, or the supply. An electrolyzer can also provide frequency regulation as a paid service by responding in real time, second by second, to control the frequency on the grid, with hydrogen as a valuable byproduct.

Another disruptive innovation is storing compressed air underwater, using the pressure of the water to help contain the air. The bags that hold the air are a proven, low-cost and quite reliable technology, long used to lift sunken ships. The deeper the water, the higher the containment pressure, and the better the economics. An underwater compressed air company in Ontario won a competitive bid for a contract in Aruba.

The convergence of IT and energy is reducing barriers to entry for companies with new business models based on data analytics that don't require much infrastructure investment. For a million dollars in venture capital you can get a company off the ground versus $10-15 million for big infrastructure projects. These capital-light companies can move much faster than any infrastructure company. They use open collaboration, open software and shared protocols to connect appliances, for example.

This shifts customer relationships away from the utilities, which is already making them extremely nervous. Simultaneously, much of the utilities' infrastructure is past its service life; significant investment is needed just as utilities are starting to see drops in revenue. And they are struggling to keep pace with innovations due to spending constraints and a risk-averse culture.

Ontario Power Authority started a program called the Peak Saver Program to control air conditioners for reducing peak loads, in exchange saving the customer a small amount. When I signed up for it, my local utility rolled a truck and installed a surprising amount of equipment on my air conditioner. Then I learned that it is controlled from one switch that takes down all the air conditioners in Ontario at the same time.

Now along comes Nest. I paid for the thermostat. No truck came to my house. Nest knows when I'm home and whether or not I care whether my air conditioner goes off. They can shut off different regions of the grid selectively. Less than a year after the utility spent all that money, everything that they had installed was inferior to the product I bought myself.

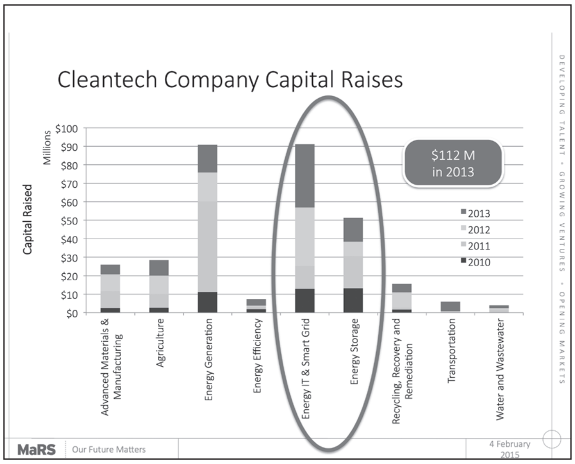
As soon as people start leaving the grid it creates a very dangerous scenario in which the people that leave the grid are the ones with the capital to invest in doing so, and the ones that stay on the grid are those that don't have the capital, probably the lower class. So now the same amount of infrastructure is serving only the lower class, reducing the revenue base that is paying for electricity.

We did a survey to find out what's stopping innovation in the sector. Major factors were: heavy regulation; a culture of government-led direction; the organization of the electricity sector; and utilities not necessarily knowing what is possible [Slide 27].

In Ontario, for example, regulations did not accommodate energy storage until recently. And benefits are very difficult to monetize over multiple stakeholders. Some of the benefits of electricity storage accrue to the transmission and distribution side, others to the system operator side. Who pays for the system when a portion of the benefits are going here, and a portion of the benefits are going there? Innovation is coming, whether entrepreneurs and innovators go straight to customers or they work with utilities.

We believe that if the utilities work together with the innovators, we can generate a significant advantage, create sustainable jobs through exports, and have utilities help these innovators sell in other jurisdictions as well. Of course, the regulatory mechanisms need to change to reward operational and system efficiencies. MaRS as an independent third party brings the utilities, regulators and innovators together to discuss the situation. We've had a lot of success and we are helping to get some regulatory change.

If we can do it first in Ontario, there's a massive export market because all jurisdictions are looking at similar challenges.



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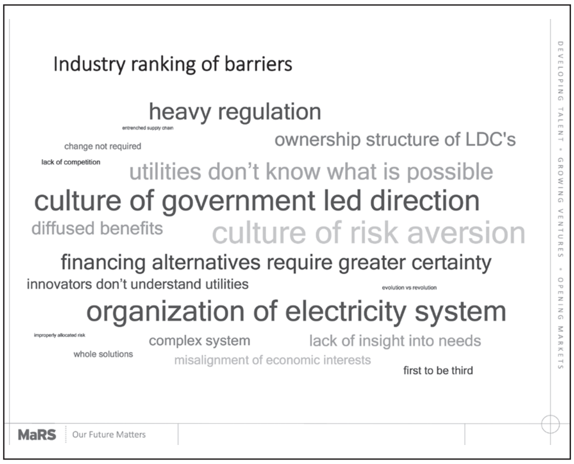

[Slide 27]

Speech 8: Mr. JON DOGTEROM

Infrastructure Disruption

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Speech 9

Centralized or Distributed? The Power System Reformation and Business Chances in Japan: A Case Study in Hokkaido

Speaker: Mr. AKIHIRO KOGURE

Executive Managing Director, Eneco-op, Japan

My name is Akihiro Kogure, and I am the Executive Managing Director of Eneco-op. Eneco-op is a subsidiary of Co-op Sapporo, a consumer cooperative in Hokkaido with a membership ratio of over 50% of households. Hokkaido is Japan's northernmost main island, and has a cold climate and a lot of snow. I will be speaking on the topic of power system reform and business opportunities in Japan, with a case study from Hokkaido.

Speaking about the future of electricity technology and policy in Japan is like talking about the past for the U.S. or European countries. Let me start by outlining the electricity business in Japan.

There are 10 vertically integrated power companies called EPCOs, and new entries called PPSs (power producers and suppliers).Market volume is 1,094 terawatt hours. There is retail competition for over-50kW customers (62% of the market in 2013). The share of power sold by PPSs (i.e., not by EPCOs) was only 4.2% in 2013.

In 2000, the Japanese government liberalized the market for the highest voltage segment, constituting 26% of power sales, and then in 2004 extended it to the over-500kW segment, 40% of the total power market. And in 2005 they opened the over 50kW market, 63% of the total power market.

Why is only 4.2% of the liberalized segment supplied by new entrants? Because they can't sell electricity on the market; only 0.6% is trading in the market. Almost 17% of electricity is generated by non-EPCOs, but it is mainly sold to the EPCOs on a long-term contract basis [Slide 6].

Before the Great East Japan Earthquake, nuclear provided almost 30%, and natural gas almost 30%, of Japan's electricity. Now natural gas accounts for 40-50% because we can't use nuclear power at this time. Many European countries are trying to use renewable energy, but Japanese EPCOs seem to have a different policy. There are two reasons. First, transmission is very limited for wind or PV. I couldn't build new wind power in Hokkaido if I wanted to right now, because HEPCO, the Hokkaido Electric Power Company, won't allow me to connect to the grid. And they don't want to replace existing power generation.

Second is the demand and supply relationship. EPCOs want to make maximum use of existing nuclear plants and maintain existing thermal power stations (oil, natural gas, coal), with no substitution of renewable energy [Slide 8 in PDF]. Their ideal usage is nuclear, hydro, and geothermal for the base electricity and then use wind and solar, but they want to exercise output control for wind and solar.

One key to introducing more renewable energy is grid parity. Currently the home power tariff is about 27 yen per kilowatt hour, but PV solar over a life of 20 years would cost 21 yen per kilowatt hour, considering all maintenance costs. So if I buy a PV system for my home I can get cheaper electricity than from the EPCOs.

Another key is PPS purchases. EPCOs don't want to buy renewable electricity but PPSs can, so renewables depends on PPSs, not on EPCOs. The residential electricity market is not open yet, but it will be next year. After the Great East Japan Earthquake, the Japanese government decided to open the residential sector and also unbundle transmission and distribution from generation and retail.

Power transmission and distribution will be regulated, but power generation and retail will be competitive. In this new landscape three issues are securing a stable supply, fair competition and consistency with Japan's Energy Basic Plan. Under a monopoly, EPCOs had a duty to ensure a stable electricity supply, and new entrants will also have that duty. For fair competition, new entrants lack generating facilities and can't build new facilities because it is time and cost prohibitive, so what we—that is, PPSs—want to do is to buy energy from the EPCOs and sell it to the consumers.

As for the Japanese government's Energy Basic Plan, it changes every year—who knows what will happen with it in the future. They say now that they want 20% renewable energy, but EPCOs don't want to buy renewable energy, so in fact lack of consistency between EPCOs and the government's Energy Basic Plan is a very big problem.

Hokkaido is almost the same as Denmark in population but twice the area and half the GDP of Denmark. Energy consumption by sector in Hokkaido differs substantially from the rest of Japan. Industry in Japan as a whole uses 40% of energy, but in Hokkaido that number is only 23%. The home sector in Japan as a whole accounts for 14%, but in Hokkaido it's 21% [Slide 17].

So in Hokkaido, the home sector has a big share of energy consumption. Hokkaido is very cold, and we use a lot of kerosene for heating, as well as heavy oil in the fishing industry and farming. Energy consumption by source for households shows kerosene around 55% and electricity only 33%. In Japan as a whole, electricity is 55% and kerosene is 20%.

In Hokkaido heating uses 50% of energy (not much air conditioning), light and other power 26%. Japan as a whole uses 24% for heating and air conditioning, and 41% for light and other power.

Hokkaido is a very isolated island in the sense of electricity transmission. Hokkaido's peak demand is about 5.7 gigawatts, and it's connected to the rest of Japan's grid by a DC line of only 0.6 gigawatts. So we can't buy electricity from other areas of Japan to make a new electricity company—we have to buy all the electricity from the Hokkaido area.

Before the Great East Japan Earthquake, Hokkaido Electric Power Company generated almost 90% of Hokkaido's electricity [Slide 20]. Only 12% is generated by a third party. And over 70% of that (12%) is generated by J-Power, a generation company formerly owned by the government that only sells to HEPCO and other EPCOs on a long-term contract basis.

So we only can buy at the most 3-4% of the total electricity. This is the chart of energy supply on the lowest power demand day in Hokkaido, May 26 [Slide 21]. Under the zero line you can see output control at the bottom, and renewables at the top, and they are almost the same on this date.

HEPCO says that pumped storage has a limitation because in May there are many low demand days, so output control is needed almost every day in May. This is how they want to use renewable energy in Hokkaido, while over 50% is supplied by nuclear.

Denmark generates about 3.4 million kilowatt hours yearly, almost the same as Hokkaido, and its population is almost the same as well. If Denmark can get 39% of its electricity from wind, why is Hokkaido using renewable energy at such a low level? I don't know. Denmark plans for renewables to supply approximately 71% of electricity consumption in 2020. Hokkaido's governor hasn't committed to how much renewable energy is needed. She says that we have to restart the nuclear power plant.

Eneco-op's share of kerosene sales in the home sector is about 5-7%, the top share in Hokkaido, worth about 10 billion yen. Starting two to three years ago we branched out from fuel delivery into home power generation and the power retailing business [Slide 25 in PDF].

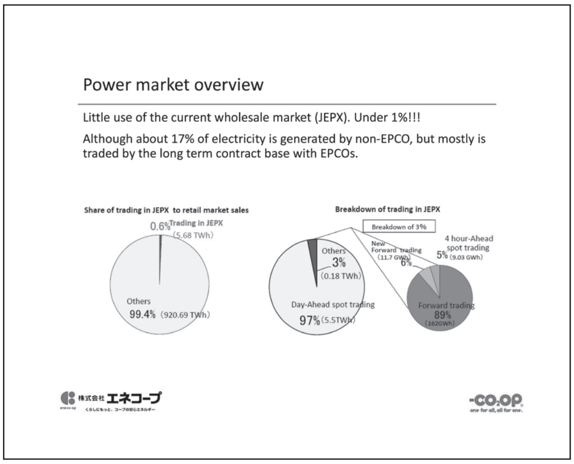
Our main target is power retailing to households: purchasing electricity from other companies and selling it to Co-op Sapporo's members using HEPCO's transmission network, with maximum use of renewable energy.

Now, a word about our work in the electricity business. Firstly, we at Co-op Sapporo used to purchase all electricity from HEPCO, but now we are purchasing some electricity from PPSs. Almost 33% of that is from our PPS, and 66% is from a combination of Hokkaido Electric Power Company and other PPSs. Second, we have completed a two-megawatt mega-solar plant in Hokkaido. Third, we are purchasing renewable energy from outside, and using it in our stores.

We can enter this new market (retailing electricity to homes) that other companies can't because we are already selling items and services in the "home sector": foods, drugs, home delivery and kerosene; we already have a customer relationship and loyalty program, the CRM systems and billing systems. So we can just add electricity.

Our strategy is first to contract for renewable energy (solar, biomass and hydro). Our members have a lot of solar panels, so we will buy power from them and sell it to other customers.

We want to adopt new pricing models, time-based pricing, demand response, combining PV and on-site generation, storage batteries and demand control, HEMS, big-data analysis. Anywhere else these things might be old news, but they are new and needed for the Japanese market, and HEPCO doesn't want to introduce them. I hope this gives you a picture of the current situation with Japanese electricity policy and some of the barriers that a newcomer to this business must overcome.



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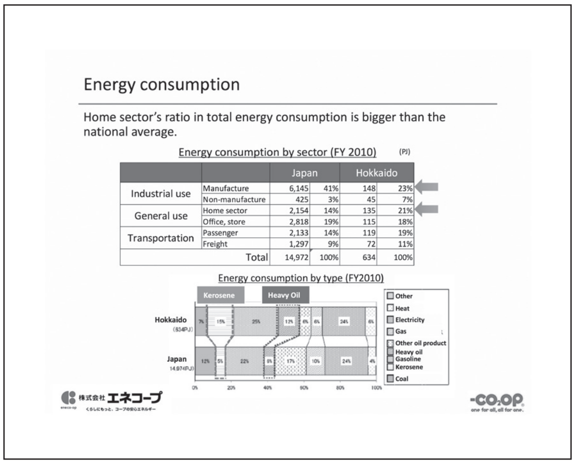

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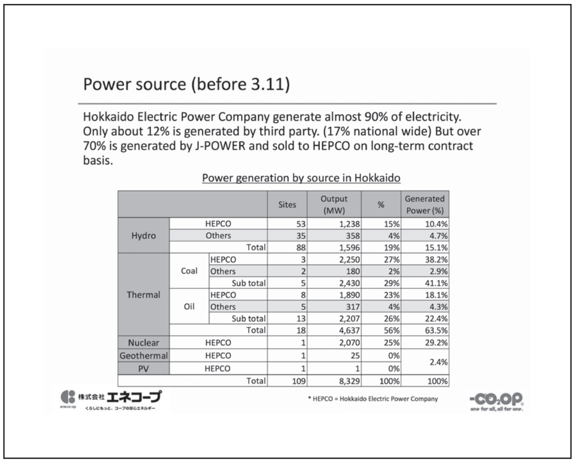

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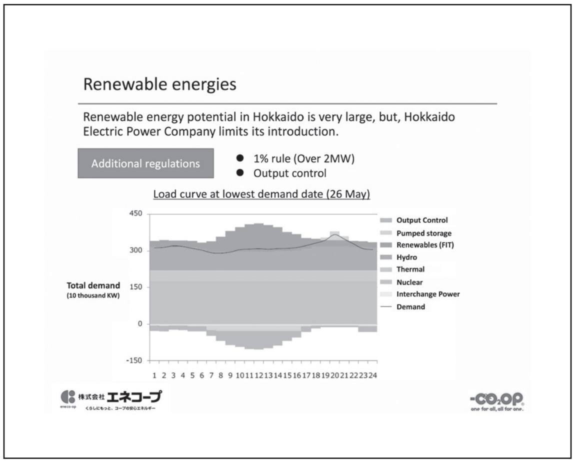

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Speech 9: Mr. AKIHIRO KOGURE

Centralized or Distributed? The Power System Reformation and Business Chances in Japan: A Case Study in Hokkaido

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Speech 10

A Holistic Approach to Distributed Sustainability

Speaker: Mr. VINCENT PAUL PONTHIEUX
Director and CTO, Blue Planet Research, USA

My name is Vincent Paul Ponthieux, and I'm with Blue Planet Research, a small, privately funded organization based in Hawaii. Our main focus is on renewable energy technologies, with emphasis on storage for sustainability. Today, I'm going to talk about a holistic approach to distributed sustainability.

As an architect, I started working with Henk Rogers, the founder of Blue Planet, on some projects for his ranch on the Big Island of Hawaii. The Big Island, at 4,000 square miles, is roughly twice as large as all of the other Hawaiian Islands combined. It has a population of about 190,000 people and it receives about 1.5 million tourists a year.

Hawaii is the most isolated landmass on the planet, and 90% of the food is imported. 100% of the fuel is imported. However, the Big Island alone has about 7.5GWh of renewable energy potential, and enough agricultural land to feed the entire state.

Pu'u Wa'awa'a Ranch is where Blue Planet Research is located. It's on the west side of the Big Island at an elevation of 2,700 feet above sea level. When the ranch was founded in 1884 it was off-grid, and now, 128 years later it's off-grid again.

When we started, the intent was to install solar panels and get a net metering arrangement with the local utility, HELCO. However, it took two years to get permitted, and the utility wanted a lot of money for an interconnect study. By then, storage technology had advanced enough that we decided to go off-grid. Our idea was to see if it was possible to use available technology to be completely off-grid sustainably, without using any fossil fuel.

Our Energy Lab is about 10,000 square feet with 85kW of PV on the roof. We have a small 1.5 kW wind turbine, but we don't have very good wind at this location. Our primary storage is with batteries, and we started with a Vanadium Redox Flow Battery.

The entire ranch microgrid [Slide 9] covers 32 acres and has the equivalent of about 10 homes, plus machine shop facilities, office space, workshop space and lab space. From the roof, the solar energy is converted into AC, powering the existing lab building at 240/120 single phase. From there we step it up to 7,200 volts and push it out to the rest of the buildings, where we step it back down to 240/120. That minimizes the transmission losses to about only about 400 watts of parasitic load.

So to minimize the size of system components needed, obviously we wanted to be able to control the loads, do some kind of demand-response, and to intelligently sequence loads so that they don't come on at the same time, but in a way that doesn't disrupt the lifestyle of the people living on the ranch, or its operations. So the PV goes into a large 2400 amp DC bus (we're a DC coupled system) that supports lots of DC components: bidirectional, unidirectional. DC equipment is very expensive compared to AC equipment. DC goes into a flow battery. Because we're off-grid, the system has to be sized larger than would normally be the case with a net metering agreement. That means we're always going to have excess energy at times, and if we're not connected to the grid and can't sell back to the grid, what do we do with that excess energy?

You can only buy or put in so much battery storage. So we use a hydrogen electrolyzer as a load bank. This allows us to maximize the potential of the PV array on any given day. It's all automated, like a watt sponge on the roof, just absorbing the excess energy when there are no loads otherwise. And then the hydrogen that it makes gives us a wide range of usage options later.

The 85kW of peak PV were originally stored in a Vanadium Redox Flow Battery. We didn't want to go into lead acid at all, so we went straight to a more exotic technology. We started off with 10kW using two stacks with 80kWh of storage in the electrolyte tanks, later increased to 20kW of power by adding two more stacks. It worked well for about the first year and a half, and then we started to experience some degradation in the stacks. It's now been decommissioned and we're waiting for new stacks to come from the company that built them.

After that failed, we moved to lithium-ion batteries. We tested several different lithium-ion chemistries on the market and then we came across the Sony lithium-iron phosphate batteries at the Asia Pacific Clean Energy Summit back in 2013.

We bought some and tested them for about six months with a dynamic range of loads, parallel to the flow battery before it failed, and we were astonished at how well they worked. They don't generate much heat, so there are no thermal management issues, which was a big advantage. Others we looked at needed liquid cooling on every cell, which creates many potential points of failure.

During construction of our Energy Lab, we tested seven different types of PV technologies. The other purpose of testing was to find out the real mean insolation in this area. Our microclimate is usually sunny and clear in the morning, but by the early afternoon, it gets overcast and cloudy. It turned out we had a very small solar window, 3.8 hours of average sun, to grab all of our energy for the day, and for the night. The array being 85kW allows us to actually carry the ranch loads and charge batteries even when it's overcast.

But on good, sunny days we have almost double the energy output. We dump that energy into an alkaline electrolyzer which makes 1.5 to 3 kilograms of hydrogen per day during our solar window. We store the hydrogen in a hybrid low pressure/high pressure system. The reason for that is we can use very inexpensive virgin propane tanks (ones that have never been filled with propane) for low pressure hydrogen. Ideal for fuel cells, which need only very low pressure to operate.

We have a fueling station with high-pressure hydrogen at 6,000 PSI, or 350 bar. We use the compressed hydrogen to fill up vehicles, and we have a hydrogen fuel cell forklift. Tax credits on alternative fueling infrastructure help to reduce the cost of the system. We can convert hydrogen back to electricity with two 6kW stationary fuel cells, giving us 12kW of DC.

The other thing you can do with hydrogen is cook with it. We're in the process of converting all of the stoves on the ranch to hydrogen, and we're going to put in an underground poly-pipe distribution line that can hold the hydrogen at 2,500 PSI. With over a half-mile of that pipe, it will simultaneously serve as good storage. So we can replace propane with just sun and water.

We also have a couple of Ford Escape trucks that have been converted over to hydrogen. It's not the most efficient use of hydrogen for mobility; fuel cells are 2.2 times more efficient.

One of the other projects that we have is a Mars habitat, sponsored by and rented out to NASA up on Mauna Loa at 8,500 feet. It's powered by 10kW of PV. We use the same Sony batteries for the energy storage and we use a 4kW hydrogen fuel cell as the back-up generator. Six "habinauts" (not astronauts; they're all engineers working for NASA, ESA, etc.) living in a 1,200 square foot enclosure for eight months in an isolation experiment where they can't go outside without putting on spacesuits. They have to pretend they're on Mars.

They have very small sleeping pods. It's similar to life on a submarine. The energy system is all off-the-shelf equipment. One of the incredible things about these Sony batteries is that they can go from zero to 100% in about 90 minutes if you give them full current. So that fits the small solar window profile that we have really well. And allows us to use the rest of that solar window to make hydrogen. This is the dashboard that the astronauts inside have, a prototype of our control system at the ranch [Slide 20]. It gives a readout of energy production and consumption, battery state of charge, and environmental conditions.

Inside the habitat are 130 sensors that monitor CO2, temperatures, etc. It all goes into a database. Clicking on any one of those values brings up the historical graphing capacity so that you can look back in time. When the batteries get down to a certain state of charge, typically 10%, the fuel cell kicks in and charges the batteries back up till they're about 12 to 15%, then shuts off. It keeps doing that until the sun eventually comes back and charges them. This allows it to operate it without any backup generator other than the hydrogen fuel cell.

So what does a holistic approach to sustainability mean? In our view, to become sustainable, we have to not just tackle energy, but also agriculture, energy, transportation. Waimea Nui is a project on the Big Island that is in the design phase right now. It will be a 165 acre agricultural community complex, 100% off-grid from the get-go, with solar, wind, biomass, and hydrogen.

Another project underway right now on the Big Island is a 2,400 acre Ahupua'a. In pre-contact days Hawaiians numbered anywhere from 200,000 to two million people, just on the Big Island. And they were 100% sustainable. Today we import 90% of our food and all of our energy to sustain just the low end of that range of population.

They were sustainable without any technology, so obviously we went wrong somewhere. We have to get back there. A 2,500 foot deep water well not only supplies the ranch but all of the community around it. It's a co-op, it does not belong to the ranch, it just happens to be on the property. The electric bill for pumping the water is about $15,000 a month. It makes our water among the most expensive in Hawaii—at $20 per thousand gallons, it is 10 times more expensive than county water.

So our next storage project is a flywheel storage project. A start-up makes a 10kW/40kWh long-term storage flywheel that's only 2 feet high, less than 4 feet in diameter, and weighs 5,000 pounds. The rotor is lifted with a magnetic lifter that has a parasitic load of 30 watts. Ten of those will give us 100kW of power and 400kWh of energy to be combined with a 200kW PV array. That will allow us to pump six hours after the sun goes down. This will be a model for many community water systems on the Big Island that have a huge cost of energy.

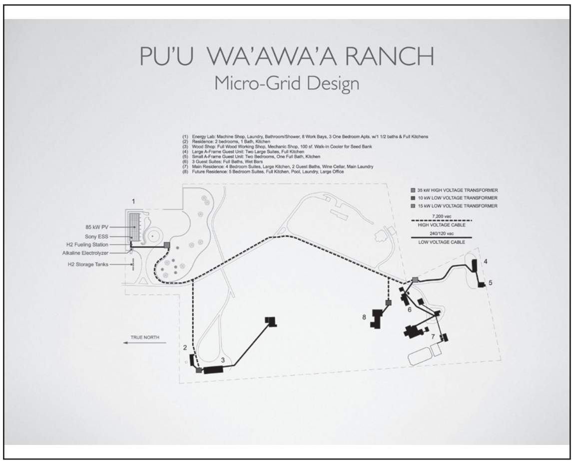
We're putting in five or six hydrogen fueling stations around the Big Island, which is enough for complete mobility. We have elevation challenges, distance challenges, so it is the perfect test bed for hydrogen. We want to move the Big Island from oil for transportation to hydrogen, and this is going to be the first step. With the amount of geothermal, wind and solar potential we have, we can make hydrogen competitive to the cost of gasoline.

The 1.2 billion internal combustion engines on the planet, soon to be 2 billion, that are contributing to global warming and pollution, if converted to hydrogen, would become air cleaners. If we wait for fuel cells to take over, it will be 10 more years. By converting existing internal combustion engines, we can utilize hydrogen with an existing fleet.

We're working with a company in Arizona that has injector technology that can efficiently use the hydrogen in both gaseous form and liquid form, meaning a methanol-based hydrogen carrier. To reverse climate change, we have to start looking at carbon-negative as well as carbon-neutral technologies. Removing CO2 from the atmosphere, or that which would go into the atmosphere, we can sequester and harvest the carbon, and turn it into durable goods like carbon fiber, carbon foam, graphite, nanotubes—technology which will make batteries more efficient–and into absorptive storage of hydrogen that requires less compression. This way, the carbon is actually worth more than the methane that you're extracting it from.

A 1MW demonstration in Germany is taking excess wind power, making hydrogen, and combining it with CO2 from coal-fired power plants to make methanol. Methanol serves as a liquid carrier of hydrogen, making it easier to transport, store, and utilize, and can be put into an internal combustion engine.

One of my favorite sayings is, "Civilization didn't emerge from the Stone Age just because we ran out of stones." There's no single magic bullet for sustainability. We have to utilize everything that's available, and we have to start utilizing it now, before fossil fuels run out, or we run out of time.



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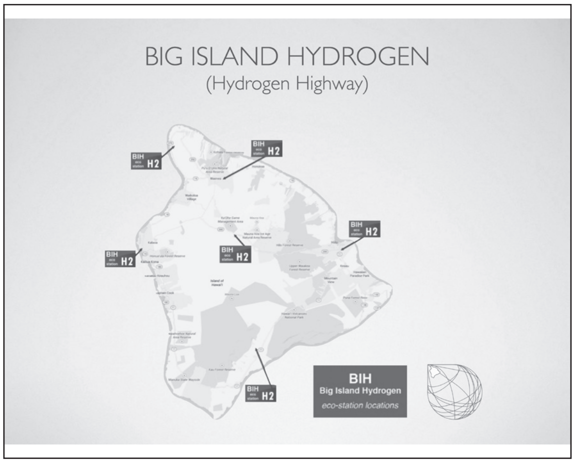

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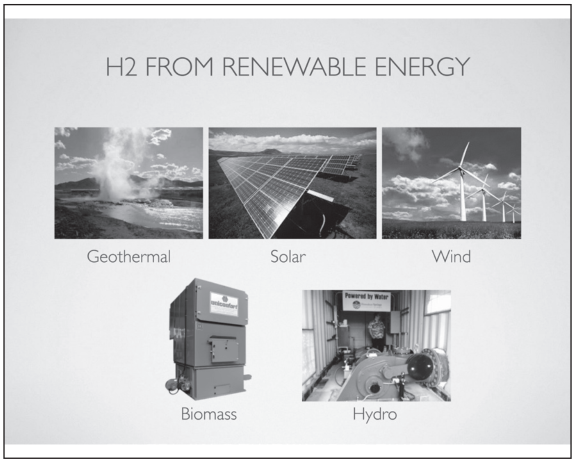

[Slide 25]

Speech 10: Mr. VINCENT PAUL PONTHIEUX

A Holistic Approach to Distributed Sustainability

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Speech 11

Keys to Consumer Engagement and Cooperation: How to Get Consumers to Adopt and Participate in Commercially Viable Open Energy Systems

Speaker: Dr. PHILIP E. LEWIS
CEO and Founder, VaasaETT, Finland

I work for VaasaETT, a Helsinki-based think tank and consultancy focused on consumers and energy markets around the world, especially–but not exclusively–liberalized markets. We have a database of more than 500 smart energy projects that we use to compare what works and doesn't work around the world, and we track the best and latest smart developments globally. We're also co-founders of the Smart Energy Demand Coalition in Europe, a group of companies including utilities and other players. In Europe, this group has been crucial in tackling regulations that were absolutely not favorable towards demand-side measures.

We focus on the consumer, on consumer behavior and how to push models to consumers within the energy industry. In other words, we start where everyone else usually ends. Consumers behave very differently in the real world than they do in pilots, which makes creating a mass market difficult.

We're taking on that challenge with a broader set of life-changing offerings and services together with our clients, using technology to deliver value to the customer. We help take the customer through a journey to build trust, experience, understanding, and the propensity to behave as we need, want, or expect so these services will work. It doesn't happen overnight.

Massive success stories like the iPhone, which was the right product, done in the right way at the right time, are extremely rare. "Nearly there" will not succeed with consumers. Nokia, for example, had been working on similar products, but didn't do it as well and didn't get the timing right, in my opinion.

All the building blocks have to be in place in order for Open Energy Systems offerings to succeed, because consumers will have to change. Fortunately, consumers desperately want change.

And many building blocks are in place. The market has developed, solutions have improved, costs have come down, wireless technology has changed things a lot, and new bridging protocols have come around. It is a very different environment from just a few years ago. The smart home is now a reality that works well. In Norway where consumption is high and most energy is used for heating, a smart home can pay for itself in two to three years.

A whole range of ideas are already commercialized. One Nordic firm offers heating systems controlled every hour of every day to match the price on the Nord Pool Spot market so that energy is used when it's cheaper, with the benefits shared between the customer and the utility. It is an inexpensive solution, requiring a smart meter plugged into your router and your heating system, that can be installed quickly and simply.

Commercialized solutions don't have to be complicated or expensive. There are apps and solutions to find out where to sell your electricity at the best price. Solar projects are being rolled out very successfully in mass markets. There are even crowd-funded solar projects. Offerings by solar providers in Australia include off-grid hybrid systems for consumers and a demand-response system that allocates energy usage in the home to periods when the sun is shining. With storage, battery technologies that are apparently almost there will really move the goalposts.

In Great Britain, every home with a smart meter is mandated to be offered a free in-home display; 5 million displays have already been distributed, or are ready to be. Feedback used to be very boring. But these days some is quite cool, with touch screens and color graphics. There is a Swedish product, a flower lamp that is a beautiful piece of furniture which changes shape depending on your energy usage, looking cooler and more impressive the less energy you use. People don't buy that just to save energy. They buy it to show off or to make their home more stylish. The point is, it doesn't really matter what you motivate consumers with, as long as you find what makes them tick. In this case, they would pay far more money for the lamp than they would ever save from the lamp just because it's cool and they can show it off to their dinner guests.

An analysis that we did recently for the Norwegian energy regulator estimated that the use of in-home feedback to consumers alone in Norway in two years would save approximately 7TWh [Slide 13]. Meanwhile, across more than 160 pilot projects around the world working with almost half a million customers, those consumers who were fully educated in conjunction with the rollout of feedback systems saved about three times more than those who weren't.

Where solar is concerned, in the minds of consumers it can already now present a competitive alternative to centralized utility systems, at least if the cost of off-grid solar is presented in comparison to retail plus distribution costs. Granted, solar is still not quite at parity, but if the cost of solar, as many expect, drops by 50%, then no subsidies will be needed to make this incredibly appealing to consumers.

Many different variables affect consumer behavior. The mind of the consumer is just as complex as the engineering. And yet we don't take any of that complexity into account when we try to sell to them. We build lots of complexity into the solutions and no complexity into the service design, marketing and communication.

But even if we get the offerings and communications right, there is much more we need to change. We shouldn't assume that old-fashioned utilities are not a threat to new business models, for instance. They are, because utilities have a lot of influence over regulation and they also have future business models of their own up their sleeves. Not all of them are going to take this disruption lying down. When building an actionable framework for customer behavior, regulation is probably still the biggest factor in inhibiting all kinds of smart offerings we're trying to deliver [Slide 18].

Then there are all the factors within the industry itself, such as infrastructure, and customer relationships. Don't assume that energy customers hate big utilities and love new entrants. Unfortunately, in many markets, energy customers just don't like anyone associated with the energy industry. Bad publicity for the energy industry hurts everyone, not just the big guys. Small players enter the market and encounter some of the same problems. Technical solutions alone are not enough. Information and education, plus offerings and rewards, need to be powerfully presented.

Social media is the ultimate method of presenting these to consumers, but it only works when there's something to shout about; consumers don't normally talk about their energy bills on Facebook. So we need to create offerings that give people something to shout about. Keeping in mind that comments by media and consumer organizations can make or break many offerings.

Most consumers are not very good at jumping with both feet into the next big thing. They like to move slowly, a step at a time [Slide 20]. Prime means pre-educating the customer. Peek means that you give them a chance to experience a little bit of what you want to give them more of. Explore means that you let them try more and more things out one at a time. Encourage means that you have to show them the benefit of what they're doing. Customers won't do something for long unless they know it's benefiting them in practice and that requires a lot of feedback. Instill means making it a habit and ultimately a social norm. But also making something which has a market surrounding it. Enhance means starting off by selling one thing that grabs the consumer and then building it out from that point. Once you've done that, Sharing the word will be the thing that matters.

New business models are already emerging. In Germany, for example, LichtBlik is creating an integrated platform to offer to its 700,000 customers. They started off selling green energy. Now they sell other things to do with smart services and they're putting it together in a common platform between their customers.

Ovo Energy in the UK, with 600,000 retail customers, is trying to turn local communities into energy retailers. What's the difference between a community retailer and a large micro grid? A distribution network. In the future there is a regulatory potential to let community retailers take over local distribution grids if the traditional players do not deliver the solutions that the communities want. Add to that a next-level community energy network, like this great project at OIST by Sony and its partners, and you have an instant infrastructure for distributed community systems.

Energy companies typically assume that they are building from being utilities and then they want to add additional services. What's happening more is that companies are coming in at the other end, they're offering solar and then from the solar they work backwards. Start with solar, then provide air conditioning, then provide some storage, and eventually offer car charging or fuel cell service and finally provide home energy management to regulate it all. A gradual process, providing one thing at a time and building outwards.

What we are realizing more and more is that customers don't want to buy just green energy from a company, they want to buy from a company that's green. The don't just want to buy more independence from a traditional company, they want to be independent. They want to believe in something and it goes far beyond greenness to the whole ethos of the company that they're dealing with. They want to go beyond a company that provides greater control to a company that gives them control.

The message to customers should never be about investment. That's a very scary term to them. Investment makes consumers think, "Wait a minute. I'm paying now and I don't see the benefits until sometime in the future?" Consumers have resented this about the energy industry since forever. "We'll raise your prices by $100 this year because we have to invest." And what benefit do consumers see from it?

Customers want control and fairness. But above all, freedom. Freedom from price rises. Freedom from utilities controlling you. Freedom from being spied on. Freedom from someone controlling the temperature in your home when you don't want to cede control, for the sake of large-scale negative demand-response. Demand-response has always been seen as something which is done to you and something which is done for the benefit of the utility. I believe that will be turned around and demand-response will be for the consumer, by the consumer.

The whole idea of these systems is independence, so why would you then want someone to control you? It doesn't make sense. You don't want to be controlled by utilities so they can make more money from you, although you might be willing to give up some control for the benefit of your community.

Freedom means being able to have the temperature the way you want it without being afraid of the energy price you will have to pay. In the future, when customers have efficiency built into their homes they will be able to live more independently and feel more free. Ultimately we are selling emotions and lifestyle, not technology, to these customers. (I'm focusing mainly on the multi developed markets in the more developed countries or the more middle class groups in the developing countries. I realize it's very different for those segments.)

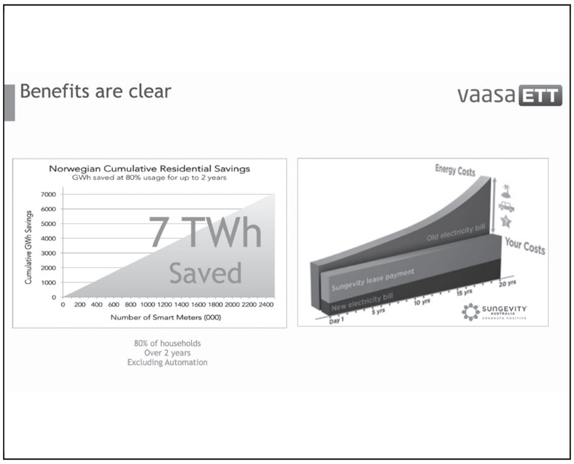
Real illustrations of the power of electricity customer enlightenment already exist. One program by E.ON in Sweden for instance was especially exciting. Recruiting 10,000 participants, they then gave them a special app, connected to their homes, that monitored their power usage in real time. Then, during the course of one year, we visualized their energy consumption in five different ways. To see which one would make them save the most.

We started off by showing their energy consumption as real money spent in real time. Next up was a virtual battle between participants. Later, a mean coach spurred you on to save more. And, finally, their consumption was linked to a cute

Tamagochi that died if they didn't save enough. Around the participants we built a larger campaign with a site where everyone could follow their progress. You could see who saved the most or least energy, compare different parts of the country and even compare your own consumption to others with similar homes. We helped everyone share their best energy saving tips, which we turned into a book, and even TV spots. News of the experiment spread throughout Sweden.

The result: seeing how much energy you use makes you save a lot. By the time the experiment was over, our participants had reduced their energy consumption by an average of 12%. And, by the way, last year, the world's total energy production provided by nuclear power plants was 12%. Now imagine if the whole world would join the experiment.

The message? Touch consumers, give them something to shout about and we can make a start towards I think a better future.



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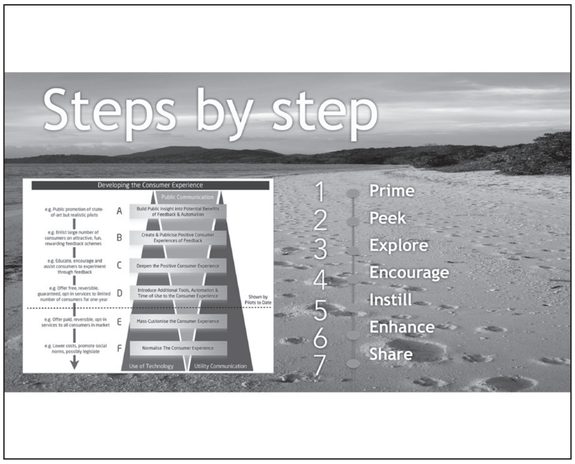

[Slide 20]

Speech 11: Dr. PHILIP E. LEWIS

Keys to Consumer Engagement and Cooperation: How to Get Consumers to Adopt and Participate in Commercially Viable Open Energy Systems

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Speech 12

The HVDC Power Supply System Implementation in NTT Group and Next Generation Power Supply

Speaker: Mr. TORU TANAKA

Senior Researcher, NTT Energy & Environment Systems Lab, Japan

My name is Toru Tanaka, and I am a Senior Researcher at the NTT Energy & Environment Systems Lab in Japan. NTT is evolving from a telecom company to a company pursuing the global cloud business. Our lab's mandate is to reduce NTT's environmental load. We aim to achieve a sustainable and low carbon society.

Today I will be discussing NTT's rollout of HVDC (high-voltage direct current) power supply systems that are higher in both efficiency and reliability and our work on next-generation power supply systems for future networking and data centers.

I will explain the advantages of HVDC power supply systems and NTT's strategy for HVDC.

NTT has been employing HVDC power supply systems with DC 48 volt power bus for many years because these systems offer high reliability and high efficiency.

Power consumption per ICT rack is increasing and the scale of data centers and telecommunications buildings is increasing, making reducing power consumption an important issue for the NTT group, whose business activities account for about 1% of the total power consumption in Japan! Since 2008 our energy consumption is almost flat but our electric bill has been increasing in the wake of the big earthquake. Energy saving is a critical issue because cloud and IP services are spreading widely and they consume lots of electricity.

On the utility side, high-voltage DC is over 1,500 volts. HVDC power supply systems for telecommunications buildings and data centers are 300 to 400 volts.

NTT's HVDC power supply system supplies 380 volts DC, converted from commercial AC 200V, to ICT equipment and to charge backup batteries. Currently, data centers mainly use AC power, but this entails many power conversion steps, which means many conversion losses. In telecommunications buildings we mainly use 48 volt DC. But as the power consumption of ICT equipment increases, current increases, requiring the cable diameter to be thicker. Our HVDC power supply system solves these issues.

Here are the advantages of the HVDC system. One is high efficiency because of fewer conversion stages. HVDC systems are very simple and have high-efficiency components. At 92%, efficiency is more than 10% better than AC. Another is higher reliability, again because of simplicity and because it allows direct connection of batteries. Calculated design reliability is 10 times greater than AC. We have gone many years without a single DC failure in the field. And space saving: the simplicity again yields a 30% reduction of space required.

Another advantage is reduced construction costs. Higher voltage means decreased current, so the cross section of the cabling is one tenth that of a 48 volt DC system. This aids in airflow through the floor and reduced cabling costs.

We chose a bus voltage of 380 volts, which is compatible with the UPS and PSU DC buses we have been using for UPS systems and ICT equipment. The battery cells are crated by piling up 168 cells. When the charging voltage is 2.23 volts per cell, the voltage gets to around 380V. The 168 cells are arranged into 7 blocks of 24 cells. For a 48V system, the number of battery cells is 24, so it's easy to scale up from a 48V system.

Let me review the obstacles to the spread of HVDC power systems. The technical obstacles are safety, electrical stability and availability of power supply equipment. And uptake obstacles are the availability of ICT equipment and standardization.

Concerning safety, touching the cable of an HVDC system would subject someone to a dangerously high current of about 270mA. So we introduced a high-ohmic midpoint system that reduces the current from touching the cable to about 10mA, which is safe.

We are developing a new type of socket outlet that prevents electrical shock. Many people say that with DC it is difficult to break the circuit when a short occurs. But there are in fact many circuit breakers and fuses that can do this. The issue is voltage fluctuations when the breakers protect from a short circuit. When the voltage fluctuations are large, other ICT equipment can shut down. We therefore developed a new fuse and PDF to suppress voltage fluctuations.

Addressing the uptake issues, we have worked on international standardization through two published ITU-T documents. Several ICT vendors offer ICT equipment for HVDC. But there is a chicken and egg dilemma over adoption of a new system. ICT equipment vendors say that carriers and operators must commit to buying lots of HVDC ICT equipment first.

On the other hand, carriers and operators are saying that ICT vendors must offer more types of HVDC ICT equipment before they can introduce HVDC systems. The NTT group intends to break this deadlock by declaring that we will adopt HVDC systems. The NTT road map calls for bringing HVDC systems to 100 buildings by fiscal year 2015. And 1,000 buildings by 2020.

A 4MW HVDC system already installed lowered power consumption by 20% at an initial cost of less than that of a conventional system. And we published technical requirements for ICT equipment. Our group intends to spread HVDC systems not only within NTT, but also around the world.

Next, we are developing new applications for HVDC. NTT has developed adaptive control for further reducing data center power consumption by controlling the number of working power modules according to the ICT load situation. This is possible because it is easy to control DC systems; control and synchronization of the bypass system is not required as in AC systems. NTT has pioneered HVDC systems for renewable energy. Our Obihiro project uses HVDC in an office building with DC-EMS controlling power modules such as rectifier, battery and PSU.

In Yamagata we have constructed an HVDC DC bus between buildings and houses. Using an HVDC system, it is easy to control energy flow [Slide 7].

We're introducing HVDC systems on the infrastructure side, but on the ICT side there are many power conversion steps, so to reduce power conversion loss we have to consider the circuit from the input port of the building to the input port of the IC chips. We created a next generation power supply typology with only three power conversion steps.

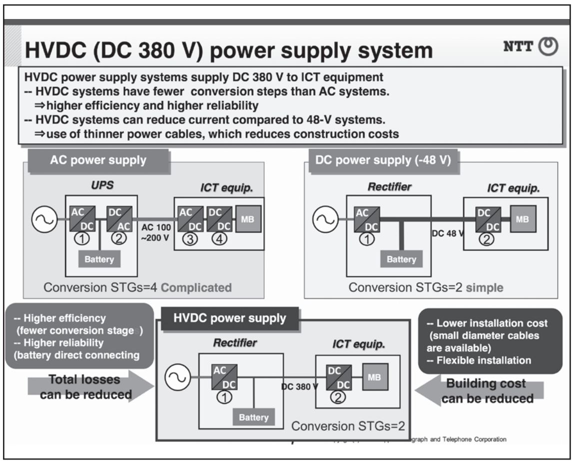
Two kinds of DC voltage (DC 380V and DC 48V) are used as bus voltage in this system. The important point in this system is that voltage of the motherboard is raised from the conventional 12V to 48V.

Changing the motherboard voltage from 12 volts to 48 volts reduces the capacitor size and cross-sectional area of cabling to save space. The conversion efficiency and safety level are equal. So there are no disadvantages of moving to 48 volts. Meanwhile, German automakers announced that they will use 48 volt power supply units in vehicles. So the standardization of 48 volts is proceeding.

The application area of the 48 volt system can be visualized in units of kW-meter, a product of cable distance and power consumption. In the ICT industry for a 19-inch rack the distance is 3 meters and the power consumption is about 20kW, so the total is 60kW-meters. In the auto industry the distance is 6 meters and the power consumption of an idle stop motor is about 10kW so the total is also 60kW-meter [Slide 43].

So I believe that voltage will be aggregated to 48 volts DC and 380 volts DC across multiple sectors in the future [Slide 44].

So we can expect a significant cost reduction for equipment and parts by using common voltage. We will continue to promote the use of DC systems throughout the world.



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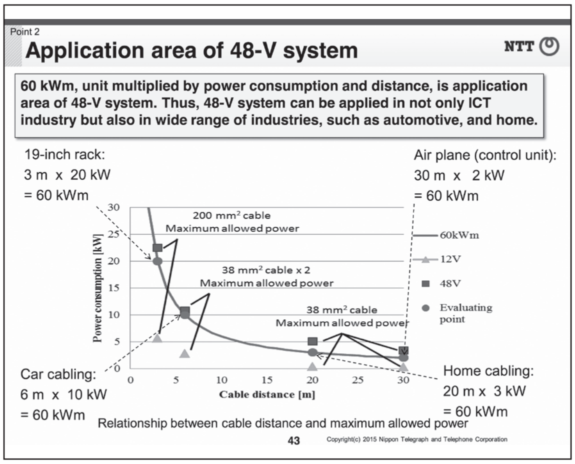

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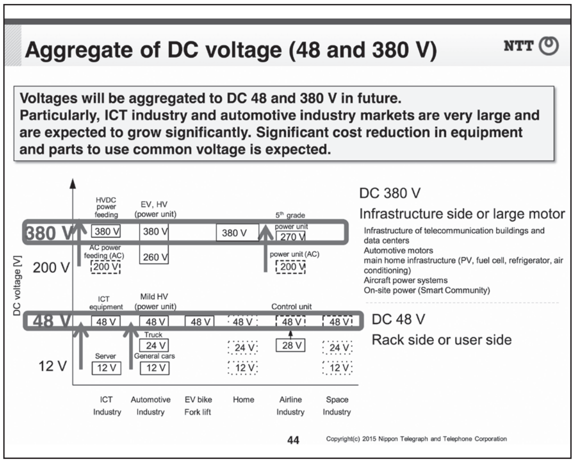

[Slide 44]

Speech 12: Mr. TORU TANAKA

The HVDC Power Supply System Implementation in NTT Group and Next Generation Power Supply

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Speech 13

Hawaii's Renewable Energy Future: The Maui Smart Grid–An Energy Technology & Applications Showcase

Speaker: Mr. LEON ROOSE
Specialist, University of Hawaii, USA

I'm Leon Roose from the Hawaii Natural Energy Institute at the University of Hawaii and I'm here to talk about Hawaii's renewable energy future and the Maui smart grid as an energy technology application showcase.

My focus is in grid system technologies and integrating renewables on the power grid. Change is happening at a very fast pace in Hawaii, which is driving innovation, and the island of Maui is an interesting showcase for smart grid technologies and renewables integration.

Hawaii's big challenge is our geographic isolation, which has profound impacts from an energy perspective. Nearly 90% of our energy is met using fossil fuels. The bulk of that is oil, 100% of which is imported, split roughly evenly three ways between electricity, air transport, and ground and marine transport. This nexus between transportation and electricity is critical because we could solve 100% of our electricity problems and that's still only a third of our bigger problem of reliance on fossil fuels.

This heavy reliance on fossil fuels has created an incredible threat to Hawaii's security, economy, and environment. Cost was the big driver that changed policy; in 2008 oil prices went through the roof, to $100/barrel–and pushed the local economy into a recession, right along with the housing collapse. Historically, low costs meant there was little motivation before this spike.

The cost of electric service in Hawaii right now is about three times the national average. The other issue is volatility. It is hard for businesses especially to budget with so much price uncertainty. With renewables, the known capital investment is to get the resource in the ground, and then you can decouple from fuel cost, smooth the cost and eliminate the volatility. And Hawaii has an abundance of renewable resources—solar, wind, geothermal, river hydro—as well as waste to energy.

Ocean energy technologies are a little bit more forward looking but have huge opportunities for an island state like Hawaii. Bio-fuels are also in the picture, and of course energy efficiency is a big part of the equation, and each of us can do things to lower our energy usage.

After the 2008 crisis, US DOE approached us at the utility where I worked for 20 years before I joined the university in 2012. I was asked to integrate 400 megawatts of wind energy on the Oahu grid within one month.

The utility company recognized this would have a huge impact on our business model. To survive and thrive, we ultimately had to figure out how to decouple utility rates from sales, because no business wants to reduce its sales. Fundamentally that was a regulatory matter for the ultimate trade-off in this deal to be negotiated. This exemplifies how to drive major paradigm shifts in the energy sector. It is critical to align the key stakeholders: regulators, customers, community, utilities, and all the third parties that produce capabilities and services.

So everyone started moving in the same direction in Hawaii in 2008. Today there are still many challenges; it is hard to align everyone's interests. There was a big trade-off: give us a set of regulations that allows the company to continue to exist and be effective and provide a service as a utility, and we'll do renewables. The Hawaii Clean Energy Initiative was signed in October of 2008 [Slide 6].

The state legislature set renewable portfolio standards: 40% by the year 2030 with intermediate targets for 2015 and 2025. At the time, we were at roughly 9%. The other piece of that equation was energy efficiency improvements, with a target of 30% reduction by 2030—a significant goal in a fairly short period of time.

It's among the highest RPS targets in the US. Amazingly, in 2013 we exceeded the 2015 renewable energy target of 15%. The 2014 numbers are not out yet but with renewable energy at 18.2% and energy savings 15.7% we made a gain of more than 33% in just four years. So we're ahead of schedule but there's a lot more to do. Oil used for electricity production is also down by 16% since 2008. So how are we doing it?

In 2014, there will be 390 megawatts of rooftop distributed PV across the main islands of Oahu and Maui. Almost 51,000 distributed rooftop systems—a lot on a fairly small grid. To put it in context, the peak demand of the Oahu grid is 1,100 megawatts. Another 240 megawatts of utility-scale PV projects are in negotiation and development on Oahu. So these numbers are going to get really high quickly. Oahu already has 100 megawatts of wind operating today. Maui has 72 megawatts of wind. When the transition to clean energy first started I think we had 12MW in aggregate on the islands.

Now Hawaii is at the top in solar PV per capita. On the Oahu grid 11% of all the customers have rooftop PV. That's quite a high penetration level. Given present trends, and capabilities, we expect to hit the 40% renewable energy target by 2021, potentially topping 65% by 2030. Today Hawaii's islands are not interconnected by power cables; each has an independent, little, isolated grid. There are a lot of issues with integrating renewables on grids like that. It will take a lot of technology and innovation.

Let me talk about Maui and the technology projects we've been doing to help facilitate the integration of renewables. On Maui there's 72 megawatts of installed wind capacity and 55 megawatts of PV as of year-end 2014, with another roughly 20 megawatts in the pipeline.

That's a lot of intermittent renewable energy on a grid whose peak is only 200 megawatts during the day [Slide 15]; at night the load gets as low as 85, and you've got 72 megawatts of wind. How do we integrate all that? Intermittency affects our ability to manage system frequency on the grid. Wind moves fast; a wind farm can go from near topload to gone within 10 minutes. Something has to make up that difference in real time, second by second, minute by minute. That's how the grid works.

You have to maintain perfect balance or you get frequency deviation. You can restore it once you get another source of generation on the line to balance that. Solar moves a lot faster than wind. This 10 minute period is pretty manageable with resources on the island. A 70-80% ramp in under 10 seconds is typical with rooftop PV systems. With the physics of today's AC power grid, you have to balance those changes in real time, instantaneously. Otherwise your frequency goes off, you've got a problem. How are we handling that intermittency from the renewables on the grid?

Excess energy is a big issue. I really like the idea (mentioned in another session) of being able to extract and use that energy for another purpose; for example, in the production and storage of hydrogen for use in the transportation sector. There's wind energy that's essentially thrown away on Maui and the Big Island everyday. It seems crazy to not take advantage of that marginal/zero cost energy. We have to find the business mechanisms to make it happen. Another issue is distributed generation on Hawaii; DC technology excites me and could address the technical issues with high penetration of PV on an AC circuit.

With the high penetrations in Hawaii today at the distribution level, the aggregate of the PVs is bigger than the load; 27% of the circuits on Oahu are backfeeding at some point during the day, shoving over 100% of the daytime minimum load, even as high as 250% or more on many circuits, back up into the transmission grid. This is a hugely challenging issue.

How do you deal with transient voltage issues that appear because you have way more generation than load on the circuit in that instant? The utility has to manage how much they can take on the circuit. There are now inverters on the market that can disconnect in a cycle or under. If those became required, it would allow circuit penetration up to 250%—a huge leap up from 100%.

There are other issues to deal with to get to 250% and a lot of work and research and innovation will have to happen to reach that kind of goal. But this is major news.

We have a number of smart grid projects on Maui. One is to develop advanced smart inverters that deal with some of the barriers to penetration. For now, until DC comes along, it's all AC, so with every home PV system, there's an inverter on the rooftop that's converting the DC to AC to feed the power into the grid. We have a lot of work focused there.

In Hawaii, much of our work is not done in labs but on the grid, where the problems are. That requires a partnership with the utility, academia (our institute for example), local utilities, major industry partners, government, even volunteers (we use customer interaction specialists to get those folks involved). It's a major team effort to implement these projects.

For this project, we put metering infrastructure on the grid, a battery at the substation level to manage peak demand and provide some voltage support. We put in smart thermostats and had volunteers; we adjusted the temperature and gathered data on the customer response. With more than a 3-degree shift in the temperature, people pushed the opt-out button; we began to understand the thresholds of willingness to participate (at least in Hawaii with the air conditioning needs). We had in-home displays in people's homes, which gave a lot of good feedback and motivated people to change behavior.

A program to put remote control switches on water heaters has been around in Hawaii for a long time–the utility operators call on that load reduction for operational purposes. I've had it for 10 years, but it never impacted my use and enjoyment of hot water, and I get a $3 monthly rebate on my bill. If you keep the shutoff brief, it's a very effective remote control resource at a low cost. In aggregate, the Oahu grid has over 30,000 participants translating to approximately 10 megawatts of demand response.

Getting the smart meters in allows two-way interaction with the customer and gives better visibility and control to the utility and improved service opportunities (e.g. proactively fixing issues previously known only through customer complaints). That is very valuable for engagement with consumers because in such cases technically the utility is not meeting their service quality requirements. The programs were also very effective in supporting grid stability through those controllable loads.

The endgame is creative utilization of renewable energy. On Maui, where there is frequent curtailment of wind, through these resources that we can dispatch, batteries can absorb excess energy and take advantage of it. We have a number of commercial battery and storage systems. In Maui, two wind farms put in large batteries in a form that made business sense and was pretty groundbreaking, reducing the amount of energy curtailment that would otherwise be needed. We can take more on; it's just a lot of work and bringing in the new technologies; and the utilities obviously have to make a lot of changes in the way they operate but so far, it's been working fine. In some respects, reliability has actually improved a bit with renewables, given the amount of reserves we carry. So the project was able to prove all those things and quantify some of those value propositions.

Our other project is to develop advanced function inverters. We are working with three different manufacturers: Fronius, Hitachi and SMA to demonstrate seamless interoperability–the same software, language, and commands. The solution architecture uses our existing automated metering infrastructure (AMI) as a communication backbone to talk to all the inverters. (We are leveraging the existing AMI that's already paid for through another project so we don't have to put in another expensive communications system.)

The key here is to develop the control algorithms to manage the reactive power capability and control the real power output of the inverter to manage voltage stability across that theatre. As the penetration of renewables increases, we're having more issues with variability and voltage and voltage regulation and management and we believe this technology can manage it. We made the tool, and we now need to program that tool and utilize it to its fullest ability.

US-Japan co-operation on clean energy technologies, fortunately with a focus on Hawaii and Okinawa, has been going on now for almost five years and there is discussion right now about the continuation of this relationship for another five years. In addition, there are two major initiatives on the island of Maui. JUMPSmart Maui is a Japan-US funded partnership on clean energy led by Hitachi. It has been very important to leverage across existing projects, bringing new projects in order to do more with limited resources [Slides 26/27].

This project really starts getting into the heart of smart grid. The reality is that distributed resources are coming online. So how do you manage what's happening and integrate those activities with the higher levels of the grid? Historically power systems had control and management at the top layer. Now we've got 50,000 distributed resources out there doing their thing. The idea is to push decision making, command, and control out to the edges of the grid, then integrate that with decision making at the next layer. It's a hierarchical architecture of control and management of resources that are growing explosively in number and that cover the entire spectrum of the power grid, including integrating electric vehicles into the picture.

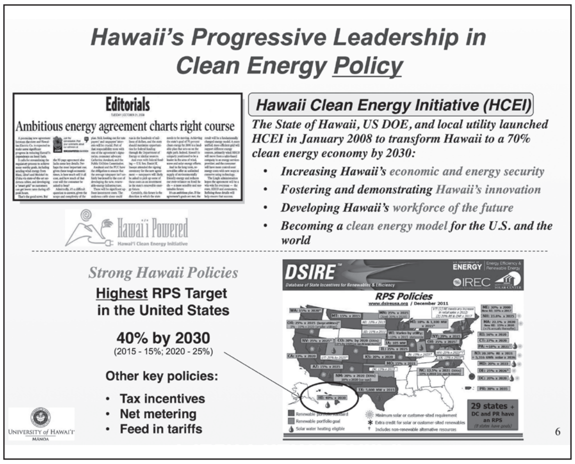
One of the key technologies introduced in this project is the micro DMS—a micro controller you can put in the grid as a key nodal point to manage resources downstream. In this case, micro DMSs are placed at the distribution transformers that serve, say, half a dozen homes, each with PV, electric vehicles, home batteries, DR, etc. So it's managing what's happening in its neighborhood environment. It then needs to co-ordinate its actions with the next layer of the distribution management system, which in turn has to co-ordinate its actions and decisions with the energy management system at the top layer—hierarchical command and control and pushing decisions out to the edge of the grid.

The other big part is electric vehicles. There are DC fast-charging stations deployed at strategic locations covering the island of Maui, so you can drive anywhere in Maui in an electric vehicle and not have range anxiety; a key factor in introducing electric vehicles. Charging cars demands a lot of power; these smart chargers actually have value as a large demand source that is controllable to help balance intermittency and variability.

If I need sudden demand response, I can cut off charging for a short period of time to respond to system events. In phase 2 of the project, it gets really exciting. We just finished testing some of the Hitachi technology, which is addressing the whole notion of a virtual power plant.

In phase 1, smart charging stations implemented smart charging. Phase 2 introduces vehicle to grid. So not just cutting off the charging but extracting power from the vehicles' batteries. I just finished a little project with Nissan motors; they're trying to evaluate the economic value proposition in the vehicle to grid picture. People have cars because we need to drive places. So how you use that resource for the grid is going to be constrained by people's use of vehicles, but if you can combine that resource with other resources like stationary batteries and DR, now you have the ability to have a more controlled overall shape of your packaged resource, virtualizing a combination of different technologies for value-added grid DR services.

These kinds of collaboration projects are really important, and they are happening in Hawaii. There's very rapid growth in renewables. The issues are real and we are looking for opportunities to partner with folks. I am looking forward to working with folks I've met at this symposium in the years ahead.



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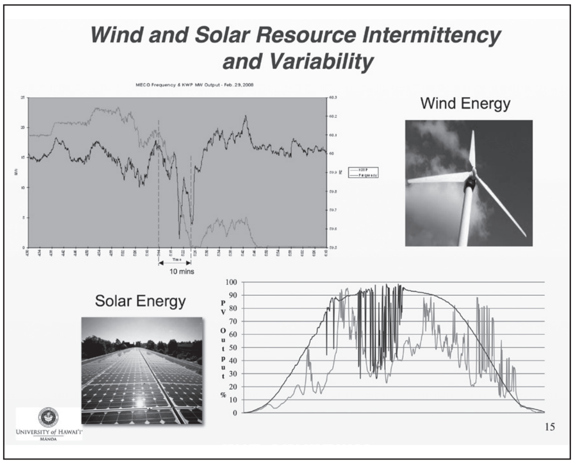

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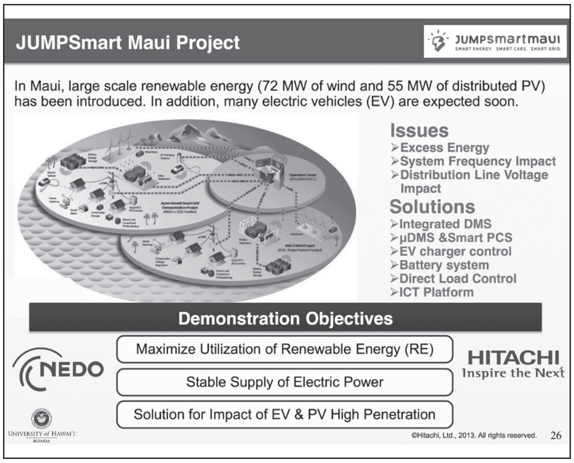

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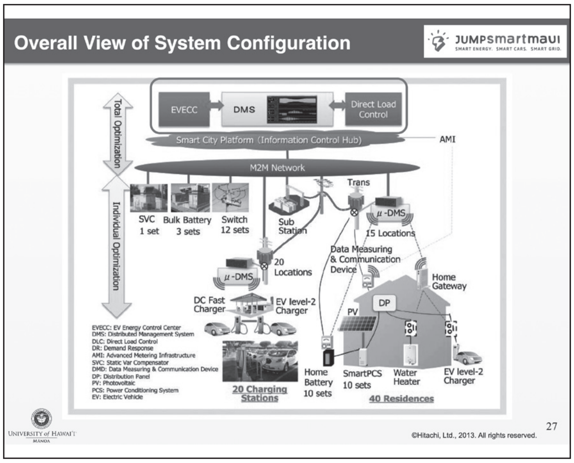

[Slide 27]

Speech 13: Mr. LEON ROOSE

Hawaii's Renewable Energy Future: The Maui Smart Grid–An Energy Technology & Applications Showcase

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Speech 14

Energy Systems Research and Applications at Monash University

Speaker: Dr. ARIEL LIEBMAN
Monash University, Australia

I'm Ariel Liebman, and I'm the Deputy Director of Monash Energy Materials and Systems Institute at Monash University, Australia. I'd like to talk about Energy Systems Research and Applications.

It's a very exciting time for energy, probably the most unprecedented transformation since Edison's day or the postwar period.

I will talk about how my colleagues and I see global and Australian energy opportunities and challenges and tell you a bit about the energy projects at Monash.

We are in a period of unprecedented change in modern times in terms of strain on fossil fuel resources. We've pulled a lot of stuff out of the ground and we've thrown it into the atmosphere, and now we have a climate problem. We have a perfect storm of rising energy costs and climate action urgency because we're depleting our fossil fuels while at the same time global demand is increasing. Oil prices are down at the moment but I think they will go up again. I hope so for renewables' sake.

Here is what we have to do in terms of emissions trajectories if we're going to limit ourselves to 2 degrees of climate warming: have world emissions peak around 2020, not very far away, and then get down the curve rapidly–a 9% decline in emissions per year. That will take a lot of innovation and transformation.

The good news is we have some pretty affordable new technologies [Slide 6]. The International Renewable Energy Agency has a graph giving the overall picture. The gray band shows the range of wholesale fossil fuel-based power generation costs around the world, and it's quite wide: there's a lot of variation. Then it shows the costs of various renewable technologies, by regions of the world, and we see that many are already sitting in the fossil fuel band. And this is wholesale cost. The picture only gets better for technologies like residential PV where we can put transmission and distribution costs into the equation.

What about Australia? Australia was a pioneer in energy market deregulation. That's been good and bad. As an amateur economist I'm not convinced that the liberalization of the energy market has led to increased efficiencies. It depends how you judge that. In Australia, each state originally owned and managed all its own power system infrastructure funded out of the state government's budget.

This whole deregulation exercise was quite interesting. The focus was on the competitive generation market. We thought transmission and distribution would be easy—figure out the efficient cost of running one of these systems and give them a revenue allowance. It didn't work out very well for the consumer.

We're such a big country; one system in the west wasn't interested in joining the market. The Western Australian system is quite far away and not connected to the eastern system. When they finally decided to deregulate, they chose a completely different market design. So we've got two types of markets. The Western Energy Market (WEM) has a capacity market that's really good for things like demand response. But the people who operate it want to get rid of it. One problem is how you actually price capacity.

With changes in government has come the policy flip-flopping on the climate issue. We experimented with carbon pricing for one year with some good results—a marked decline in emissions. We also had a renewable energy target of 20% of the projected demand in 2020. Now that demand is starting to decline, the target, which was fixed in GWh, has become more like 27% of updated projections of demand for 2020.

That legislation helped take solar in Australia from about 100MW of PV back in 2009 to something approaching 4GW, or about 10% of our peak load. The utilities don't know what to do; they talk about the so-called death spiral: as the energy they deliver through the grid goes down, so does their revenue. But the payback needed for fixed long-lived assets stays the same, so the cost per MWh goes up. Then rising prices drive consumers to do more energy-efficient activities, install more distributed solar, etc., which reduces demand further, and on and on.

This hasn't actually happened yet but it's been talked about so much that it appears as if it had. We also had a big smart meter rollout in Victoria which was very, very unpopular, not because of the smart meters themselves but because it was done with no consultation, no explanation of why it was a good idea.

The government also did a trial called "Smart Grids, Smart City. They deployed a whole range of smart grid technologies and monitored to try to understand the implications for the future. From exercises like this, it's impossible to project the value or the cost benefit if it were deployed at a massive scale, but some very good data was gathered from it.

In the opening talk Dr. Kitano mentioned the CSIRO Future Grid Forum roadmap from 2013, a very interesting analysis and modeling of four different scenarios of where the Australian market might go. It had limitations because it was a consensus based process with a lot of different energy stakeholders and some of them had specific sensitivities on what should be communicated throughout this process. But it prompted valuable discussion.

The deregulation process brought problems. The total cost per household in New South Wales increased about 100% after the new regulatory framework was put into place. Most of that came from distribution. Carbon costs and increased wholesale energy prices were a much smaller factor in the increase [Slide 11].

One effect of renewable energy on the energy market is it reduces demand for fossil fuel generation and prices go down. Fantastic for the climate. Not so good for the incumbent generators. The underlying wholesale costs have been doing what you'd expect, so the competitive part of the market—generation—has been doing okay. But consumer electricity prices went up instead of down with deregulation; that's a massive policy failure.

Despite Australia's huge size, transmission—moving energy long distances—is quite a small proportion of the final bill. Transmission technology is efficient and average losses are only around about 8%. Wholesale competition behaved as expected. The problem is retail. Some of the retailers in Australia who buy energy from various producers and set prices to sell it to the consumer market are very expensive.

Ownership varies for different states in Australia. Some assets are private, some are government owned. There are glaring difference in the size of the low voltage distribution component of the bill, whereas 10 years ago, they were about the same.

Notice though that the final price is fairly similar in all the states, the retail margins—the operating costs of the middleman—are very different. In Victoria, this retail margin is much higher than in the other states. The main difference between Victoria and the other states is that there is no regulation of the retail price. This shows us that retail competition in electricity is not that easy. We don't quite know how to make a competitive electricity market work at the retail level.

It's not the same as going to buy apples or Apple computers or whatever. People don't seem to spend as much time thinking about their electricity bill. Our productivity commission did an analysis of these network pricing issues that showed that actually the productivity of our electricity has been increasing over time before deregulation.

But somebody thought it was not increasing fast enough. Higher-productivity assets means lower cost per unit means lower prices. When we deregulated, productivity gains should have accelerated, but it's gone the other way. The general market sector had a downturn too, but nowhere near as much. So in relation to Open Energy Systems, why does productivity and cost of networks matter? Because all these Open Energy Systems –smart grids, local generation and so forth–are competing with traditional infrastructure, so the pricing of the traditional infrastructure impacts directly on when these new technologies will be competitive.

Energy demand is going to grow in the developing world and it is starting to plateau in the developed world. We seem to be decoupling economic growth from energy consumption growth. At the micro level, there are some interesting legacy challenges around keeping the operation of the power systems stable; renewables make that harder.

The legacy architecture of all these big turbines running at 3000 rpm and talking to each other via this thing called the frequency, to synchronize with each other: that's 1930s technology. It worked well when demand was fairly non-variable and nothing much besides turbines existed on the generation side. Now we have much more volatile demand with a lot of new devices such as air conditioners and all kinds of electronics. That adds to the challenges of just keeping the system stable.

Another challenge is forecasting demand and this is already an important factor that will become even more important with the new technologies we're deploying. Demand for a system with a lot of photovoltaics is much harder to forecast short term. Demand is now based not just on consumer behavior but on solar irradiation (distributed PV) varying as a function of cloud cover across the different areas of a city. We need more work on forecasting.

Managing the integration of renewables and their variability through smart fast demand-response is a challenge. If smart grid systems were realized, enabling all these devices to be on a smart grid where we can control them– turn them on and off, or back them off—at various times, it would be a benefit that really increases the value of Open Energy Systems.

What would smart grids mean for the market if implemented? Perhaps only in Hawaii do we see anything close to a full-blown smart grid anywhere in the world. Smart grids, or Open Energy Systems which is an even better term, can make full consumer engagement possible, increase productivity of the energy sector, help with integration of renewables, defer capital expenditures across the entire supply chain and reduce operating expenditures.

Smart grids should decrease the cost of building and running an electricity grid. If they don't do that then they've not served their purpose. How do you get them to do that?

How do we segment the different activities and capabilities of the different types of smart grids? How do we engineer them so we can control and provide services on different time scales? And what should we do with all the smart meter data we are getting; how can we extract value from it?

Another aspect is the long-term investment decisions. These assets traditionally are very expensive and long lived. About 80 to 90% of any power system is capital expenditures; the rest are variable costs. When we get to 100% renewables, variable costs will be almost non-existent. So how do you design electricity markets when you have no variable cost-based price signal? Your price can either be zero or infinity depending on whether you've got enough power or not.

Even when demand is not growing in the developed world, you need to make decisions about new technology. Who decides where it goes: central planners who want to maximize efficiency, or entrepreneurial utilities that want to maximize their own return? A lot of modeling and analysis needs to be done and new techniques developed for making these investment decisions under uncertainty.

Uncertainty such as whether electric vehicles will cause demand in the developed world to accelerate and grow faster than before it started to plateau. We have very interesting cross-disciplinary and systems-based problems that need new paradigms from economics, optimization theory, IT-based simulation and electrical engineering.

For example, in Australia, wind developers have to decide whether to place turbines where the wind is high and consistent, but lacking transmission, or in places with better transmission but worse wind. Do you invest in upgrading this line? And who's going to pay for it?

In Australia, governments are not in the business of building transmission lines anymore and the economies of scale don't work for one wind developer; it would take three or four wind developers. There is a market failure happening on these types of investment decisions under uncertainty. Some new mechanism is required.

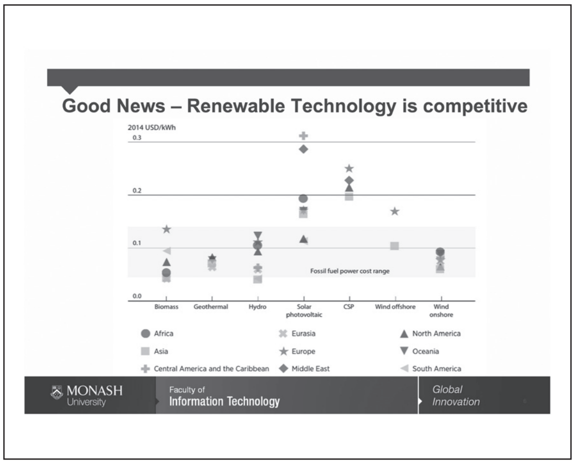
This is my pet project. How do you invest in a very complex system? How do you decide where to put new technologies? We have a test scenario, a 30 node system with 24 nodes where you can put in some renewable generation–wind, solar or maybe pseudo-renewable generation like gas, micro-turbines, or fuel cells where you pipe in the hydrogen. For 24 possible locations, 3 types of technology, that's 72 decision variables.

Say you only have five increment levels: 1-5MW. That's 5 to the power of 72 combinations. How do you decide the most economic configuration? It is doable with the right optimization algorithm deployed on cloud-based computation. We run 400 simulations at a time, with several objectives: reliability, capex, opex and emissions. Using these chronological market simulation tools, it only takes a few days to map out a Pareto frontier using 70,000 simulations and find a quite non-intuitive solution [Slide 26].

We are also working on smart meter data management and analysis: How do you identify what type of customer you have and how they behave, what devices they're using when, with just a meter at the gate of their house giving half-hour resolution? We are also working on risk-based asset replacement.

We are also working on designing markets for demand-response and smart grids simulating a dynamic price response based system where each house develops a schedule based on a dynamic price passed through to them. In summary–we've got some big challenges, energy growth in the developing world, CO_2 growth and a very short time frame over which to address these–but we've got big opportunities: cheap renewables, and using information technology to integrate existing technologies, which is about 50% of the solution. Research institutions must work with businesses and other stakeholders. I wish every university and research center would focus just on energy in the next 10 years because of how big this problem is.

Good luck to all of us!



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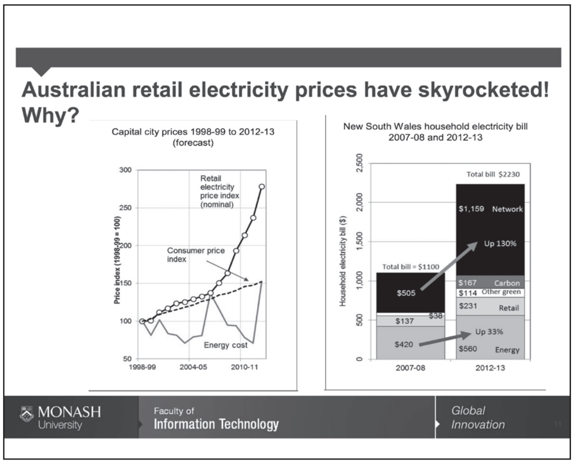

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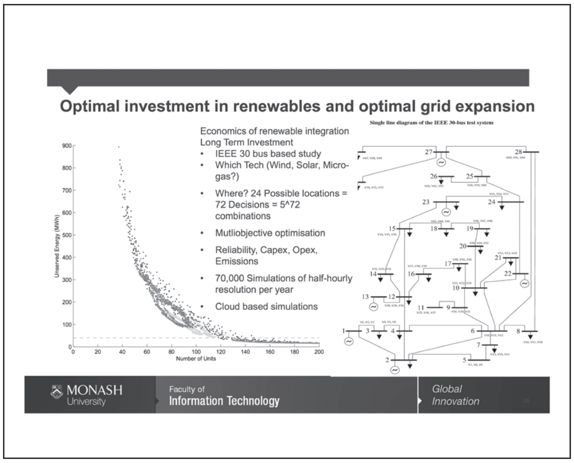

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Speech 14: Dr. ARIEL LIEBMAN

Energy Systems Research and Applications at Monash University

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Panel Discussion 2

Moderator:

Dr. ROBERT BAUGHMAN
OIST

Panelists:

Mr. LEON ROOSE
Dr. ARIEL LIEBMAN

Dr. Robert Baughman: Thematically, we've included a part here at the end that's focused on the concept of R&D clusters. Here in Okinawa we have to integrate the activities of the university with the activities on the island in the context of an international community. That means getting groups working together, doing new things. Could the two of you talk about the context in which your activities can or should interact with R&D clusters?

Mr. Leon Roose: I really believe that to make the most progress it is essential to have interaction and partnership between all the key stakeholders that can and do effect change in the energy sector. All stakeholders that are businesses, like utilities, generally bring a perspective reflecting a particular agenda or purpose. And I think a very important role that academia can serve is coming into the picture with less of a stake in the game than those businesses, to facilitate the interaction that I think is essential amongst stakeholders without having that baggage.

In Hawaii, it was really important in that paradigm shift of trying to move towards renewable energy, of trying to get alignment of stakeholders. Without that you're constantly pulling in opposite directions.

You're never going to get perfect alignment but getting people generally steered in the same direction is pretty critical and essential.

Dr. Ariel Liebman: One of the challenges to overcome for this sort of thing to be successful is the private sector's and universities' expectations of each other and understanding of each other's drivers and incentives and timeframes. Academics are remunerated or rewarded for publications in a lot of cases; that's the metric of their success, for being promoted and so forth. And a lot of that research is long term. It takes time to produce good research. At the same time industry needs shorter term outcomes.

In Australia industry is short-term focused. A company we worked with didn't understand how they were using so much electricity on their sites. Their internal stakeholders who wanted to solve this problem, wanted to do sub-metering of all their sites. And they kept getting their business case knocked back because they could not show how a modest investment of a few hundred thousand dollars in sub-metering would produce a return on investment in two years.

Industry needs to have the right sort of time frames to be able to work with universities. Universities also need to be willing to deliver results on a shorter timeframe than is traditional in academia.

Baughman: By hosting this last year and this year, OIST is building towards something that we hope might materially contribute to building an R&D cluster here. We're interested in what kind of community is involved in broadening the foundation and the context of a cluster, and what is the role of policy. As an example of the kind of thing we're talking about, OIST is about to sign an MoU agreement with the University of Hawaii.

Roose: I think the major thing about energy is that it cuts across every sector of our lives and our livelihoods. So energy solutions inherently need to be viewed and examined across a whole array of different sectors and activities, transportation being a key one. Having that broad range of research and pulling it together will really drive us as a society towards solutions quicker.

Baughman: In working on projects over a number of years, could you tell us about what obstacles you overcame to reaching this point? And how you collaborated with other people to do that?

Roose: That watershed moment in Hawaii was in 2008. Crisis can be the paradigm shifter. Sometimes crisis is good because it shakes things up. The other key part was trying to align the stakeholders. And that's not an easy thing. But I think that's extremely essential to begin to move forward. The utility, if it was going to survive, needed some things to change fairly rapidly in terms of regulatory transformation, so that was part of the deal, even if the question is still out there as to what it's going to look like as it's transforming. It was kind of amazing how in a relatively short period of time, about eight months in 2008, we were able to bring alignment of the major stakeholders in Hawaii.

Japan had its own sort of crisis with Fukushima. The question is where do you move from there? There is a very complex equation with multiple variables that you need to balance. But you have to get an alignment of stakeholders. And that's a big part of the challenge to move forward.

Liebman: It's interesting that you mention 2008. That's when I first saw some success in my activities around energy related research in the university sector. In 2005 I came back to academia from industry and I didn't see much energy related research happening. I thought, "Energy is a big deal and it's going to be a bigger deal in the future." But I could not convince anybody. They thought, "Energy? We've been doing it for 100 years, it's a solved problem." I persisted, kept getting involved with any developing relationships in the space while doing other things. It's a bit like surfing.

You've got to be paddling or swimming before the wave hits. If you wait until the wave hits you'll have missed it. You have to start lining up your ducks in a row before the crisis. Or spot your particular crisis that you're interested in addressing before it gets too bad.

Wrap-up Discussion

Moderators:

Prof. HIROAKI KITANO
Dr. MARIO TOKORO

Kitano: I would like to wrap up and discuss issues raised in the two days, which I think have been very fruitful. Thank you all again. But we don't want to leave here just thinking that was great and we had a good time. A window of opportunity is now opening up. The next couple of years are going to be a really critical period because things are going to change on big issues: regulatory schemes, markets, and we are on the verge of major breakthroughs in cost reduction. We need to seize this opportunity.

Let's look back at what we have done recently here at OIST. At last year's conference there was not much going on. It was like a forum of discussions on things we wanted to do, but that had not yet materialized. But this year we've got OES installed in 19 houses, connected, and up and running continuously. I think everyone could see the technology is there. Open energy, nano-grid, community grid, all this terminology is getting more and more familiar to people. There has been great progress in only one year. At least three Japanese newspapers, including one of the biggest, actually ran stories about this symposium. We have more and more people contacting us, saying they heard about this system and are very interested, even in the last 24 hours. People are taking this seriously now. Next year we'd like to organize this again. But what should the framework be?

Tokoro: Before I forget, I'd like to thank Ronan Stephan from Alstom, one of the program committee members who made a very, very big contribution. Unfortunately he couldn't come because he got the flu.

Kitano: I do want to add more structure to this conference, so it would be good to have more partners involved, like a standing steering committee to decide on the program and who to invite. This year's speakers are mainly our own connections, between OIST and Hawaii and Mario Tokoro and myself.

Tokoro: I am glad we could show the DCOES system in a working version, and I am also very pleased that many people working independently of us have started pursuing energy that is open, distributed, and renewable. Maybe there are still people out there working very hard in this area. If we could invite those people, this community would grow and our new vision would grow and influence the world. That is my hope.

Kitano: Let's get some feedback. What would improve the conference, make it more exciting and more proactive? I would like to have questions and comments from the floor.

Roose: I really enjoyed the conference. The array of perspectives and systems ranged from off-grid electrification to more modern grids and integrated systems. How are we ultimately going to stitch them together? As you get electrified communities, eventually they'll evolve to a level where they begin to get interconnected and tied into the bigger grid. It would be interesting to look at the whole landscape of how that evolves as a focal point.

Amoroso: One element to be further expanded next year could be the business models that arise from this technology. The technology is there: battery storage, the platform for Open Energy Systems, all kinds of micro energy systems. It opens up a number of possibilities when it comes to addressing the needs of the customer with different business models. The real challenge we're going to be facing in the next few years is how to better meet customer needs.

Tokoro: Business models competing with the current grid business model will not necessarily be easy, as Mr. Kogure explained concerning the case of Hokkaido. It sounds like the Japanese utility business is pretty much a state monopoly in reality. You have to know what the vested interest groups are.

Liebman: Thank you for this fantastic symposium. Every speaker has said a lot of very valuable things. What interests me is shaping the discussion towards solutions to problems. I'm still trying to get my head around where you guys are coming from. In Australia we've had a smart grid R&D leaders working group for the last year and a half to come up with a roadmap to find out what research needed to be done to help smart grids get taken up.

A lot of the questions addressed were, "What are we trying to achieve?" It would be great to see next year a specific outcome at the end of the workshop looking at predefined problems and trying to coalesce solutions. That might help to focus the discussions. Perhaps one way to do that would be to hold some workshops as well in the symposium.

The danger that smart grid proponents in Australia became aware of is that consumers do not want technologies, they want solutions to some of their needs.

Dogertom: I was very impressed with the DCOES set up. What I would really like to see is the breakdown of the economics and what variables you need to play with. What distance would an existing grid need to be extended before the math worked out to make that possible. What we really need too is to look at ways it can be further optimized, and not necessarily today's economics but the economics under a number of scenarios into the future.

Ponthieux: The most powerful way to communicate this is to actually have done it. We've seen that on the Big Island, where for years we talked about doing things and went to lots of conferences making PowerPoint presentations. Once we did it, then we got the attention of much bigger audiences, like the Department of Energy, Department of Defense. You've taken away that variable of "will it work or not," once you've shown that it actually does.

Lewis: Quite a lot of these business models are getting there and it would be great to see some of those, especially startups that are trying to develop real commercial solutions out there. Even if they're not yet that successful but if they're emerging. Policy makers and regulation at all different levels, national and international and so on, are very powerful barriers to a lot of what we're trying to do as an industry, and it might be good to hear more about those barriers, and how to overcome them. I know sometimes regulators are not the most exciting speakers and they're inhibited in what they can say but I do think that the regulations are not going to be overcome unless someone works at it.

Ponthieux: It seems that a lot of the focus is on microgrids and small grids having to be connected to larger grids and I don't necessarily agree with that. I don't see why you can't have both. Individual communities can be their own grid and they don't have to be connected to any larger grid system. And I think there are some advantages to be gained from having smaller grids, and having that democratically controlled by the people who actually produce and use that energy in their own community.

Closing Comment

Dr. ROBERT BAUGHMAN

Executive VP for Sustainable Development of Okinawa, OIST

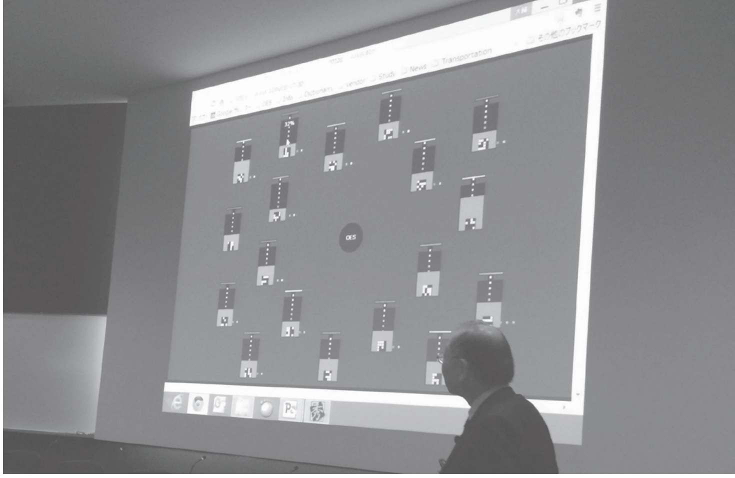
In closing I'd like to thank you all again very much for coming. It certainly meant a lot to us at OIST and I hope it has meant something for you.

In part, it has answered the question, "Why are we here?" For you, but also for us. Why are we here? What is OIST? And I think it's actually very important that OIST represents a dream to do something new. Something that matters, something that's the best in the world. Doing something like that is a special opportunity. The spot where I'm standing was just pine trees some years ago, and now we have all this. That's what OIST is about. So we hope that a meeting like this follows that theme of doing something new. Another important aspect of OIST is to be interdisciplinary, crossing into policy, crossing into science.

The hope was that in getting this group together around the idea of Open Energy Systems, new approaches to energy, we would be helping to launch a new interdisciplinary community. And I think we have actually gotten something started here.

So I want again to thank the organizers for putting this together and to thank our business development team and technology licensing team here at OIST. They helped make sure that this happened.

And thank you to all the supporting staff running around behind the scenes. I think we've got something going and I hope to see you again next year. Thank you very much.



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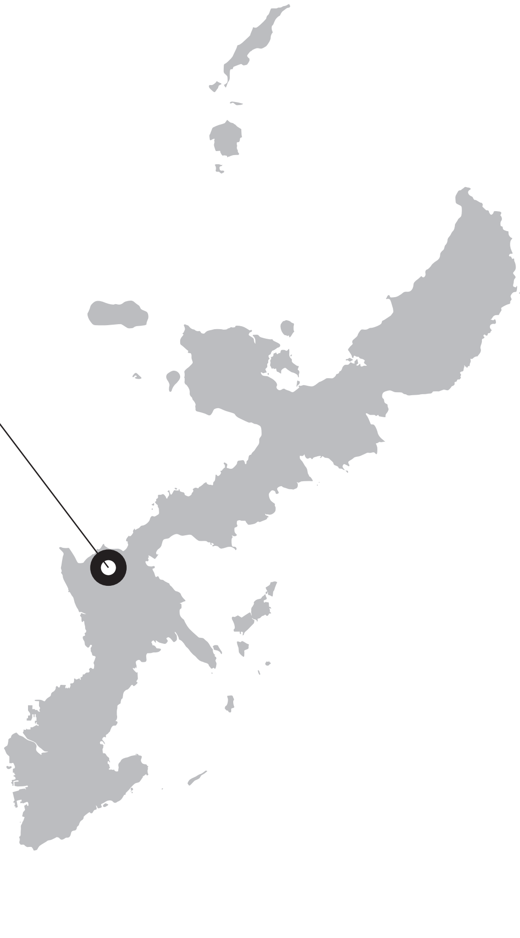

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