

Energy Regions in Transition

Europe-
California
Tour 2015





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About this Report

The report was published by the Renewables 100 Policy Institute, a 501(c)3 non profit organization. Our mission is to study and accelerate the global transition to 100% renewable energy.

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I. EXECUTIVE SUMMARY

Introduction

In October 2015, a Delegation of European grid operators, energy policy leaders, regulators and non-profit clean energy advocates visited California to learn about how the state is handling its transition to 50+% renewable electricity and to exchange experiences from both sides of the Atlantic in decarbonizing the power grid.¹

The Renewables 100 Policy Institute and Renewables Grid Initiative (RGI) organized the Tour with the aim of facilitating collaboration between frontrunner regions in the energy transition and sharing best practices on improving grid reliability, increasing economic benefits, limiting environmental impacts, and strengthening public acceptance.

Included among the topics of focus were:

- Evolving models for grid operation based on expanding regional cooperation
- Technical and market design best practices to integrate renewables and other disruptive technology market entrants
- Emerging new business models in the electricity sector and requirements for greater vertical and horizontal integration
- New cross-sectorial relationships in the energy system (e.g. between energy, transportation, water, building environment, etc.)
- Implementing related regulatory frameworks

For video highlights and interviews from the Tour, please click [here](#).

¹ By “decarbonizing the power grid,” this report means transitioning the electricity grid supply to renewable sources that do not add carbon dioxide or other greenhouse gases to the atmosphere.

Key Takeaways

During the intense four days of discussion, which included both formal meetings and informal dialogue, three dominant themes recurred among the grid operators present:

- **Larger electricity markets** result in lower costs and are better able to accommodate more renewables.
- **Balancing Area consolidation** improves reliability and increases efficiencies, thereby reducing costs.
- **More transmission is essential**, in order to share resources and support larger markets.

The following is the broader list of key takeaways from the delegation discussions that are recommended to inform future planning:

1. **California and European countries are facing many common challenges in their efforts to decarbonize the grids and share growing and widespread optimism about identifying and implementing solutions.**
2. **Expanding a regional approach to grid operation is strongly needed to successfully decarbonize the transmission grid.**



3. Upgrades must be made to grid infrastructure to ensure maximum efficiency.
4. Deeper inter-regional and international collaboration is needed on specific best practices for technically integrating renewable energy sources and complementary new market players onto the grid.
5. Further collaboration is also needed to identify, track, and strengthen business models of the future, which will require greater horizontally and vertically integrated planning.
6. Regulators and policymakers around the world must strengthen their capacity to respond to rapidly developing clean electricity technologies and consumer demand.
7. The energy transition specifically requires two sets of policy and regulatory mechanisms: one to transform the energy system, and the other to ensure efficient and reliable running of the energy system.
8. Stakeholders must be engaged in transparent transmission grid planning from the start.
9. The energy transition is cross-sectorial, and further collaboration and exchange among frontrunners is needed to better understand, navigate, and indeed create this new energy playbook.
10. The international multi-stakeholder dialogue on the Tour needs to be institutionalized into a long-term, regular exchange.



Tour Overview: Snapshot of Main Events

The four-day packed agenda included a wide range of meetings with a broad group of stakeholders in the California energy field, including industry and technology leaders, academics and researchers, regulators, economists, non-profits, and transmission grid operators. The following is a brief overview of the tour's major events. A detailed description is offered later in the report. (See Attachment D for the Tour Master Schedule.).

Tesla Manufacturing Facility Tour



Being led on a tram through the factory where some of the world's most innovative and luxurious automobiles are made was like starting the meal with dessert. The Delegates had the chance to sit in sleek sedans and watch giant robots assemble the Model S and the Model X, while also witnessing up close the interface of information and energy technology, innovation in the electric transportation sector, developments in battery storage, and the inner operations of a young company that has been trailblazing its way to a prominent place in transitioning to a decarbonized energy system. There were also several concrete examples onsite of California-European collaboration in action.

Silicon Valley Luncheon Forum



The Delegation joined representatives from pioneering Silicon Valley companies, including Google, Sunpower, and linear generator innovator Etagen to gain their perspectives on the changes happening in the energy sector. Topics of discussion ranged from the diminishing role of conventional power sources in integrating renewable generation into the electricity grids, IT leaders like Google's renewable energy efforts, and power storage to grid markets.

Stanford University Roundtable and Dinner



There was broad agreement that this unusual gathering of high level of experts in the energy field hosted by Stanford University was not only intellectually rewarding, but an example of the multi-stakeholder dialogue needed at this juncture in the transformation of energy systems around the world. As one Delegate shared, decarbonizing the grid is akin to "changing the tire while the car is running," and we will meet the challenge more successfully by collaborating and sharing points of view among various sectors than by remaining in separate silos.

California Public Utilities Commission Roundtable



This meeting, chaired by Renewables 100 Policy Institute in collaboration with Commissioner Michel Florio and additionally attended by California Energy Commissioner David Hochschild and senior CPUC and CAISO staff, allowed the Delegates to dive more deeply into the nuts and bolts of regulatory policy, to consider how these policies can create solutions or stumbling blocks, and to exchange different perspectives, approaches, and lessons learned for their various regions.

Bloomberg New Energy Finance (BNEF) Roundtable



BNEF hosted a roundtable discussion at their San Francisco headquarters, where the Delegates had the opportunity to hear BNEF Founder and Advisory Board Chair Michael Liebreich's perspective on the global energy transition's economics, as well as to question, debate, and inform these views. It served in part as a preparation and preview to Liebreich's Keynote later that week at the CAISO Symposium on similar themes and to the International Panel that he moderated at the Symposium on which several Delegates were panelists.

CAISO Stakeholders Symposium



The international Delegation was warmly welcomed as the headlining addition to this cornerstone event of the tour. The October 2015 Stakeholders Symposium enjoyed the largest attendance in the event's history, with more than a thousand registered participants and another thousand attending via live stream from all over the world. More than 30,000 people followed the Keynotes and International Panels on social media. Delegates delivered both a Keynote on the first day and the panels on the second day, which gave the audience a unique chance to learn directly from a broad spectrum of European energy experts on how they are welcoming the new opportunities for technology and market innovation in the context of the energy transition in their various regions.

CAISO Headquarters Tour and Discussion



The tour wrapped up with a site visit to CAISO's headquarters, where the Delegation was privileged to see California's grid at work in the control room and to be able to ask questions directly of California's transmission grid operators, executives and IT experts. A roundtable discussion capped the full and informative week.

Background

The 2015 Energy Regions in Transition EU-California Tour followed up the 2014 California-Germany Learning and Collaboration Tour to Germany in March 2014, which the Renewables 100 Policy Institute organized to bring top level grid operators and regulators from California together with their German counterparts.²

The first of their kind discussions that took place on the Tour focused on creating opportunities for continued dialogue and a platform for an exchange of ideas, policy, technological breakthroughs and grid management mechanisms.

This successful trip was the next step in a series of high level Transatlantic meetings organized and facilitated by the Renewables 100 Policy Institute dating back to 2011 that have focused on identifying areas of mutual interest and opportunities for bilateral support between California and Europe on meaningful climate and clean energy goals.

One of the highlights of the 2014 tour was a dinner in Berlin hosted by Dutch TSO TenneT and organized by Renewables Grid Initiative (RGI), a European non-profit organization with a mission to facilitate 100% grid integration of renewable sources and with extensive experience bringing key players together in Europe. Out of this collaboration, the Renewables 100 Policy Institute and RGI agreed to work together on organizing the recent 2015 tour to California as a next step in building on this critical dialogue.

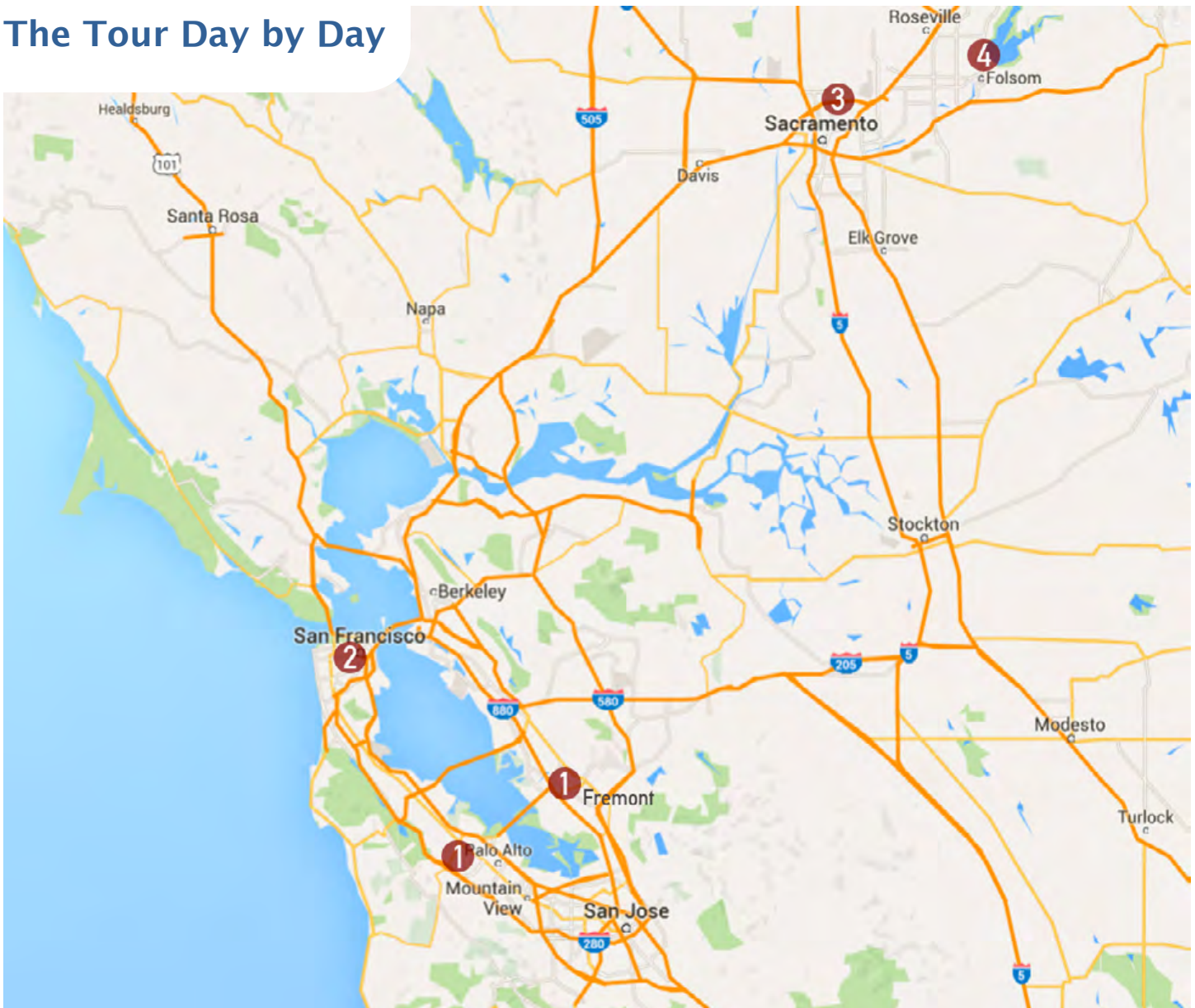


² See: <http://www.renewables100.org/en/programs/leadership-education/examples/germany-california-learning-and-collaboration-tour-2014/>

II. DETAILED REPORT

The following is an in depth look into the major events and discussions that took place day by day on the tour, the key takeaways resulting from these discussions, and conclusions about how building on this dynamic international exchange would impact participant – and global – efforts to decarbonize energy systems.

The Tour Day by Day



Tesla Manufacturing Facility

A living demonstration of 21st century battery and electric transportation innovation in action.



The Delegates spent the first day of the tour in Silicon Valley, where the morning was spent at a much anticipated visit to the Tesla Motors factory in Fremont. The production site of the Model S and Model X, the Tesla factory is a living demonstration of battery and electric transportation innovation in action.

The facility is also emblematic of the energy transition from the old system to the new. With historic roots in the traditional automotive industry, the current workforce and way of doing things are firmly planted in 21st century clean energy and information technology. Originally built in 1962, the facility was bought by Tesla from Toyota and General Motors (GM) in 2010. Underscoring that the energy transition is a job creator, the tour participants learned that Tesla's growth trajectory over the last 6 ½ years has already seen Tesla's employee numbers soaring from a few hundred to 11,000 worldwide.

Demonstrating that digital and information technologies are informing the new energy system in new ways, many employees at the factory notably are culled from Silicon Valley rather than the automotive industry. Delegates also got to hear about the company's plans to soon open its million square foot "gigafactory" for batteries outside Sparks, Nevada, which is projected to permit vehicle production to ramp up to half a million per year by the latter half of this

The Delegation was glad to see Europe-California collaboration on technology solutions on display throughout the factory, with presses from Italy and Germany and giant German robots capable of repeated and ongoing accuracy of about two times the width of the average human hair.

decade. The facility is also expected to enable Tesla's plans to expand into batteries for energy storage, which the Delegation got to glance being tested on the tour.

The facility was a reminder that the energy transition is not just revolutionary but evolutionary. The tour guide explained that to inspire consumers to adopt electric mobility, Tesla has aimed to make vehicles that are not just cleaner but fundamentally better. This has included incorporating the company's well-known design features, along with a safety profile that has earned the Model S the lowest possibility of injury in National Highway and Transportation Safety Administration testing history.

The Delegation had the opportunity to see Europe-California collaboration on technology solutions on display throughout the factory, with presses from Italy and Germany and giant German robots capable of repeated and ongoing accuracy of about two times the width of the average human hair. Notably, Norway is the largest market for the Tesla vehicles outside of the US and surely will be among the first locations to see the Model X that Delegates got to see coming off the conveyor belts in real time.



Silicon Valley Luncheon Discussion

Next, the delegation headed to Palo Alto for a luncheon discussion on the cross-section between Silicon Valley technology development and the energy transition, joined by representatives from search engine giant Google, solar photovoltaic manufacturer and designer Sunpower, high efficiency generator startup Etagen and others.

Renewables 100 Policy Institute Founding Board Chair Angelina Galiteva opened the conversation with the observation that 100% renewable energy targets, thanks in part to leaders across sectors like those in the room that day, have evolved in recent years from bleeding edge to the norm – and those present at the discussion, are among those writing the playbook. Galiteva added that while solutions must certainly involve electricity, other sectors are also being incorporated, including transportation, the gas distribution network, telecommunications, and information technology. Multi-sector discussions such as this one, she emphasized, are vital to understanding the most reliable, efficient and economical pathways forward.

In the discussion that followed, three points of interest dominated the discussion:

- the rapidly changing mindset on what is needed to integrate renewables into the electricity grids
- why a leading search engine company like Google is committed to renewable energy
- interest in storage to grid markets

Revolution in views on how to integrate renewables into the power grids

Until recently, it was pointed out, the prevailing wisdom was that it would be hard to get to high penetrations of renewable electricity. It was common to hear that we would need a 1 to 1 ratio of intermittent renewables, like wind and solar, and dispatchable conventional generation, like natural gas, in order to have a stable grid.



But in the last few years, a substantial shift in this view has emerged, with increasing recognition that not only are large amounts of renewable power up to 100% possible, but non-traditional, non-fossil fuel based solutions can help overcome the technical integration of very high percentages of intermittent renewables at both the distribution and transmission grid levels.

After 100 years of thinking that utilities would provide supply to meet customer demand, one participant noted, it is now evident that that we can shift demand to meet the available supply, with that supply coming increasingly from intermittent renewable resources.

Several participants agreed that this evolution has been helped along by the fact that the traditional wall between the transmission and distribution grid systems has begun to crumble. Yet the barriers between the two systems must be further removed. One challenge in California, noted one participant, is that transmission grid operators are not currently getting enough data. Other improvements that were recommended for the state were to further develop the Energy Imbalance Market and regional collaboration.

Why an internet search engine company like Google is focusing on renewables

Over the past few years, 100% renewable power procurement targets have become a trend in the IT sector, with many major companies like Facebook, Apple, among others now on board. A pioneer among them is Google, which first announced its goal to be carbon neutral in 2007 and has been working since then toward transitioning to 100% renewable power.

Why did the internet giant become so interested in going in this direction? Company representatives shared with Delegates that this long held interest in renewable energy is rooted in three factors: **1)** Google is a large energy user; **2)** Google is a large energy investor; and **3)** Google is a developer of products and services that are closely aligned with its core internet businesses.

This interest translates to major global investment. Not only has the company spent more than \$2 billion on renewable energy finance, but it was also an early supporter of the solar industry and tax equity for solar development, and has invested in one of the largest solar power plant in the world, as well as the largest wind projects in the United States. The Delegation learned that on that day, Google additionally announced that it would be supporting Vestas in a consortium for a 310 MW wind farm in Kenya that will be the largest wind farm in Africa. This will build out a 266-mile transmission backbone that other renewable energy projects, such as geothermal plants, can use.

Google has invested in renewable energy not just because it is the “right thing to do,” but also because it makes good business sense.

As an added benefit, the company can lock in prices for the long term and avoid exposure to fuel price volatility. The company also likes to engage in transformative projects that catalyze others to follow.

Google has a company wide goal to reach 100% renewable energy procurement, a target they aim to reach by adding to renewable power supplies rather than diverting electricity that would otherwise go to other consumers. The company has also committed with the White House to triple its renewable electricity purchasing by 2025.

How are these plans shaping up in terms of concrete metrics of installed renewable energy? So far, the company has reached procuring 37% of its power from renewable source by the end of 2015, making Google the largest corporate purchaser of renewable power in the world. This includes over 2.0 gigawatts of wind that has been procured for their data centers. Renewable power that is sold into the market is separated from its Renewable Energy Credits (RECs), which are applied to their load elsewhere.

It was shared that Google is looking for further opportunities to use its unique position in technology and assets to drive change in the energy marketplace. Among the new products efforts, Project Sunroof was recently launched, a tool that uses existing Google imagery to help customers identify whether their roof is good for solar. This is done by analyzing the shade on the roof and then the financials of solar installation.

The project came out of seeing an opportunity to help customers alleviate some of the friction that stands between customers and solar power by providing information. In the US, it was noted, most people want solar but are unaware that it is a practical solution for them. Google believes the company can help citizens become aware and to identify what solutions will be most cost effective for them.

At the time of this event, Project Sunroof was in three test markets in the US – the Bay Area and Fresno in California and Boston, Massachusetts. Delegates were naturally curious whether the project will come to Europe. The plan is to test the initial locations and gauge from there if it makes sense to expand. By the end of 2015, Project Sunroof had become available in 10 states.



Interest in storage to grid markets that enable bilateral participation in the market

Delegates were curious to hear the level of interest among the Silicon Valley players in the room in the storage to grid market and enabling bilateral participation in the market, where customers can buy and sell power. Strong interest seemed clear. Sunpower, which has traditionally focused on distributed and large scale solar photovoltaics, is already working on a next generation of products that address energy storage and energy management capabilities, with pilot projects on the residential scale underway.



Rooftop Solar, California ISO Headquarters, Folsom

Visit to Stanford University



The Delegation spent the remainder of the day at Stanford University, which hosted a three-hour roundtable discussion attended by top energy experts from their esteemed campus, by representatives from California's energy agencies, and by members of the utility sector.

The event began with a welcome by Dian Grueneich, Senior Research Scholar with Stanford University's Precourt Energy Efficiency Center and the Shultz-Stephenson Energy Policy Task Force (and a Commissioner Emeritus of the California Public Utilities Commission), followed by open discussion and brief presentations by the Stanford team and the Delegation. There was overwhelming consensus that this rare meeting of leading minds on energy related issues ought to lead to ongoing dialogue on issues related to grid integration of high shares of renewable electricity.

Discussion

During their open discussion, the roundtable participants engaged in a wide range of topics and questions. The following are some of the key concepts and concerns raised:

From problem to opportunity - Whereas integrating high penetrations of renewable electricity was once considered a problem for grid operators to ensure robust, resilient, safe management, it is now more a series of issues and opportunities.

All resources are not created equal - It is critically important that resources be put in order of merit, according to environmental value and also according to which ones can be relied on to be usable at the right time.

Transmission vs. distribution grid - There is a debate in many regions between whether the future needs the transmission grid “backbone” or a system focused on capabilities on the distribution grid. Most participants appeared to agree that it is not an either/or, and that transmission grids will remain needed to guarantee quality, adequacy, resiliency, and security. Transmission grid operators and distribution grid operators, however, do need to have clear roles. By laws of physics, noted one participant, voltage control is easier on higher level transmission operations, whereas the lower voltage level can steer electricity and interact with certain ancillary services.

Too much of a good thing - How to manage over-generation while minimizing curtailment is a challenge that will grow as more renewables come on line. Related to this, we are approaching a world where there is so much renewable generation that electricity could be free. What type of consequences will that have? For example, why be energy efficient, if electricity is free? How will we refinance projects and raise funds to implement complementary technologies like grids, storage, and heat pumps?

Data must be transparent - Regulated entities should not own or control access to data, which can hinder cost-effective, realistic energy planning and grid operations. Rules must be changed to provide access to data, consistent with customer privacy concerns.



How to solve problems when electricity demand isn't growing and take advantage of flexibility in customer loads – Forecasted electricity demand in California and in parts of Europe is flat or falling for the foreseeable future. Significant increased efficient in building energy usage is critical for climate change, but the utility (and grid operator) business model must evolve from a commodity based revenue system to support deep energy efficiency.³ And, most renewable power is from intermittent sources with a lower capacity factor than traditional generation. One of the challenges - and solutions - is fostering much deeper price responsive demand than we've seen so far. While for a century, we've had only supply to create equilibrium, now we need to look at supply *and* demand. California has focused on supported demand response for over a decade, but the penetration of demand response among customers is still limited. Factoring into the challenge in the US is jurisdictional tension between the Federal Energy Regulatory Commission (FERC), the federal agency that oversees the transmission network, and the Public Utilities Commissions (PUC's), the state regulators that oversee the distribution grids, regulate investor-owned utilities, and implement most of the US clean energy policies (since these policies are set currently at the state level).

Challenges to bringing new grid solutions to the marketplace - Creating a viable technology business that enables grid integration of renewables carries major challenge. One is creating awareness among leaders, many of whom have been dealing with the traditional models for decades. A second is "death by pilot," which can stymie proven technologies in the testing phase for too long. A third is that utility business models are sometimes not set up to capitalize the expense of new solutions, even if they are cheaper. And fourth, the gap between technologists and the business world is big, and education is needed to bridge this gap.

Invest in human capital - It is critical to invest in human capital, including the next generation who must carry out many of the ideas being discussed.

Regulatory barriers must be overcome - If we don't get policy frameworks and regulations right, the right business models won't fly. We're now in the situation where low cost technology is increasingly there, but our regulatory system is still in the last century. It was noted that some financial experts polled consider regulations the biggest risk to the new energy market. However, government is rarely that nimble and quick. How do we speed up the process?

Prosumers must be empowered - We are living in democracies. That means what we are doing needs acceptance in the population. People support the Energiewende in Germany because they are part of the new market. A lesson learned is that we need to give normal prosumers (those end use customers who have the ability to buy/sell in markets), a chance to profit. At the same time, we need to understand how to run a system with many generators instead of a few. And, if there are increased profits to prosumers, we need to significantly increase the efficiencies in the system, in order to avoid unjust price increases to those who are not prosumers.

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In California, energy utility sales are already decoupled from earnings to encourage efficiency.
See: <http://www.noel21.org/docs/Decouplinglowres.pdf>

Women in particular are key drivers - Included in the focus on prosumers must be a focus on women, who have the potential to be important drivers of the energy transition. Women around the world make the majority of household decisions on purchases and handle the energy bills. In developing countries, there is ample evidence that putting development of rural solar rooftop projects in the hands of women helps ensure success

In the US, one of biggest obstacles is money in politics - The incumbents are powerful opponents with well-funded, coordinated campaigns that can overwhelm the political process to their benefit – even in progressive regions.



Summary of Presentations

Below are summaries of the six presentations shared by representatives from Stanford, highlighting some of their important energy related research, and by two Delegates, providing perspectives on the current and future solar PV market and Germany's Energy Transition.

Presentation 1: **Dr. Sally Benson**, *GCEP, Executive Director*

Overview of Stanford's GCEP, Precourt Institute for Energy, Bits & Watts Program

To help set the context for the event, Dr. Sally Benson offered an overview of the history of three of Stanford's energy programs represented at the roundtable: The Global Climate and Energy Project (GCEP), Precourt Institute for Energy, and the Bits and Watts program.

In 2002, Stanford University, which has long been engaged in energy-related research, initiated the Global Climate and Energy Project, a collaboration between academia and international energy industrial leaders who decided that US energy research had languished. The project aimed to jumpstart research related to the energy transformation, which has resulted in a broad portfolio of research programs.

In 2009, the Stanford Precourt Institute for Energy was established to serve as the umbrella organization for all energy related research across the campus, including environmental sustainability, energy access, economy and security.

The Institute has three areas of emphasis: advancing knowledge through new technologies and policies; accelerating adoption of these solutions through partnerships with multiple stakeholders, and outreach to students.

The Institute is launching a new initiative called "Bits and Watts" with the idea that integrating energy and information technology will accelerate modernization of the electrical grid, which in turn will enable increased adoption of distributed renewable resources and demand side management.

Presentation 2: **Ram Rajagopal**, *Stanford University*,

Assistant Professor of Civil and Environmental Engineering, Director of Sustainable Systems Lab

Detailed View of Bits & Watts Program

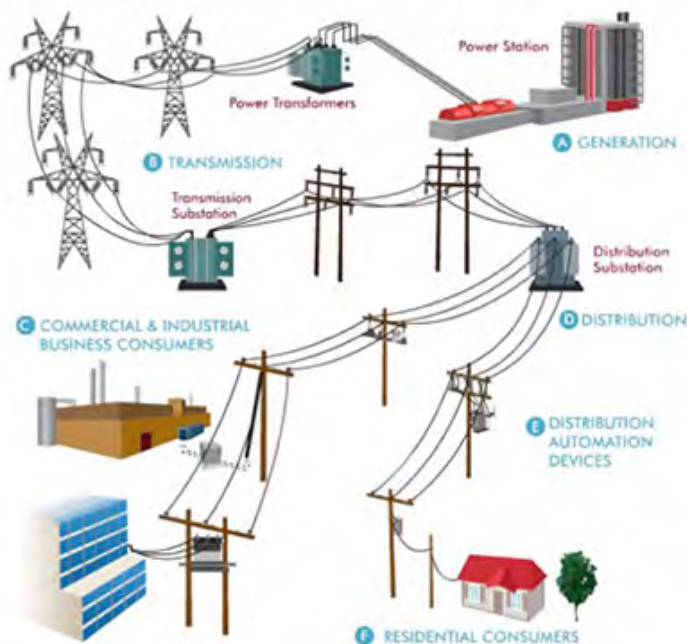
Assistant Professor Ram Rajagopal shared a more detailed view of the Bits and Watts initiative, including trends and drivers informing the initiative, as well as the program's goals, areas of research focus, and efforts to advance education and leadership.

Trends & Drivers

He started out by stating that “today’s grid is a Tesla-Edison grid” in which most generation is centralized, and the idea was that power was moved in one direction through transmission lines to consumers and industry. When this idea was conceived 100 years ago, there was no solar PV, wind power at scale, modern day storage, controllable load opportunities, internet, power electronics, or fast electric vehicles.

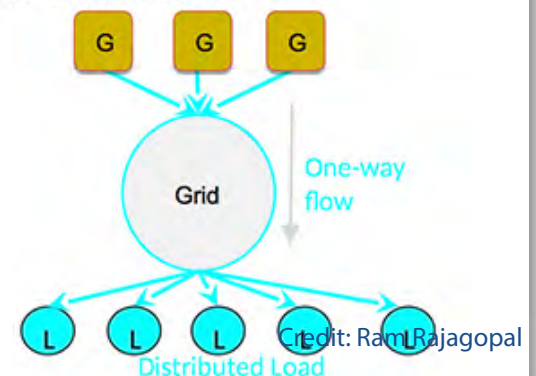
Today all those technologies are available and getting cheaper. Utility scale wind generation is at cost parity or cheaper than coal and natural gas in the US, solar is reaching the cost of natural gas, and storage prices are declining at faster rates than predicted by the US Department of Energy.

What is the current paradigm? Tesla-Edison Grid



100-year old architecture!

Grid 1.0: Centralized non-intermittent generation follows load



Rajagopal said that the old idea can be thought of as the “1.0 grid,” which is characterized by non-intermittent sources and centralized power management. Today’s technologies are calling for a “2.0 grid” that involves lots of intermittency and decentralization.

Trends in the new era include:

- Declining technology prices
- Power electronics are becoming more compact. There are efforts among Stanford researchers to bring the 2 kilowatt inverter down to as small as the size of an iPhone.
- The old grid is past its prime in age. It was designed for a 25 year lifespan, whereas it is already 42 years old.
- Security issues, like cybersecurity and physical security, that are critical to address to ensure grid resiliency
- Various policy goals related to renewable energy, efficiency, demand response, climate and other energy related issues
- The ever increasing threat of climate change

In this dynamic context, one main challenge, Rajagopal said, is to figure out how to reduce the integration cost and increase scaling of solar, storage and smart demand technology to enable 50%+ renewables by 2050. To achieve this, the initiative aims to answer four essential questions:

- How to enable a more resilient and secure electricity system by integrating the grid edge?
- How to enable consumers to be active participants in the grid edge?
- How to help markets support 50%+ renewables?
- How can we offer solutions for access to affordable energy?

In this new paradigm, there is a world of new opportunities for information technology – bits – to interact with electricity – watts to enable new solutions. For example, there are smart thermostats, and onsite solar can be combined with storage and smart meters, all of which can communicate through the information network with utilities.

How to coordinate all these new ways of doing things is a challenge. Rajagopal mentioned that there are some, including researchers at Stanford, who think we may need a cloud system that can measure and control this demand side system, as well as the distribution network, and link it via the cloud to the transmission grid control systems and markets. Whatever the solutions, a priority must be coordination, synchronization, and extraction of services from that “grid edge.”

In conclusion, he stated that the Bits and Watts has two key messages:

- We have to figure out how to reduce costs and scale up technology to reach a majority renewable electricity system
- The big picture vision is merging the power and information networks.

Every viable solution Bits and Watts looks into must have three important characteristics.

It will need to:

- answer to cost and scalability
- be open source and available around the world
- engage all the stakeholders, not just to gain funding or research consumption, but also to help inform and shape these solutions. Among these stakeholders, regulators and other key players that implement the system must be on board.

Presentation 3: Sila Kiliccote, Staff Scientist at Stanford Linear Accelerator Center (SLAC), Demand Response Expert at Google

Context and Priorities for Energy Related Research at Bits & Watts

To begin with, Kiliccote explained, it is important to know the context in which energy related research is taking place, including the key bodies that influence electricity grid technology and markets in the US.

US Entities with Jurisdiction Over Electricity Issues

Federal

- National Institute of Standards and Technology (NIST) - tasked in 2009 to deliver smart grid interoperability standards
- National Energy Research Council (NERC) - provides reliability standards and reporting
- Federal Energy Regulatory Commission (FERC) - oversees federal policies and laws governing wholesale market operations
- North American Energy Standards Board (NAESB) - an industry forum that develops and promotes standards in the wholesale and retail power and natural gas markets

State (partial list)

- *Public Utilities Commissions (PUCs)* - regulate the utilities
- *Independent System Operators (ISOs)* - along with transmission grid operators, run structured markets and engage with customers and other players that bring grid related services into the wholesale and retail markets.

Kiliccote also shared the changing grid landscape that is also key to the context in which the Research Trusts are working.

Examples of how the grid landscape is changing include:

- rise of solar and wind power
- customer side solutions that make power flow both ways
- storage
- new ways of collecting more data from the grid, such as phasor measurement units (PMUs), hundreds of which have been installed along the Western Interconnection
- smart meters and sensors.

Examples of new challenges that Silicon Valley and Stanford are addressing:

- *Data management* - Traditional grid operators on the utility side, she continued don't know how to deal with all this data. This is where Silicon Valley can help, and Stanford is aiming to bring that world's capability together with the power industry.
- *Market management* - The markets are also changing. As more intermittent renewables come on line, better algorithms and other new tools are needed. We also need to figure out how to put a value on all these different resources to enable their deployment.

A variety of research projects have been undertaken in Stanford's Bits and Watts Research Trusts program to tackle these challenges.



Examples of research projects that address new challenges include:

- projects that focus on how utilities can handle the large new amounts of data
- new, low cost sensing technologies for distribution grid that enable faster integration of new technologies
- plug-and-play integration platforms

Looking to the future, Kiliccote emphasized that most important will be understanding the industry and other stakeholder needs through collective engagement, and strengthening education to build the next 30 years of energy leadership by providing a comprehensive syllabus in multiple areas, including power systems, data analytics, controls, power electronics design, testing, and implementation, market issues, and technology trends.



Presentation 4: Dr. Jimmy Chen, Stanford Energy 3.0, Managing Director

Dr. Chen is Managing Director of the Stanford Energy 3.0, which aims to forge energy-related exchange and collaboration between companies and Stanford graduate students and faculty.

Chen shared that dozens of well-known companies were founded by Stanford faculty and Alumni, and the school has a long history of engaging with industry.

Companies from Stanford

Thousands of companies founded by Stanford faculty and alumni



Stanford | Precourt Institute for Energy

To build on this tradition, the Precourt Institute for Energy funds both sponsored research, which is scripted and formal, and affiliated program research, which is flexible and unrestricted. The types of programs supported range from strategic corporate engagements across multiple disciplines, to programs that are committed to a particular technology area, to individual projects, to startup companies.

Presentation 5: Prof. Dr. Eicke Weber, Fraunhofer Institute of Solar Energy (ISE), Director

Prof. Dr. Weber offered his views on the development of solar technology based on his perspective as Director of Fraunhofer ISE, Europe's largest solar energy research institution.

Weber asserted that solar PV, already of significant importance, will be a main pillar of the energy transition far into the future. The International Energy Agency, he noted, already predicts that 5000 GW solar power will be installed by 2050.

In the last 5 years, he pointed out, there has been a production overcapacity, and prices fell. In Southern California, Weber stated that solar electricity costs 5 cents/kwh and less, and in Germany, the cost is about 8 cents/kwh. He predicted that 2016 will be turning point and that the market will grow to beyond 50 GW.

“While there has been a great deal of advancement in solar PV in recent years, we are only at the beginning...2016 will be a turning point.”

Weber explained that in Fraunhofer ISE's study of how Germany's grid system can work with 80% renewable electricity and 50% renewable total energy, they concluded that there will be major overcapacity, which means the electricity can be fed into battery storage and hydrogen production, among other uses. This raises the question of how to develop the grid and market conditions accordingly.

Weber ended his remarks by emphasizing that the world is becoming engaged not just in an energy transition but a transformation, in which the fundamental process is to replace fossil and nuclear based energy with renewables.



Presentation 6: Dr. Harry Lehmann, *German Federal Environment Agency, General Director*

Dr. Lehmann is a General Director at the German Federal Environment Agency (Umwelt Bundesamt), where his Division is tasked with finding a path to a sustainable energy and climate future in Germany and the world.

He opened by explaining that Germany's energy transition – commonly known as the “Energiewende” – may have only in recent years become well known in the US, but has a long history dating back to the oil crisis in the early 1970s. The crisis prompted serious discussion, not only in Germany, but also throughout much of Europe about changing the energy system. By the end of the 1970s, climate change had also begun entering the dialogue, and by 1990, phasing out nuclear power and advancing renewable energy entered the discussion. In 2000, the feed-in tariff law created by parliamentarian Hermann Scheer was enacted, with an updated version passed in 2004, which catalyzed major growth in the renewable electricity sector and inspired dozens of other locations around the world to adopt feed-in tariff based policies.

By October 2015, Germany reached a share of about 30% renewable power in the grid, mostly with a combination of biomass, wind and PV, which grew faster than the others, but is now slowing down. Germany is committed to reaching 80-100% renewable electricity and at least 60% renewable energy overall by 2050, with interim milestones along the way.

One current advantage, stated Lehmann in what would be come one of the recurring themes of the week, is that wind and solar are now cheaper than other technologically viable options. Clean energy is also a major economic driver, with nearly 370,000 jobs in the field in Germany, the majority focused on the export market.

Looking ahead, the German Energy Agency (dena) has confirmed the opinion of grid experts such as those among the Delegation, that further development of wind power in northern Germany and off the German northern coast will require cross-regional extensions to the extra high voltage transmission network.

Future developments also include the need to include making buildings more efficient, adopting storage technologies and making sure other energy sectors are covered in the transition to renewables, including difficult industries like aviation.

“To achieve 80% greenhouse reductions (below 1990 levels by 2050), clearly Germany will need to transition to 100% renewable sources in at least the electricity sector. To cut emissions by 95%, the whole society will need to change.”

It is also critical, Lehmann emphasized, for Germany not to lose sight of its long term targets for energy and climate, the most important of which is to reduce greenhouse gas emissions by 80-95% below 1990 levels by 2050.

“What does it mean to decarbonize society?” asked Lehmann, showing a slide of the G7, including German Chancellor Merkel, declaring their commitment to decarbonize their economies by the end of this century.



Understanding that it starts with reaching a 100% renewable target at least in the electricity sector, the German Federal Environment Agency has examined various scenarios for how Germany could achieve this target.⁴ The analysis spanned a gamut of options, from decentralization to super grids, from small to large installations, from large corporations to prosumers driving generation, from local energy independence to regional networks to international cooperation that includes long distance transmission.

What the agency concluded was that every one of the scenarios is technically possible, but each has a different societal and economic impact. For example, for local energy independence, there must be far greater intelligence in buildings, while for regional approaches, we have to understand better how to connect to producers and build out storage, and for international scenarios, transmission grids have to be connected between countries. The agency has been in favor of emphasizing a regional approach, in order to maximize use of existing infrastructure, which could save resources and optimize efficiency. However, Lehmann shared, a hybrid is likely necessary.

What are some specific approaches to stabilizing the grid in a 100% renewable electricity system that has high shares of intermittent solar and wind power? Biomass is a 24/7 source, and Germany has more than 8000 anaerobic biodigesters installed, as well as biomass for heating. However, in the end, the German Federal Environment Agency determined that biomass, while not to be neglected, can still only cover a small share of the electricity portfolio because to be sustainable, it can only come from organic waste, which is a significant but not massive supply.

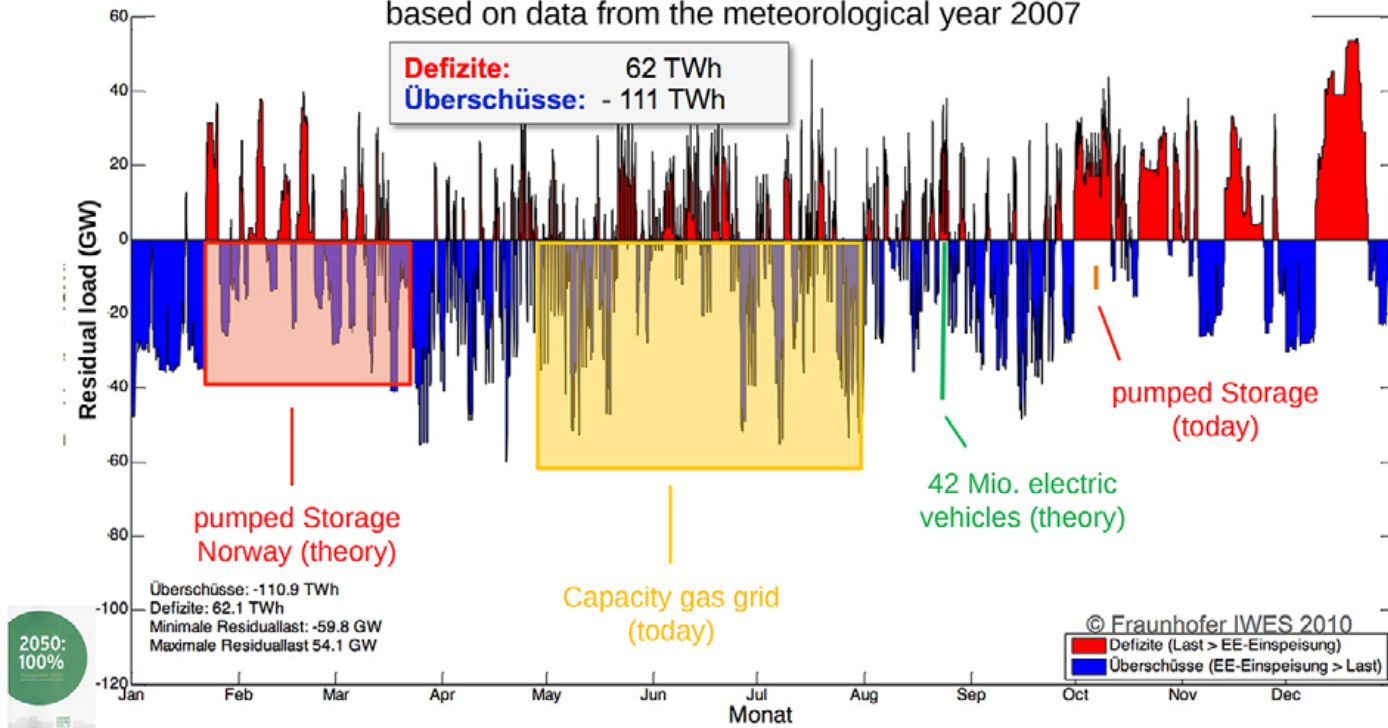
To better understand how to maintain grid stability, Lehmann said, we have to look at the electricity system's behavior using real time data. The agency worked with Fraunhofer IWES to take real time daily meteorological data from 2007 and use it to compare four different storage options for stabilizing a 100% renewable electricity system in 2050: These four options are 1) pumped storage from Norway, 2) the German gas grid for storing methane and hydrogen made from renewable over-generation, 3) making all 42 million passenger vehicles electric, and 4) German pumped storage. A combination of these solutions, along with others like storage batteries, will probably end up being adopted, but Lehmann said that it was very interesting to see the study reveal the massive potential for renewable solutions that use the gas network, like power to gas.

⁴ See 2050:100% - Energy Target 2050: 100% Renewable Electricity Supply, German Federal Environment Agency (UBA); 2010 <https://www.umweltbundesamt.de/sites/default/files/medien/publikation/add/3997-0.pdf>

Storage Size Comparison

Speicher im Größenvergleich

Total residual load (with load management and pump storage) in the year 2050, based on data from the meteorological year 2007



In the end, whatever archetype or archetypes are chosen to transition to 100% renewable energy, there will also be more electricity in other sectors, that is, heating and transportation. "It's crazy to throw away electricity," said Lehmann. Therefore, solutions that make use of over-generation of renewable power, like power to gas and power to heat, should play a significant role. Power to gas, he pointed out, could also help solve the problem of decarbonizing aviation. Lehmann thinks it's a mistake to plan on using only advanced biofuels, which to date have been favored by the industry, because they will not be able to entirely replace fossil fuels for aviation without resource constraints and environmental problems.

California Public Utilities Commission (CPUC) Roundtable



With one of the dominant themes at the Stanford discussion being the importance of speeding up electricity related regulations, there was no more relevant place for the Delegation to spend the morning of Day Two of their tour than in San Francisco with the CPUC, California's regulator of privately owned electric companies. Joining the Renewables 100 Policy Institute as co-chair of the roundtable was CPUC Commissioner Michel Florio, one of five Commissioners appointed by the Governor. Participants also included California Energy Commissioner David Hochschild and senior staff from the CPUC and the California Independent System Operator (CAISO).⁵

The first part of the meeting was dedicated to briefings from both sides of the Atlantic, two by CPUC staff, and three by European Delegates focused on regulatory, technical, market, and policy issues. This was followed by open discussion. The following is a summary.

Briefing 1: CPUC Staff - *Background on CPUC & California Electricity Landscape*

To start off, CPUC staff offered a short history of the CPUC, which has evolved since its beginnings in 1911 as a railroad regulator to its status today as the state's main utility regulator, with jurisdiction over not only railroad rail transit, but also over privately owned electric, natural gas, telecommunications, water, and passenger transportation companies, as well as over authorizing video franchises.

Energy is a major area of focus, with more than a quarter of the Commission's approximately 1000 employees working on energy related issues.

⁵ Please see Attachment A for a description of California's energy agencies and their jurisdictions.

California Electricity Sector: Key Facts and Figures

1. **Californians pay slightly lower than average monthly electricity bills**
\$92 vs. national average of \$110
2. **The California investor owned electricity sector includes:**⁶
11.5 million customers - 32,698 miles of transmission lines - 239,112 miles of distribution lines - more than 200 electric generation units - \$23.7 billion in revenue
3. **The state has a wide range of electricity related policies and programs, including:**
safety investments - climate change - decoupled sales from revenue - energy efficiency - demand response - utility scale renewable energy - rooftop solar incentives - dynamic/time of use pricing - energy storage - smart grid - assistance for low income customers
4. **California has aggressive greenhouse gas reduction targets.**
State law (AB 32) requires California to reduce greenhouse gas emissions to 1990 levels by 2020. The Governor recently signed an Executive Order calling for a 40% reduction below 1990 levels by 2030. The state also has a policy target of reducing emissions 80% below 1990 levels by 2050.
5. **The state Loading Order prioritizes clean electricity sources.**
State policy requires that utilities procure cost-effective electricity resources in the following preferred order: first, efficiency increases; second, rate design changes like demand response; third, eligible renewable energy sources; and lastly, only if the other three are unavailable, cleanest available carbon-based power sources.
6. **California has a Renewable Portfolio Standard (RPS) of 33% by 2020 and 50% by 2030.**
Utilities are currently on track to achieve these targets.
7. **The Smart Grid Vision includes:**
integrating digital technologies, smart meters, sensors and automation, advanced communications, interactive/real-time information, and an integrated network of distributed generation, plug-in vehicles and storage.
8. **California is a frontrunner on energy storage policy and adoption.**
In 2013, the state mandated a target of 1,323 MW for utilities and other load serving entities to build, buy or contract for energy storage by 2020. At least one investor owned utility exceeded the first year target set by the CPUC.⁷

⁶ California's electricity needs are served by, in addition to the IOUs, 46 publicly owned utilities, 3 Community Choice Aggregators (CCAs), and 4 rural cooperatives. 22 Electric Service Providers (ESPs), which are non-utility entities, also offers "Direct Access" electric service to customers located within the service territory of an investor-owned utility. For a list of all electricity load serving entities in California, see: <http://energy.almanac.ca.gov/electricity/utilities.html>

⁷ In November 2013, Southern California Edison signed contracts for 250 MW of capacity, exceeded its required minimum procurement of 50MW.

Briefing 2: CPUC Staff - Maintaining California Grid Reliability with 50% RPS

Next, CPUC staff introduced Delegates to how the Commission, in coordination with CAISO and other state energy authorities, are tackling challenges and forming plans to integrate higher amounts of renewable energy into the electricity grid now that the state has recently increased its RPS to require that utilities procure 50% of their electricity portfolio from renewable energy generators by 2030.

To better understand the reliability impacts that might occur with an increase in variable renewable sources, like sun and wind, California's energy agencies have identified the following four signposts to track.

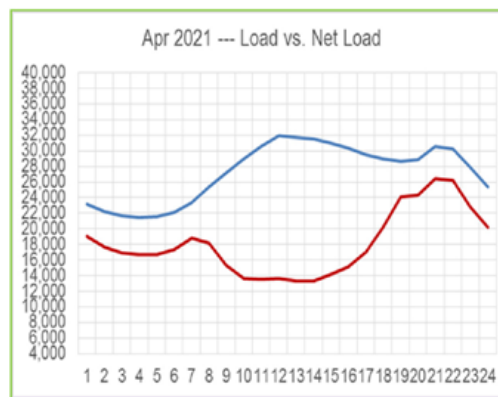
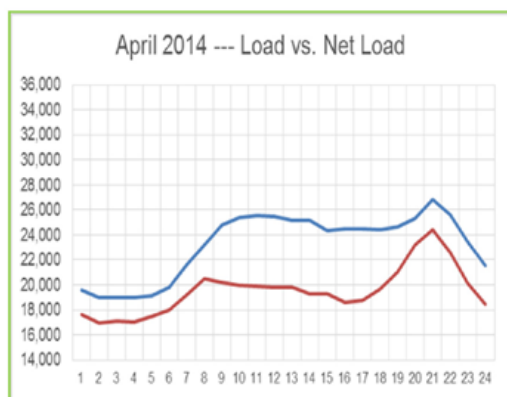
Signpost #1: Changing Shape of Net Load and Ramping Needs

The net load is the full electricity load minus sun and wind generation, also sometimes referred to as "residual load." "Ramping" is a sustained increase or decrease in the demand for electricity. Currently, the ramping need in California is less than about 6 GW in 5 hours and has been posing no significant reliability concerns. But by 2021, it is expected to increase to 10 GW in 5 hours, as more renewables come on line. This raises concern, and therefore, this changing shape of the net load and ramping requirements merit ongoing attention.



What reliability impacts might occur with an increase in variable renewable resources?

Sign-Post of Reliability—changing net-load shape and ramping needs



- So far, net load shape is not creating extreme ramping needs
- Example: <6 GW/ 5 hrs in 2014. By 2021, 10GW/ 5 hrs

Source: CAISO operational data and forecasting



Signpost #2: Over-Supply and Over-Generation

The CPUC and CAISO distinguish between “over-supply” and “over-generation.” Over-supply simply means a situation when there is more electricity capacity than needed and does not necessarily present a reliability issue, if the market can effectively deal with it. On the other hand, “over-generation” is a condition of over-supply in which more electricity is generated than the grid operator can effectively manage through markets and which must be manually curtailed, potentially impacting grid reliability because human action is required.

So far, over-generation events in California are very rare. However, CAISO modeling suggests that within a decade from now, there could be significant over-supply of solar power in the middle of the day in non-summer months, which needs to be planned for and managed. (See chart on the right below). Among the questions this possibility raises is whether continuing to run gas fired generation at present levels during non-peak demand periods will remain viable. The CPUC’s Joint Reliability Plan proceeding is examining the potential impacts of un-planned gas fired generator retirement.



Sign-post of reliability: ramping needs



- no reliability impacts related to ramping needs under present conditions.

Source: CAISO Quarterly Market Performance & Planning Forum 6/15

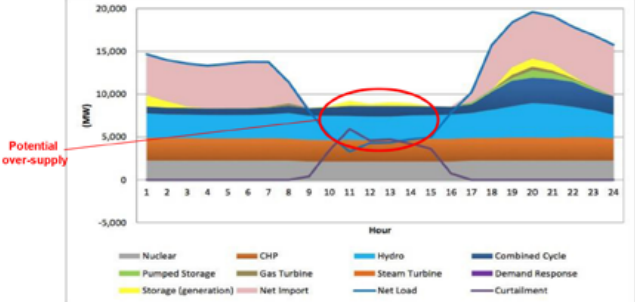


Hydropower generation may be more flexible to ramp down than what this chart assumes.



How might moving towards 50% RPS affect reliability?

Changing net-load shape



LTTP modeling conducted by CAISO showing potential net-load shape and available resources in March 2024-- 40% RPS Scenario (source CAISO testimony in 2014 LTTP)



Assumes approximately 45% of RPS generation is from solar power. Also does not account for potential significant additions to the load, especially in later years, from electric vehicles and possible increases in desalination.

Signpost #3: Renewable Curtailment

Over-supply has also raised a question regarding the impact of renewable power curtailment on reliability. The conclusion thus far is that while curtailment is an economic concern, it represents a very small proportion of renewable power generation and does not currently appear to be a reliability concern. Total economic curtailments in California in 2014 were only about 33 GWh, which represents less than 0.1% of RPS eligible generation. Manual curtailments totaled only 2.2 GWh. That said, curtailment patterns are being tracked for future grid reliability planning.

Signpost #4: Changing Need for Ancillary Services

Ancillary services are currently most often provided by conventional generators, and as the proportion of conventional generation decreases, the question arises whether renewables will be able to supply them. There seems to be ample data that renewables can indeed not only provide ancillary services, but also if market designs and policy frameworks encourage this, we can accelerate the transition to renewables and minimize curtailment. Studies by the Union of Concerned Scientists⁸ and the Western Electricity Coordinating Council (WECC)⁹ support this conclusion.

Three Approaches to Adding Flexibility and Reliability

CPUC Staff shared that there are three main spheres of activity within California's energy agencies aimed at increasing flexibility and reliability to allow for high penetrations of renewable electricity sources into the grid.

- Adjusting load to better match patterns of renewable - particularly solar - generation.
- Using transmission connected wholesale resources to balance out renewables, which can perhaps include procuring renewables differently (e.g. creating a renewables integration "adder" that could potentially result in a more diverse resource mix.)
- Improved forecasting for renewable energy source availability and for load.

Pilots

Additionally, pilots and studies are underway in California to study a number of initiatives, such as dynamic and time-of-use rates and integrating electric vehicles into the grid. Demand response (DR) has also begun to expand from being used just to modify load to participating in the CAISO wholesale energy market as a capacity supplier.

⁸ <http://www.ucsusa.org/sites/default/files/attach/2015/03/california-renewables-and-reliability.pdf>

⁹ <http://www.nrel.gov/docs/fy13osti/55588.pdf>

Creating Flexible Load

Staff also is exploring other possible ideas to add flexible load, for example:

- leveraging advanced water reuse plants
- creating hydrogen and methane out of excess variable renewable power generation
- incentive programs for customer-sited solar with storage
- load-building DR enhanced by co-siting storage
- vehicle to grid charging and discharging
- time-of-day and seasonally specific energy efficiency programs

Procuring for Flexibility

Additionally, Staff is looking into ways that procurement to could add to flexibility. Possibilities might include:

- Procuring a higher percentage of flexible resources, such as reducing use of inflexible CHP;¹⁰ retrofitting existing thermal plants to be more flexible, and adding flexible imports which don't currently participate in the market
- Somehow highly valuing diversity of renewables
- Incentivizing RPS resources to provide ancillary services, such as contingency reserves, regulation up/down, frequency and voltage support

Next Steps

As next steps, CPUC staff recommends digging deeper to understand the challenges and potential solutions more clearly. Ideas mentioned included the need to:

- comprehensively analyze flexibility needs, including what time scales they are on
- develop a range of scenarios depending on different policy and procurement choices
- analyze the full impact of and possible implementation time tables for the various solutions proposed above

¹⁰ CPUC staff points out that the biggest CHP producers in California are the oil refineries, and for their purposes, it is needed as a baseload, not a flexible resource.

Briefing 3: Patrick Graichen, Agora Energiewende

Regulatory Trends and Challenges in Moving Beyond 50% Renewable Electricity in Germany and Beyond

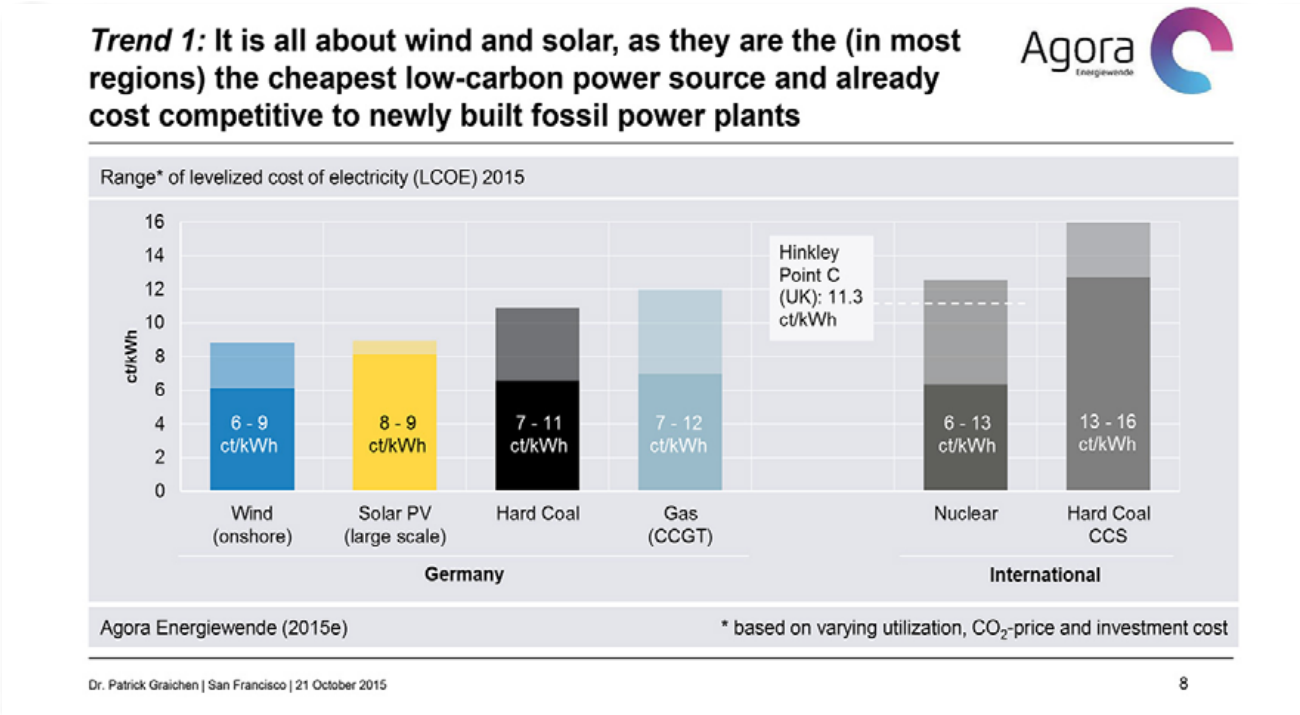
The first presentation from the European side was by Dr. Patrick Graichen, Executive Director of Agora Energiewende, an independent, non-partisan German think tank with a mission to research and analyze how to make the German energy transition work successfully.

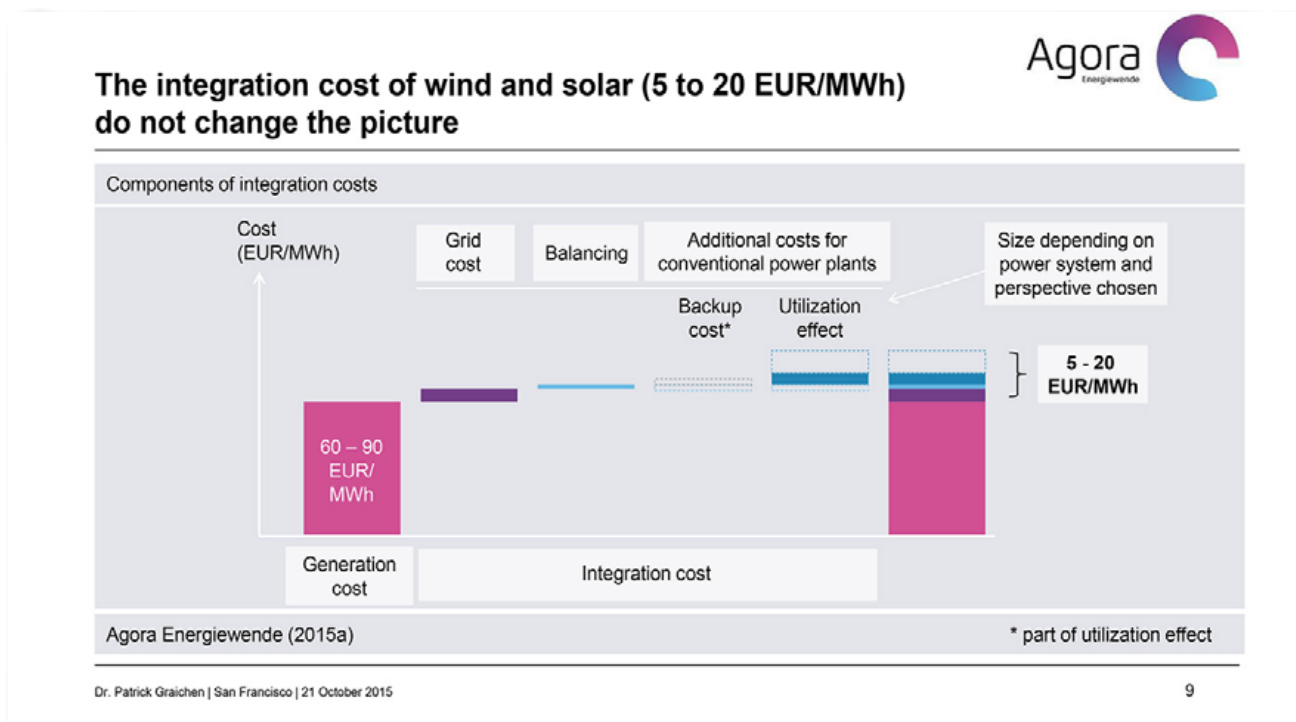
Graichen began by explaining that Germany, like California, has a 50% by 2030 renewable electricity goal. However, the country has also already agreed to a more ambitious future goal of at least 80% by 2050. So there is already considerable thought being put into how to get past 50% to the far higher targets.

“Integrating 50% is not that hard. The interesting part comes afterwards.”
– Dr. Patrick Graichen, Executive Director, Agora Energiewende

Graichen mentioned five key trends happening in Germany and elsewhere that have been identified by his organization.

- 1. **Wind and solar will drive the power market** because already, they are the cheapest low-carbon power source and cost competitive with newly built fossil power plants in much of Europe and parts of the US. This is so even with integration costs, which range from 5-20 Euros per MWh.





2. **The new power system will be based on flexibility.** Baseload capacity will be part of the load, but will no longer have the same role as it did in traditional generation. Options to allow for more flexibility are:
 - Flexible fossil fuel and bioenergy plants, including CHP. Although fossil fuel generators once denied they could operate flexibly, it has been proven that many can.
 - Grids to import and export power
 - Demand side management
 - Storage
 - Integration of the power, heat and transport sectors (power-to-heat, electric cars)
3. **Transition from centralized production to centralized + decentralized system with multiple new players.** Germany, for example, used to have about 300 power plants that provided all the electricity, and now there are about 1.5 million power suppliers because there are 1.3 million rooftop solar systems.
4. **The electricity system is increasingly based on high capital cost-low marginal cost technologies.** Meanwhile, our traditional refinancing systems are based on marginal cost pricing, which will not work in a post 50% renewable electricity scenario.
5. **Increased use of digital technologies and more toward distributed systems in the energy sector, which is fundamentally changing utility business models.** Regulators and utilities need to become partners, not impediments, to prosumers and the IT industry.



Graichen continued that with these trends come seven key challenges to meet:

1. **Building grids.** This is not just a German issue because renewable power production will not always occur where the load is. This raises acceptance issues, which are a point of serious debate in Germany and beyond.
2. **What is the exit game for existing conventional power plants?** As renewables increase, some form of energy is getting pushed out. In Europe, there is a dilemma that natural gas has been getting pushed out instead of coal because power and carbon emissions prices are such that coal is more economically viable than natural gas. The negative climate impacts are a subject of intense debate. A long-term consensus on coal generation is needed to provide the certainty required to push stakeholders in the right direction.
3. **Energy efficiency is lowering consumption, so the new energy system is being designed in a scenario where there is no growth.**
4. **Flexibility – both a solution and a challenge.** The way to overcome this challenge is to have a highly volatile, energy only market that is at least quarterly hour based with intraday trading. This has to be accompanied by a flexible, short term energy balancing and services market that has yet to be established in Europe.

5. Power market design must have four components:

- Flexibility to allow different resources to interact
- Resource adequacy - for example, Germany is now looking at peak pricing and a reserve margin for the hours when they fear peak pricing won't work. Others in Europe are going toward capacity markets.
- Investment scheme for renewables that includes long-term contracts. Otherwise, the capital costs will be an issue.
- Carbon pricing that enables the phase out of carbon intensive resources like coal, which currently needs to be revised in Europe

6. Fees and tariffs need to be revised to enable refinancing of infrastructure like grids and storage. For example, Graichen pointed out that as uptake of behind the meter solar generation goes up – which we want to see happen – how will we refinance these other necessary electricity system components? We need to find new ways of getting the funds that were previously raised via kilowatt hour usage, such as tariffs on the installed capacity which has distribution impacts. These are politically difficult challenges that must be overcome.

7. Regional integration to build further cooperation between neighboring countries and regions and to deepen European power market integration.



Briefing 4: Power Market Design and Ideas for Reform from European Grid Operator Perspective

The last briefing emphasized that among the first questions that must be asked when designing a power system are what the aim is to encourage, what challenges must be considered, and most importantly, how can it be proven that what has been designed is robust – that is, that it has succeeded in encouraging what it aimed to and survives this success.

It is also critical to plan for extreme situations, and in the case of increasing renewables, this means looking at extreme weather and climate conditions. For example, in northern Europe, an electricity system based on 50% or more renewable sources that includes high amounts of sun and wind power must factor in the possibility of long cold spells without wind and sun.

Not only does this raise vital technical planning questions, but also a question of how the market will respond to such an extreme situation. It is dangerous to make the system operator a buffer, particularly under extreme weather conditions. Instead a market ought to be designed so that it is always confronted with – that is, creating appropriate prices for – itself. To ensure this is the case, anyone who contributes to the system what is needed in a given period must earn the same amount of money; or on the flip side, anyone who does what the system does not need has to equally pay for it. In other words, every kilowatt hour, whether from a large industrial power generator or a small producer like a farmer or household, ought to be subject to the same benefits for balancing, as well as penalties for creating a grid imbalance.

As households become integrated into the market, smart meters can help optimize their power related capabilities - including normal load, solar panels, electric vehicles, battery storage, and power to heat - by allowing residential customers to adjust these items according to the needs of the grid reflected in pricing.

In conclusion, such a market that understands the real value of energy and in which all players are exposed to the same risks and opportunities can bring on a high share of renewables.

A market that understands the real value of energy and in which all players are exposed to the same risks and opportunities can bring on a very large share of renewables.

Briefing 5: Dr. Harry Lehmann, German Federal Environment Agency

Policy Perspective from German Federal Environment Agency

The last briefing was presented by German Federal Environment Agency General Director Dr. Harry Lehmann, who began by sharing that in Germany, as in California, advancing renewable energy and efficiency is primarily a means to address climate change.

As we aim to achieve an all or nearly all renewable electricity system by the middle of the century, we must tackle two major issues at the same time: How to transform the market and get people to invest in the new technologies needed, and how to actually run the system.

While it may be possible for the electricity system to be purely market driven by 2050 when the system is purely renewable, until then, there will also need to be incentives that encourage people to invest in transforming the system. This means, for example, attracting investment in renewable power installations, even when old coal plants or other traditional generators are cheaper, and finding money to adapt the grid to the new system, when it is built to run on the old system. Funds for traditional generation services may also be needed along the way for added assurance of reliability, for instance, by means of capacity markets or reserve markets.

Lehmann shared several parameters that will be important to consider as guidelines while planning for increasing the share of renewable electricity from 30 to 60%:

- The mix of markets and measures adopted must not prevent reaching greenhouse gas reduction goals.
- Grid issues must be addressed both at the high voltage and low voltage levels.
- It must be determined what smart grid technologies are needed and in what amounts.
- Electricity use will increase dramatically due to adoption of new technologies, such as digital technologies, electric vehicles, and power to heat. While this may be offset by efficiency improvements, increased efficiency is also prone to a “rebound effect” – that is, the phenomenon that even if electrical devices become more efficient, more people tend to use more of them more often. So far, there is no solution to this rebound effect.
- Regional integration is required that links electricity systems between cities and regions.
- Digitalization and access to that market can help stabilize and manage the grid.

- Designing the exit game is a political decision, which will be different for each country and region. For example, Germany will have to discuss lignite, France will have to discuss nuclear power, and Austria may have to discuss hydropower. A price on carbon will not likely be of much help because the price of carbon required to change the exit game would be higher than is politically feasible – around 70 euros per tonne, compared to current ETS pricing of less than 10 euros per tonne.¹¹
- Flexibility is probably enough to ensure stability for shares of up to 50% renewable electricity sources, but beyond that, we will need markets (for fast reaction, frequency, etc.).
- Self-generated electricity should be encouraged not hindered, whether through a feed-in tariff or other means that makes it financially feasible for small power producers to enter the market.
- As we transition to a more decentralized electricity system, grid defection in significant numbers would present a socio-economic problem – those who can afford expensive off-grid energy systems will end up leaving payment for the grid to those who cannot afford to defect. Therefore, grid defection in significant numbers ought to be prevented.

Discussion

The following were some of points made in the open discussion that followed the briefings:

California is helping to lead a major change in the US energy and climate debate.

While the European Union has been ahead of United States on the climate debate, change is occurring in the US, and California is at the forefront of this change.

On the national front, Americans are becoming less skeptical that climate change is happening and being caused by humans.¹²

Also underscoring a radical transition in the American energy outlook, four years ago, four companies with a combined value of nearly \$40 billion provided most of the coal in the US, and since then, their value has declined 98%, representing the steepest decline in the history of the US energy industry. The percentage of coal in the national electricity mix dropping in the double digits. This is in part the result of natural gas production and federal policy on emissions, but also of California's leadership, such as the state's ambitious renewable energy, efficiency, and climate programs, its moratorium on new coal plants, and its biggest cities' commitments to phase out coal over the next ten to fifteen years.

¹¹ For comparison, the price per tonne of carbon on the California emissions trading market was similar, at approximately 12 USD, in October, 2015, according to data compiled by the Climate Policy Initiative: <http://calcarbondash.org/>

¹² For example, polls by Yale and Gallup show that Americans' concern about climate change is on the rise, and most Americans believe humans are causing climate change. See: http://www.gallup.com/poll/190010/concern-global-warming-eight-year-high.aspx?g_source=CATEGORY_CLIMATE

In addition to California's 50% RPS, the state also gets about 10% of its power from large hydro, in addition to being America's biggest market for rooftop solar, with about a half million systems, thanks in part to Germany's leadership. More people work in the solar industry in California today than in all the state's three investor owned and forty-three public utilities combined.

The state also is the only one in the nation to have set a specific goal for new distributed generation of 12,000 MW between 2010 and 2020, of which about half has been installed.

"Six years ago, California seemed to have less a clear idea on where to go with its energy transformation. That has changed, and there has been an impressive progress." – Edouardo Zanchini, Vice President, Legambiente, Italy

California is beginning to expand from standard to "smart" solar.

Standard solar is south facing with no smart inverter, whereas "smart solar" is in many cases now west facing, which is given a higher incentive by California Energy Commission funding because while it generates 20% less power on an annual basis, it generates 55% more power from 2 to 8 pm when the grid needs it.

Smart inverters could have made it more possible for solar to backfill the unexpected loss of voltage support and other ancillary services caused by the unexpected 2013 shutdown of the San Onofre Nuclear Generating Station in Southern California.

Adding smart inverters that can adjust voltage further helps the grid maintain stability. There are now safety standards in place for using smart inverters, but economic incentives need to be established to encourage customers to turn them on and off as needed.

Perspectives on cost-effective solutions for renewables curtailment

While renewables curtailment, as mentioned, is not presently a real reliability issue, it is an economic one, and policy frameworks and markets need to design better economic incentives to address it.

In the U.S., production tax credits for wind present a challenge for curtailment because under that policy framework, wind generators make their money when they generate electricity and, therefore, do not like being curtailed.

What about storage as a cost effective approach to curtailment? While California has ambitious storage targets, storage has so far not been as much of a priority in European energy transition policy-making. This is true despite far higher curtailment numbers in countries like Germany, where as much as a terawatt hour of renewable is curtailed a year, and legislation will require planning for up to 3% curtailment in the future.

The reasoning behind the European viewpoint is that storage is the most expensive solution, so there is a focus on cheaper options, such as grid extensions that connect high renewable penetration areas to areas without high penetration. Or when CHP is a must-run capacity, heat can be made with the electricity to add to its economic value.

The fact is that storage, while an important technology in the overall energy transition, is also expensive today in California, and the cost is being passed on to ratepayers via general rates. Some Californians acknowledged that this is illustrative of the state's tendency to make energy policy with a piecemeal approach, in which the goals and rationales of the programs don't necessarily mesh perfectly, even if they've succeeded in helping the state reach many ambitious goals and in making the California a frontrunner in the country on climate and clean energy.

CAISO staff added that from their standpoint, expanding the regional market is the lowest cost solution to addressing the curtailment issue. Whereas the CAISO currently operates more or less as a California balancing area, they have a real time market expansion that is bringing in other Western areas. In November, 2014 a voluntary energy imbalance market (EIM) service became available to other grids operating in the West as a way to share reserves and integrate renewable resources across a larger geographic region reliably and efficiently.¹³ There is an aim to grow that into a day ahead market, so that when there are over-supply conditions of renewables, that electricity could be exported.

The second low cost solution on which CAISO is focusing is finding ways to use renewables to integrate renewables, that is, having renewable power plants adjust their power output as demand for electricity fluctuates throughout the day. CAISO shows that curtailments are dramatically reduced as a result. After this low hanging fruit is picked, CAISO staff suggested storage can be added as needed.



¹³ For more details on the EIM, please see: <https://www.caiso.com/informed/Pages/EIMOverview/Default.aspx>

Both California and Europe need to pay closer attention to longer term, transparent planning.

In California, the way incentive policies and market designs are currently set up may be encouraging what the state wants to see now, but not necessarily what it wants to see in the end when 80% below 1990 level greenhouse gas reductions are reached in 2050. And changing the current market design may be difficult when success is achieved. Similar challenges are being experienced in Europe.

One illustrative example from California is that to overcome the market entry barrier, the state's solar rooftop program allows customers to get paid back as a bill credit the full retail rate for input of power from solar installation into grid. This "net metering" program has been very popular, but at some point, these customers won't be paying their fair share for grid services. On the other hand, it is also unfair to change the rules on so many customers who bought their solar systems based on this set up. The issue has become a serious point of contention, which could have perhaps been prevented or at least mitigated, if policymakers and regulators had focused on a longer term roadmap that could have enabled better consumer communication and education about where the state was headed.

This is only one example among several that underscores the importance of long term, transparent and consistent policymaking that keeps the end game of success in view, in order to avoid unnecessary expense, volatility, and conflict. How California and Europe reach their mutual climate target for 2050 of at least 80% greenhouse gas reductions below 1990 levels may be different, but the end goal is the same, and both should be making their energy transition planning with this end goal in mind.

It was pointed out that in California, recently passed legislation, SB350, presents an exciting opportunity, not just as a 50% RPS or efficiency mandate, but also as an integrated resource planning law, in which procurement is focused on fulfilling the state greenhouse gas reduction goals, with other programs woven in.¹⁴ So for example, then DR or storage can be viewed not just as its own end, but as part of a whole system, which as discussed, is not historically how California has rolled out its clean energy policies.

That said, the state will still need to plan even further ahead and beyond the SB350 energy and efficiency targets for 2030 to reach its 2050 climate goals.

Energy agencies in Germany and other countries in Europe and elsewhere have set energy sector targets up to the year 2050 that are in line with their greenhouse gas reduction targets and have begun a rigorous, if imperfect planning process to achieve these goals. California will need to do this as well, and the sooner it begins, the more likely it can avoid the inefficiencies of piecemeal planning.

¹⁴ Senate Bill 350 was signed into California law in 2015 with the aim of increasing mandated utility power procurement to 50% by 2030 and doubling the energy efficiency savings in electricity and natural gas final end uses of retail customers through energy efficiency and conservation. See: https://leginfo.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350

The German power market is undergoing some practical design changes.

Two specific changes brought up that can help decrease Germany's 20,000 MW of "must run" capacities, that is, conventional power plants that are currently considered necessary to keep running sources of control power and ancillary services.

1. Moving toward the Dutch system of more purely market based balancing.

Whereas in California, the Independent System Operator (CAISO) controls all power plants on the transmission grid in real time, in most of Europe, apart from some countries like Poland, the market does the dispatching. This means that every energy market player is responsible for being balanced; that is, they must buy the same amount of energy that they use or produce exactly the amount that they sell. In Germany, at times when prices are high and there is an imbalance, the TSO steps in during peak pricing times to balance out the market using average costs over the last month. German grid operators are currently looking to move toward the Dutch system, so that there is always an incentive for the participants who have the balancing responsibility to be in balance.

2. Bringing renewables into the control power market, which will reduce "must run" conventional power.

Another next step in Germany, similar to California, is to get renewables into the control power markets. Currently, control power is bought in Germany as a market product a month in advance, which makes no sense for renewable power generators because it is hard to know that far ahead, especially in places with volatile weather like Germany, whether the wind will be blowing or the sun will be shining. Germany is looking to change this, so that major shares of control power can be bought on a day ahead basis, and renewables can take part in 4 hour blocks as a first step, with shorter blocks becoming perhaps possible in the future.

Markets can also encourage renewable technologies that are more optimal for the grid. For example, wind turbines can be designed to ramp their output up or down by a few percent, which with decentralized storage, gives them a higher value to the control power market. This is already in practice in the Netherlands, where wind farms are responding to hour ahead control power and reserve pricing. Until now, wind producers have not had the proper incentives to provide this benefit in Germany.

The bottom line is that renewable energy has a big future in Italy, but it is unfolding in a different way than anyone had imagined and needs new regulatory strategies going forward to work well.

Among the lessons learned so far on Italy's path to rapidly increasing renewable power are: 1) With big new changes, it can be hard to predict the future. 2) Large shares of renewable electricity, even up to 100% are possible and economically beneficial to citizens and communities, but regulation and vision is needed to scale this up successfully.

It was explained that in the last eight years, Italy's share of renewable electricity soared from 16% to nearly 40%. This previously unimaginable growth was catalyzed by very attractive feed-in tariff prices, which then prompted a political backlash that led the government to halt the program and look for a new strategy.

Renewable energy is most popular in northern Italy, where local municipalities have long been able to own the grid, make cooperatives, and share energy they produce. They have invested in renewables for both electricity and heat, which has worked very well. Thousands are linked to the grid, and several municipalities are generating 100% of their electricity supply with a mix of mainly solar, hydro, and biomass, which greatly reduces their energy costs.

Such areas, however, have their own special rules, which it was pointed out cannot be applied to the whole country without problems. In a sunny country like Italy, similar to California, if every municipality or region is given the opportunity to go to self or local level power production, renewables are economically competitive. But for the whole system to work, there needs to be regulations and vision. For example, people need to be encouraged to stay connected to the grid.

Why does California separate its distributed generation renewable targets from its large scale renewable targets?

In European countries and regions, renewable electricity targets generally don't make this distinction. In California, separating targets into silos is rooted in the order in which the programs were created and complex politics. For example, the legislation for rooftop solar was passed separately from the legislation for the RPS. Recently there was an effort by the investor owned utilities to include rooftop solar in the newly increased RPS, but some participants explained that unwinding the existing programs and figuring out the renewable energy credits and other mechanics turned out to be too difficult.

What is California's experience and outlook for the demand response (DR) market?

California has had a long history of interruptible programs for large industrial consumers – that is, in tough situations when the grid needs extra support, those consumers can curtail their electricity use in exchange for a rate discount.

The state is now trying to open up new kinds of DR using technologies, such as those that automate when lights are dimmed, when water is pumped, when air conditioning cycles, and when thermostats are adjusted. This "DR 2.0" program has been taking longer than hoped, due to legal questions on the federal level regarding whether DR can participate in the wholesale market. Getting the technologies implemented and communications between the ISO and end user are also complex and require new protocols.

However, the state has made progress, and there is a DR auction currently underway, in which state energy authorities hope to see some of the DR 2.0 technologies participate.

That said, one participant explained that there may be a need to take a step back from the old way of doing things, which could reduce DR in the next couple years, in order to send the right price signals that increase more strategic uses DR in the longer term.

It also was noted that California may lack the DR potential of some other places in the world because unlike Germany, for example, the state does not have a big industrial load.

What impact is Germany's nuclear power phase out having or expected to have on grid stability?

Because of the relative lack of flexibility of the nuclear power plants, German experts explained that the nuclear phase out will enhance the transition to a more flexible grid. In France, where legislation has been passed only to reduce nuclear power from 75% to 50% by 2025, the nuclear reactors are more flexible, so the expectation is that renewable generation will have to be very high before there is a flexibility problem. That said, France does have a minimum output level that its nuclear reactors are required to not go below.





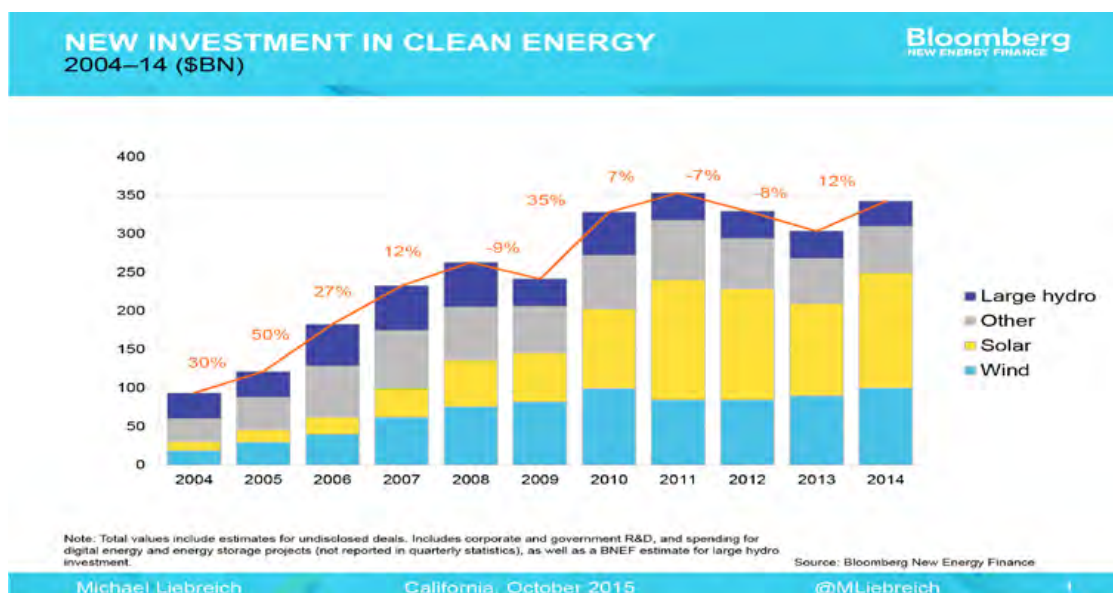
Bloomberg New Energy Finance Roundtable

The Delegation's final event in the Bay Area was a roundtable hosted by Bloomberg New Energy Finance (BNEF), a firm that delivers analysis on new energy developments to decision makers around the world. BNEF Founder and Advisory Board Chairman Michael Liebreich offered a pre-view of his Keynote to be delivered the following day at the CAISO Stakeholders Symposium. This served as a springboard for a group conversation on economic, market, and financing issues related to the global energy transition. The following are highlights from the presentation. A video of the Keynote can be viewed [here](#)

Flow of capital into clean energy technologies is a rising trend.

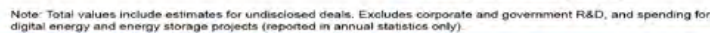
Liebreich started with an overview of the flow of capital into new, clean energy over the past decade, including renewables, storage and complementary technologies like storage and smart grid products.

There has been a general rising trend, despite some ups and downs since the start of the global recession in 2008. The ups have been spurred by policies, such as the 2009 American Recovery and Resources Act – popularly known as the “stimulus bill” – which included massive incentives for clean energy investment, while the downs have been prompted by a combination of the economic crisis, which was responsible for approximately a third of the drops in recent years, and the rapid decline in technology costs, which was responsible for the other two thirds.



Fossil and nuclear fuel based energy are not included in the statistics analyzed for this slide.

NEW INVESTMENT IN CLEAN ENERGY Q1 2004-Q3 2015 (\$BN)



Source: Bloomberg New Energy Finance.

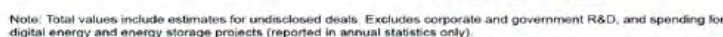
Michael Liebreich

California, October 2015

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AMER NEW INVESTMENT IN CLEAN ENERGY BY SECTOR Q1 2004-Q3 2015 (\$BN)

Bloomberg
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Source: Bloomberg New Energy Finance

Michael Liebreich

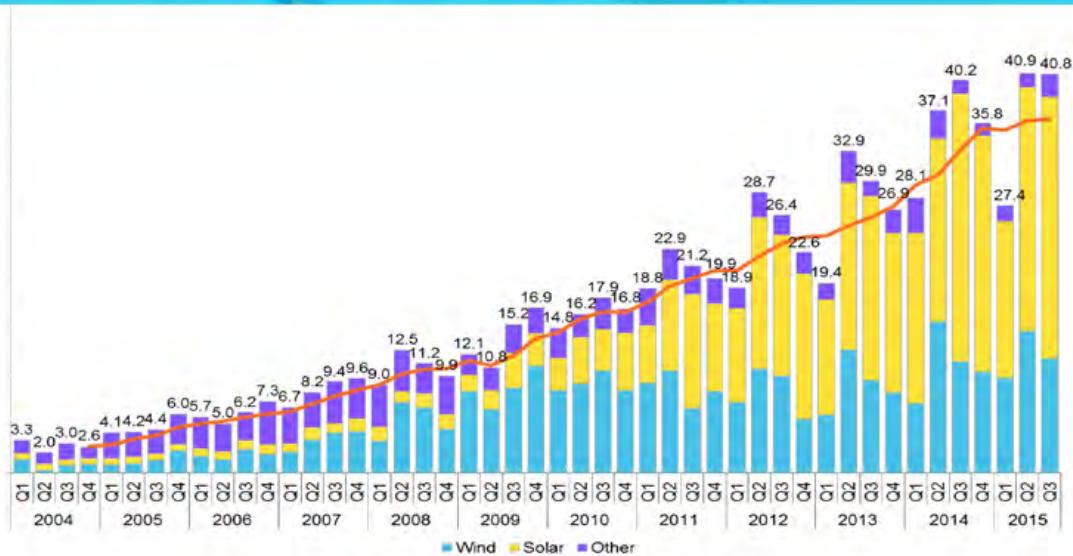
California, October 2015

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APAC NEW INVESTMENT IN CLEAN ENERGY BY SECTOR Q1 2004-Q3 2015 (\$BN)

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Note: Total values include estimates for undisclosed deals. Excludes corporate and government R&D, and spending for digital energy and energy storage projects (reported in annual statistics only).

Source: Bloomberg New Energy Finance

Michael Liebreich

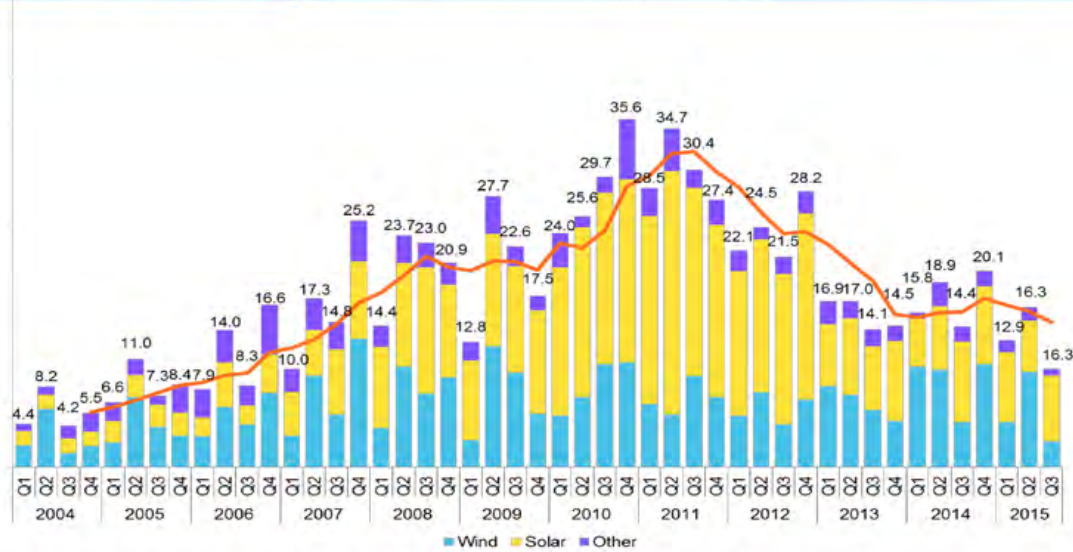
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EMEA NEW INVESTMENT IN CLEAN ENERGY BY SECTOR Q1 2004-Q3 2015 (\$BN)

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Note: Total values include estimates for undisclosed deals. Excludes corporate and government R&D, and spending for digital energy and energy storage projects (reported in annual statistics only).

Source: Bloomberg New Energy Finance

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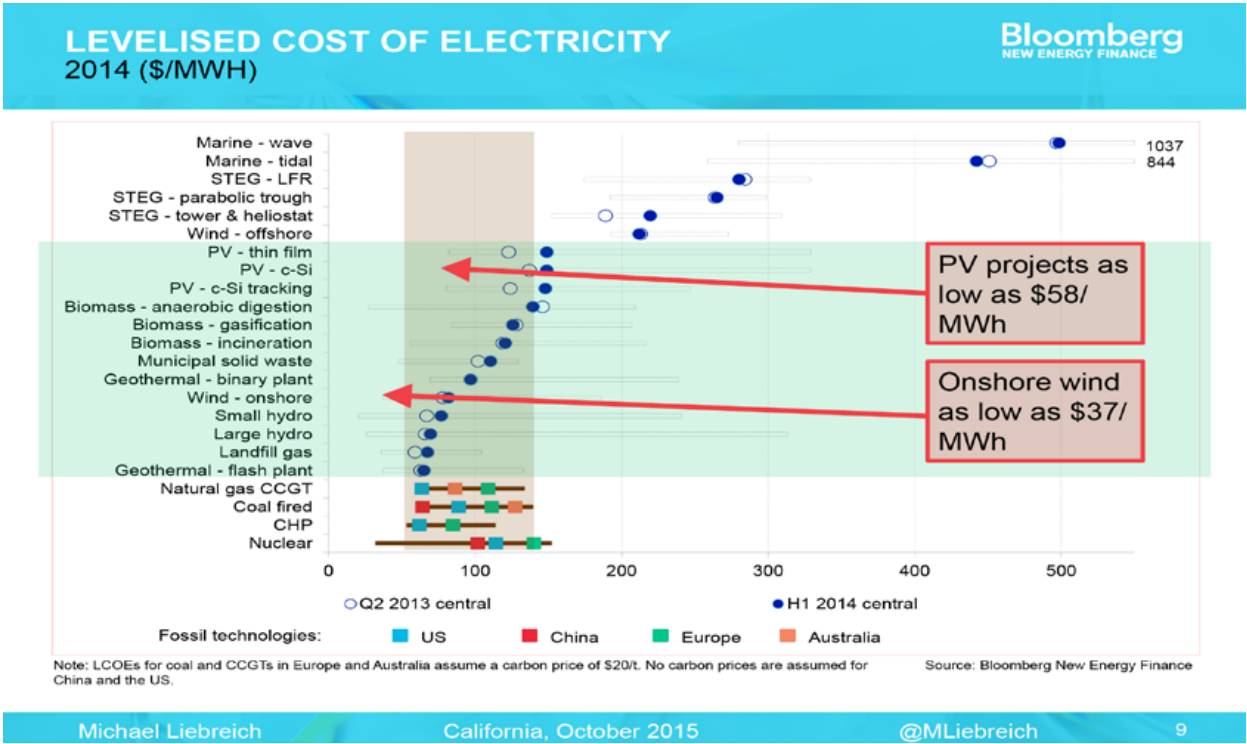
Policy trends impacts on current investment climate

Reverse auctions for renewable electricity are becoming more popular around the world, and Liebreich said these can achieve lowest price bids for renewable energy projects but do not address other elements of dispatching renewable electricity, such as fluctuating rates of demand between different times of day and night, or generation, such as when the wind is not blowing. He asserted that additional mechanisms are needed to fill the gaps.¹⁵

Weighing on investor uncertainty is a trend to issue caps for renewable energy investment, which are competing with price signals and making analysis – as well as running programs like auctions – difficult because it is hard to know whether the cap will be reached or changed by the government.

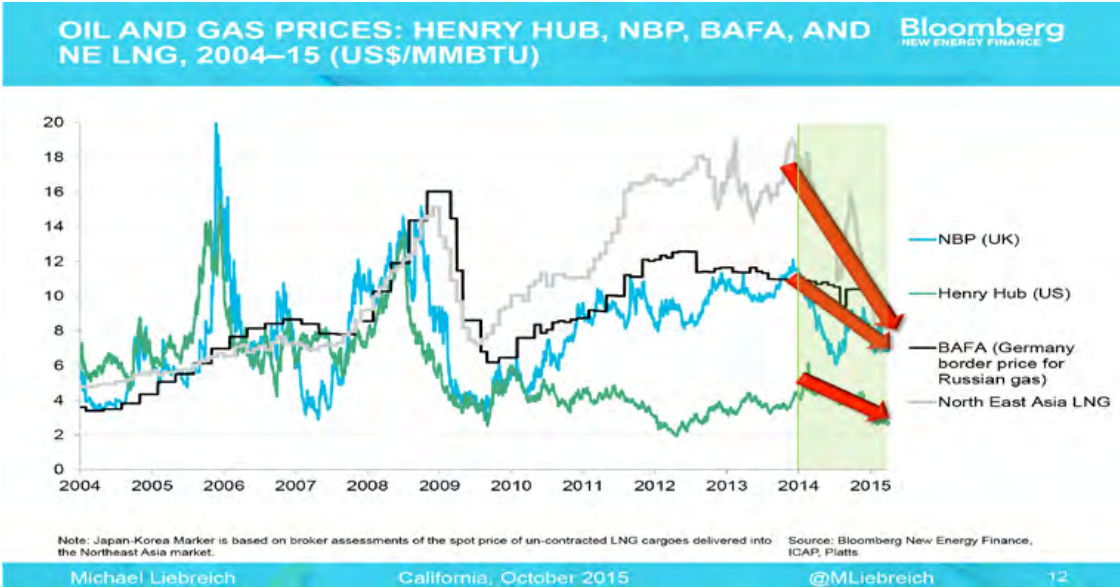
Latest price trends across energy sectors

Prices for renewable electricity capacity are reaching new lows and are expected to drop further in the year ahead.

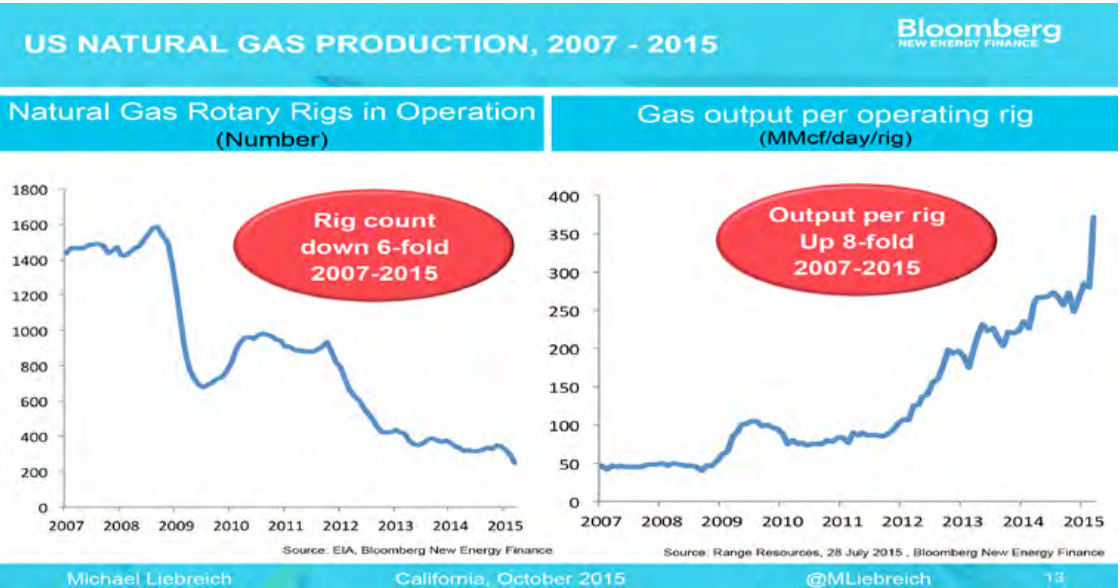


¹⁵ Reverse auctions have also been criticized for other shortcomings, such as not promoting diverse sources for renewable electricity or projects located in proximity to load centers. See, for example, *Balancing Economic and Environmental Goals in Distributed Generation Procurement: A Critical Analysis of California's Renewable Auction Mechanism (RAM)*, Wentz, 2014 <https://gwufile.wordpress.com/2014/06/v5i2-wentz-article.pdf>

Natural gas prices have also been dropping globally, and the gap between Asian, European, and US prices narrowed in 2015 compared to the few years prior, and those prices are expected to continue to converge. Gas prices also were historically more or less indexed to oil prices, but there was a large spread starting around 2010. These prices are also starting to converge again.



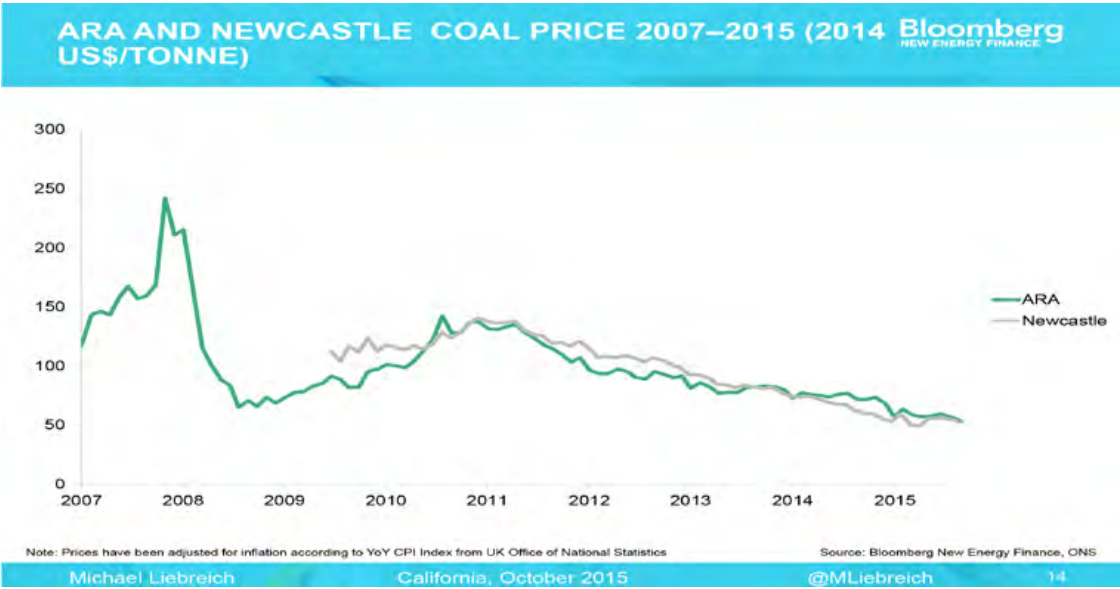
Liebreich’s view is that the current period of low oil and gas prices is likely to continue, due in part to innovation in the unconventional oil and gas sector, which is producing more fuel with fewer wells.



With production per rig going up dramatically in recent years, the cost of oil and gas has been coming down at approximately same rate as solar. This is driving down the break-even point for oil and gas.

The bottom line is that this is an age of intense competition between energy sources, and while the old is expected to be replaced by the new, the old is putting up a serious fight.

One big loser is coal. Prices have been plummeting, while coal companies have been rapidly going out of business.



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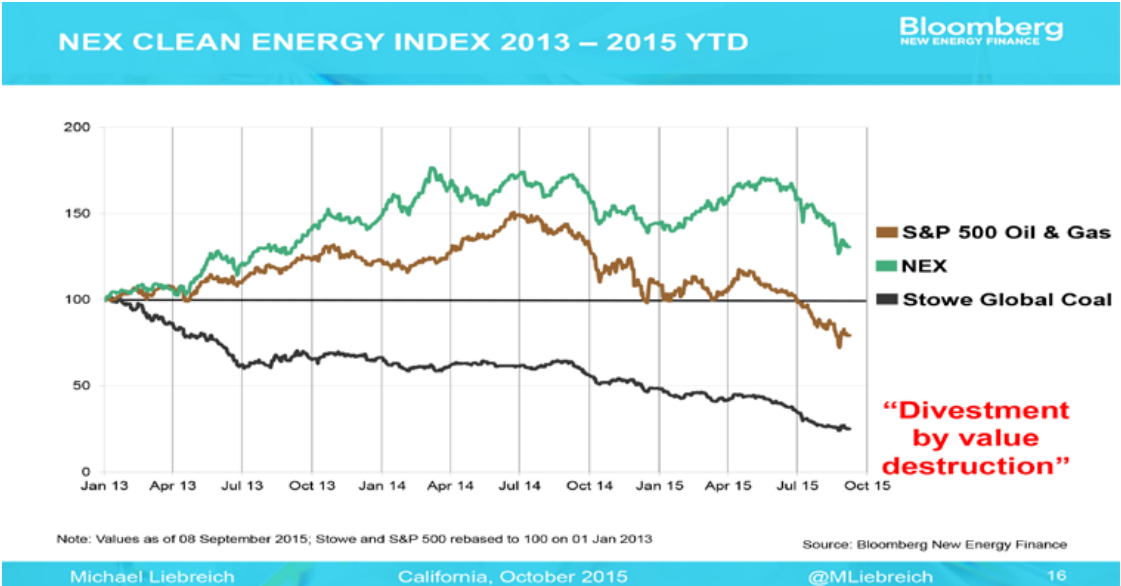
BUMI
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PATRIOT
COAL

Image: various company sources

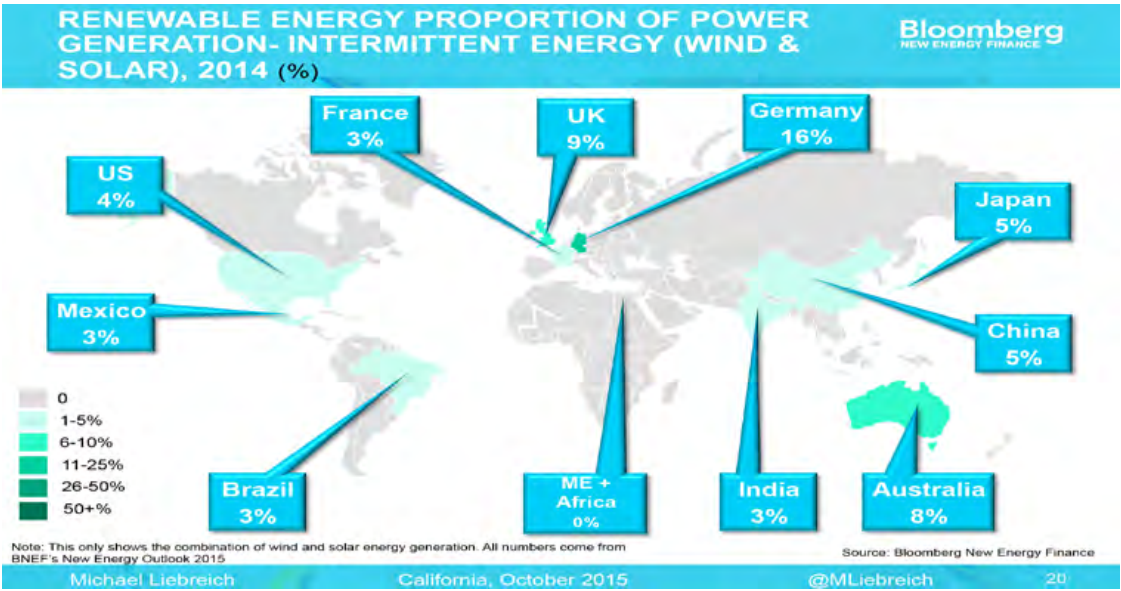
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Value has shifted from the coal industry to the new energy industries in what could be called “divestment through value structure.” In other words, because of the economics of the coal industry, it is divesting itself.



Renewable electricity capacity is going up, which is spurring innovation and new market players.

Percentages of renewable electricity are going up around the world and are expected to continue to do so in the coming decades.



Since much of the capacity will be wind and solar, the price of the technologies needs to be low in order to have budget left over to handle the intermittency. Liebreich explained that intermittency can be managed, for example, by diversifying types of renewables, linking markets, collaborating regionally, and implementing complementary technologies, such as demand management, software, efficiency to bring down scale of problem, and the more expensive solution of storage (e.g. batteries that could include electric vehicle batteries, heat, etc.).

In order for customers to be able to use the increasing menu of cheap energy types at the times of day, places and ways that they need it, new services will be needed to retain customer relationships. This is spawning new startups, as well as pushing old, large companies, both utilities and otherwise, to offer new services.

Big companies are also starting to self generate electricity with renewables because it is a cheaper way to meet their energy needs.

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Images: Various; Bloomberg New Energy Finance

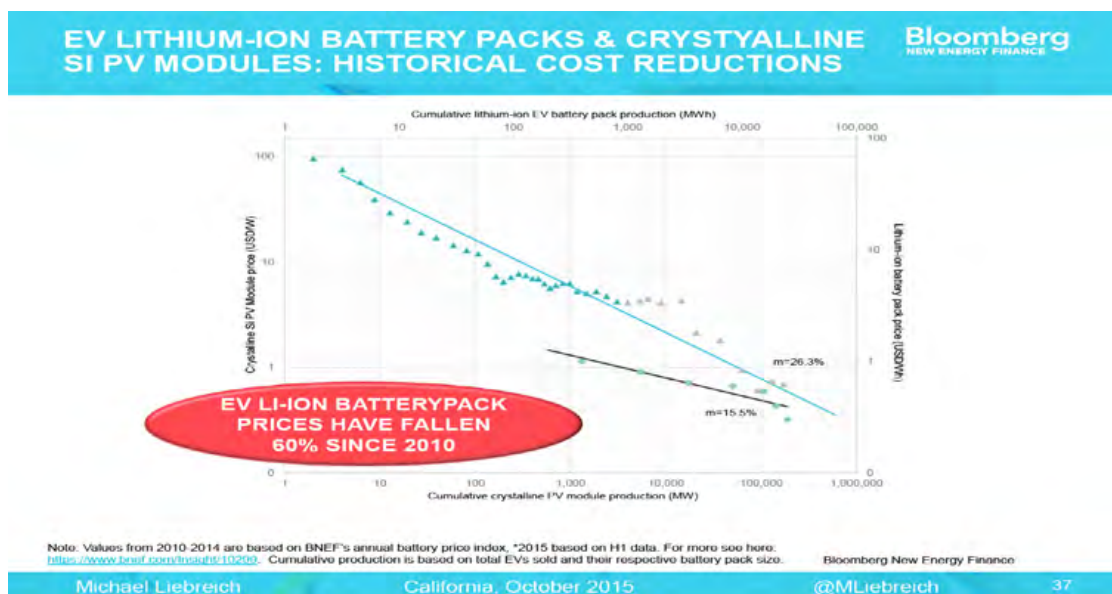
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The rise in renewables raises many new questions. Included are: How will utilities respond to demand being taken away and the massive new opportunities before them to offer services that help manage this transition? How to predict what investments will be needed in the grid and other infrastructure? And how to cope with negative pricing when a high influx of renewable power exceeds demand?

Electric vehicles are part of this equation, although to become a large part will take a while until the numbers scale up.

On the one hand, the EV market is growing, and BNEF is bullish about their future. On the other hand, they still represent a very small part of market share of vehicles worldwide, and considerably more must be on the road in order for their vehicle to grid and demand response capabilities to be fully realized.

Decreasing battery costs, as well as concerns about air quality will help advance the process and could help push developing regions to leapfrog on technological adoption. "Dieselgate" has also made it exceedingly difficult to argue that emissions goals can be met while depending on diesel-fueled vehicles.



It's become mainstream to talk about deep carbon cuts, but more meaningful commitment to action will be needed to get us there.

Decarbonizing is now the mainstream agenda, as evidenced by such recent events as the Pope's Encyclical on climate and the G7 agreeing in June 2015 that carbon emissions must be cut 40-70% by mid-century and phased out entirely by 2100. The downside is that with the current set of policies around the world, BNEF forecasts 44% of electricity generation can be expected to still be fossil based by mid-century, not to mention other sectors. Other forecasts are more and less conservative, but the bottom line is that the world is yet to be fully on the trajectory scientists are urging of keeping average global surface temperatures from rising more than 2 degrees Celsius.

The question is whether decision makers around the world will go beyond the status quo to take the necessary actions to adequately address our climate problem.



CAISO Stakeholders Symposium

The last two days of the tour were spent at the CAISO Stakeholders Symposium in Sacramento and visiting the CAISO headquarters nearby in Folsom. The Stakeholders Symposium is CAISO's annual major gathering of energy executives, where in 2015, there was record attendance of more than 1000 experts in the field, with another 1000 joining by live stream and tens of thousands participating via social media.

Delivering the Dinner Keynote at the end of the Symposium's opening day was Boris Schucht, CEO of German TSO 50Hertz. The two panels on Day 2 of the Symposium presented a further opportunity for several of the European Delegates to share their insights on challenges and opportunities presented by integrating high shares of renewables into the grid.

Below are highlights from this final part of the tour.



Opening Day Dinner Keynote by **Boris Schucht**, 50Hertz, CEO

Videos of the Keynote and panel discussions can be viewed [here](#).

Introduction: 50Hertz, a living laboratory of the energy transition

After a warm introduction by CAISO Governor David Olsen, Boris Schucht began by sharing that when he was a young utility engineer, had the question been asked whether safely integrating more than 5% solar and wind into the system was possible, all experienced engineers would have said, "No way. We will face serious problems, and reliability will go to hell."

But 50Hertz, which covers about a third of Germany, has been proving this wrong. The TSO has so far succeeded in integrating a share of 42% variable renewables without reliability problems. And they are planning for more.

Schucht explained that 50Hertz is a living laboratory at the center of the German energy transition, or "Energiewende," the largest industrial transformation in the nation since the reunification of East and West Germany. Renewable energy, especially wind power, he shared, has developed quickly in the TSO's region in northeastern Germany and already dominates the system with over 25 gigawatts of installed capacity so far, compared to a conventional fleet of only about 20 gigawatts.

This is happening in the context of a national overhaul of Germany's electricity system, where approximately 90 gigawatts of renewables are now covering an ever increasing share of the country's total consumption of about 600 terawatt hours, approximately double that of California. Breaking the renewable electricity portfolio down by resource type, the capacity in Germany now includes 40 gigawatts of wind, 40 gigawatts of solar, and roughly 10 gigawatts of other renewables (primarily biomass). With a minimum load requirement of 35 gigawatts, Germany already regularly meets it with renewable sourced power.

Almost zero to 42% intermittent renewables in a decade – What are the lessons learned?

The first lesson learned, Schucht asserted, is not to fear these volatile renewables, but to “just go for it.” Those responsible for reliability will learn step by step how to cope.

The first step, he said, was the very beginning when renewables rose to a share of just 5-10%. During this period, he and his team learned how to develop forecast systems and other tools to deal with these new power sources, but renewables were still a niche product, and mistakes had no real consequences for the overall system.

In the second step, when renewables rose from 10-40% on the electricity grid, these sources become major players. California, he observed, is in the middle of this phase now.

For the 50Hertz team to succeed at this stage, several factors came into play.

For one, regulations had to change. For example, curtailment had to be permitted, and technicians needed to learn how to curtail.

Forecasting models, especially weather forecasting, also needed to become far more accurate.

The team furthermore needed to learn how to steer renewables, whether via the market by forcing renewable generators to sell their power on the wholesale market, or technically via the TSO's control centers.

Another major lesson learned was that the existing system offered “far more flexibility than expected.” In fact, there was enough “every second of every day.”

That said, the team also needed to quickly start thinking about the infrastructure of the future, which also holds true for all of Europe.

How to manage more than 40% renewable electricity in the grid

Now, Schucht said, 50Hertz is on the third step, with shares of variable sources of renewable electricity in the system climbing above 40% and becoming the dominant source. Here's what he recommends for this phase:

To begin with, we need new market products closer to real time. For example, quarterly hour products have been introduced, and shorter time products may be as well, such as those in California, which are already down to 5 minutes. Also market designs need to be better tailored to renewables.

Renewables additionally have to take over stabilizing the system by providing ancillary services.

Furthermore, he believes grid extension between regions and European nations will play an important role.

For Europe, Schucht predicted, storage will only likely become critical when 70% or higher shares of renewables are reached, which translates to 15-20 years from now.

Additionally, he stated, "we expect electricity, heat, and gas to converge more and more." For example, power to heat is already seen in the system in his region.

Have all those renewables caused a "duck curve?"

With such large amounts of intermittent renewables already in the grid, he guessed that some may wonder whether German grid operators have been experiencing the "duck curve."¹⁶

The answer is no. While there are incidents of over-generation, this is managed with several tools. One is strong interconnections between grids, with massive programs to further increase connectivity within and between regions both in Germany and internationally. Such investment is being made throughout Europe, which has a budget of about 200 billion euros for grid expansion. The budget for grid expansion at 50Hertz alone is about 6 billion euros.

Second, there is work being done on commercial integration between regions, with the aim of creating a single European electricity market. Already there is a well coupled market in place in Germany. For example, 50Hertz's neighboring states can buy inexpensive wind power on a windy day or cheap solar power on a sunny day. He noted neighboring region customers love this. Generators do not.

¹⁶ CAISO predicted that as California increases wind and solar capacity over the next decade, there is a risk of over-generation in the afternoon and an increased need for ramping as solar drops off at the end of the day, which creates a chart pattern that looks like the belly and neck of a duck – hence the term "duck curve." For more information, see: https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

Integrating higher shares of renewables into the market

How have higher penetrations been integrated into the market? For one, starting two years ago, renewable electricity generators have been able to sell directly into the market and receive a market premium. That means that such electricity will only be produced when there is a demand and when it can be sold.

Renewables are also being increasingly included in the ancillary services market. For example, voltage control by wind power has become normal. Renewables can also offer frequency control, among other services to stabilize the grid when the sun is shining or the wind is blowing. Gradually, the result is that must-run capacity of conventional electricity is being reduced and replaced by renewables.

Overcoming obstacles successfully has made 50Hertz confident in the future

To illustrate why 50Hertz is confident that they will master the next phase of rising amounts of renewables, Schucht shared the story of the solar eclipse in March 2015, in which an unprecedented disruption in Germany's solar power production caused a rapid reduction in supply. His team prepared extensively and readied the market for this unusual circumstance, and when the time came, Germany was free of problems, as was all of Europe, which underwent similar preparation.

Another more grueling example occurred a couple years ago, when integrating large shares of solar power into the grid was still relatively new. 20 gigawatts of solar power production were sold into the system on the day ahead market, and overnight, the grid operators learned that an unusual fog layer was going to result in actual solar generation being nearly 9 gigawatts lower than expected. The grid operators had only two hours to activate the shortfall. Although it was a tough lesson, they succeeded with the help of neighboring states in maintaining grid stability.

What does the energy transition mean for various players in the power market?

Renewables, Schucht asserted, "are a game changer" with new business models and new players. As an example, he cited the lignite model as one that is most likely disappearing because conventional power plants suffer under low wholesale electricity prices resulting from rising shares of renewables. Former large, integrated utilities will also split or disappear, while others survive.

On the policy and regulatory fronts, Schucht added that these innovations and transformations require appropriate frameworks, and it is a critical challenge to keep up the pace of regulatory and legal developments with such a dynamic environment.

Looking at the bigger picture, Schucht observed that the transition to renewable energy is not just happening in Germany, Europe or California, but has become a worldwide movement. To make progress, people from multiple sectors will have to work together, locally, regionally, and internationally.

We need “a collaborative approach to master this transition,” said Schucht. “Many stakeholders are needed to make it a success.” This, he explained, includes greater cooperation between transmission, distribution, demand and generation, as well as between regions, and with the public to ensure their acceptance.

The public may be in support of the energy transition in general, but, he warned, not of transmission lines and windmills in their backyards, and it is up to the grid operators to handle this dilemma as good communicators and public servants. This includes being transparent, upholding environmental standards, and developing local projects that make up for grid impacts on nature and the landscape. He cited the Renewables Grid Initiative as an example set up in Europe to bring together TSOs and NGOs to advocate together both for the necessary grid development that will support more renewables and for protecting the environment.

In closing, Schucht shared that he is inspired by California’s ambitious plans for its energy transition, and that despite some differences, California and Europe have many similarities with respect to their commitments to renewables, climate policy, multi-stakeholder dialogue, and building greater cooperation.

“I have already learned a lot during this trip to California,” he concluded. “No one of us has the silver bullet nor the master plan. That’s why it’s so important to learn from each other...After three days of intensive exchange of experience and thoughts, I will travel back with many inspirations and valuable insights for the next phases of the energy transition in Europe.”



CAISO Stakeholders Symposium Panel

Transition to a Low Carbon Grid: European Perspectives Part I



Panelists: Hervé Laffaye, Deputy CEO of RTE | Auke Lont, CEO of Statnett | Boris Schucht, CEO of 50Hertz | Joerg Spicker, Head of Market Operations at Swissgrid | Ben Voorhorst, COO of TenneT

Moderator: Antonella Battaglini, CEO of RGI

Following an introduction of the panel by Renewables 100 Policy Institute Founding Board Chair and CAISO Governor Angelina Galiteva, Moderator Antonella Battaglini, CEO of RGI, invited the panelists, who represented five European TSOs, to share initial remarks on specific issues related to how they are managing the energy transition. Highlights were as follows:

Auke Lont, Statnett, CEO

Norwegian perspective on regional cooperation

Norway generates the equivalent of all its electricity demand with renewables & exports much of it.

Auke Lont, CEO of Norwegian TSO Statnett, shared that Norway generates the equivalent of its entire electricity demand with renewables, principally hydropower, and exports massive amounts of this electricity to neighboring countries.

The nation's Nordic neighbors meanwhile have some of the most ambitious renewable energy goals in the world. Denmark has mandated that all power and heat demand be met with renewable sources by 2030 and that transportation also be 100% renewable by 2050. Sweden aims to cover at least half its final energy consumption with renewable sources by 2020. Finland has set a goal to get 38% of its final energy consumption demand met with renewables by 2020.

Regional cooperation is helping to accelerate the transition to high shares of renewables in the Nordic region. In the past three years, climate change has become a driver of this regional cooperation. But, Lont explained, such cooperation first gained interest in Norway as a means of securing energy supply and driving down costs. The hydropower driving the Norwegian grid, although not usually called an intermittent resource, does fluctuate depending on weather patterns, and Norway was seeking ways to make sure power supply remained stable during dry years. Enlarging the electricity fleet by including neighbors, Lont explained, was and is a way of reducing costs.



At the start of the Nordic grid collaboration, he recounted, the electricity portfolios in each country were distinctly different from one another. Norway had more or less 100% hydropower, Sweden was about 50% hydro and 50% nuclear, Denmark was on oil, coal and gas, and Finland had a mix. Integrating these various scenarios happened over three phases, and it's still a work in progress.

Three phases of Nordic regional grid development: physical, market, and systems integration/IT

First came the physical phase, which started in the 1960s and 1970s, and during which interconnecting grids were built between the countries.

Then the market phase took off in the 1990s, beginning in 1993, when in the spirit of liberalization that was popular at the time, the internal Norwegian power market was launched. All Norwegian producers participated in this market. Two years later, Sweden was added to this market, followed soon after by Denmark and Finland. Today, the Nordic exchange is a well functioning market that helps Norway maintain a secure electricity supply in dry years and share oversupply with neighbors during wet years. It also helps enable climate policy. For example, regional integration has enabled Denmark to get off coal and build out a massive wind capacity, which was only possible because of Denmark's connection to Norwegian hydro supplies.

The Nordic countries are now in the third phase of this regional cooperation, which is focused on systems integration and specifically building a common IT system.

To sum up his confidence in this model, Lont shared that at Statnett, they used to say "the future is uncertain but electric," and now they simply say "the future is electric."

Joerg Spicker, Swissgrid, Head of Market Operations

Switzerland, the balancer at the center of Europe

Swissgrid is the publicly-owned operator of the transmission grid in Switzerland. Joerg Spicker, the company's Head of Market Operations, opened his remarks by explaining that Switzerland is one of Europe's smaller countries with a long history of neutrality and ties to tradition, yet also leads both in profitability and innovation.

He explained that the country's energy history started 130 years ago when Switzerland first began developing its natural resources for energy. Concession contracts established then are still in place. The first run-of-river hydro plants were then built 120 years ago and paved the way for the first international energy cooperation between European countries, as one of the rivers in Switzerland is the Rhine, which borders Germany, and another is the Rhône, which borders France. In the 1930s,

transmission lines were built that enabled Germany to use Swiss hydropower for its peak supply, and in the 1950s, there was a decision to connect the grids between Switzerland, Germany, and France.

Europeans see the market based approach that they have been following in the electricity sector for the past 15 years as the best way to deliver customer choice, fair pricing, and innovative solutions.

Although Switzerland is not a part of the European Union, which has adopted laws mandating the implementation of the electricity market, the nation has nonetheless played an instrumental role in developing the market. Because of its central location in Europe, its large number of cross-border lines, and its flexible hydropower supply capacity, it is a vital hub. It thereby serves as a central location for providing ancillary services and flexibility across national borders.

Ben Voorhorst, TenneT, COO

Markets as a means of increasing shares of renewables

TenneT is the Dutch TSO, which also owns part of the German grid, and CEO Ben Voorhorst offered his perspective from his long-time experience in the European electricity market.

He explained that in the late 1980s, Europe decided that an internal, European market would be more cost-effective for consumers. In response, the Netherlands established a TSO that is completely unbundled from generation. This TSO has a monopoly over the transmission grid, while nine regional grid companies maintain the grid, and commercial companies make up the rest of the system.

Interest in integrating the market, Voorhorst shared, led the TSO to build the longest undersea cable to Norway because there was inexpensive energy there, and Norway was able to benefit by diversifying power supplies during dry years. This also prompted TenneT to acquire a 40% portion of the German grid when it came up for sale. This acquisition has made the company responsible for inter-connecting offshore wind farms in the North Sea into the German AC grid, which Voorhorst says is expected to bring 7 gigawatts of wind energy into the European system in the next few years.

While it is a challenge to be a TSO in two countries with different approaches, major steps have been made to integrate the European markets. Voorhorst explained that the Netherlands and France worked together to couple their markets with Belgium, for example. The next step was to bring in Germany, and now the market covers all of Europe. This type of cooperation among TSOs is motivated by a common desire to make Europe competitive, to keep costs down, and to integrate renewables.

The way forward, Voorhorst stated, must include cooperation among a range of stakeholders, including not only TSOs, but also regulators, policymakers, and industry associations, working together to continue to speed up internal markets and ensure secure supply. Although to date legislation requires countries to secure supply on their own, a regional approach could be more cost effective.

Boris Schucht, 50Hertz, COO

Cooperation Between TSOs and DSOs

Schucht focused his remarks on the importance of cooperation between transmission and distribution grid operators to make integrating renewables successful. Secure supply on its own, he emphasized, is not enough.

Schucht explained that Germany was forced after the reunification between East and West Germany in the 1990s to implement this kind of cooperation because the transmission infrastructure in East Germany, which is in 50Hertz's service territory, had to be newly built. While Germany is proud of this state of the art infrastructure, which virtually never has an outage, transmission grid operators had to be in close discussions with distribution grid operators on how to manage this development.

Another big change since the reunification, as Schucht mentioned in his Keynote address, is that Germany has gone from having a few hundred, centralized conventional electricity generators to nearly 1.7 million, decentralized, increasingly renewable electricity generators that are mostly connected to the distribution grids. Steering this electricity requires entirely new ways of managing the system and redefining who does what. He explained that this will lead to some responsibilities shifting from the transmission to the distribution system. For example, voltage control can be well managed at the local level. However, when voltage needs to be steered in higher levels or over a wider range, transmission will be necessary.

Underscoring the importance of continued collaboration between the two systems, when the distribution system operators in 50Hertz's region undertook a two- year process of envisioning their role in the energy transition, they concluded half way through that transmission grid operators were going to continue to be needed.

50Hertz and the regional distribution system operators have been working together to develop a vision for how their roles will be defined in the future. An example Schucht offered was that the TSO has agreed not to go directly to generators for ancillary services, but rather through the distribution system operators, who will have jurisdiction over deciding which individual generators to contact when for such services.

While Germany's experience may not be a model for all of Europe, Schucht said in conclusion, it does represent an important step in what he believes will be an increasingly necessary process of closer collaboration between transmission and distribution system operators.

Hervé Laffaye, Rte, Deputy CEO

Challenges and Solutions to Public Acceptance

Mr. Laffaye focused his remarks on how increasing shares of renewable electricity are changing grid operations and requiring grid development. He also spoke about the challenge of completing those developments in a societal landscape of minimal public acceptance.

Laffaye laid out two basic ways in which renewables are bringing about major changes to transmission grids and how they operate. One is geographic. Where the watts are generated is moving, and the grid must follow them. An example in Europe is offshore wind, which is leading to the development of new interconnection via undersea cables, which are, in turn, transforming the job of the transmission grid operators. A second change is that the installed capacity in Europe is expanding – and is expected to as much as possibly double in TSO service territories in the next 15 years – while consumption is expected to remain stable. Similarly, on the distribution side, capacity will need to grow to meet the demand of new technologies like batteries.

These massive changes require regulatory frameworks that support grid expansion. However, such development has little to no public acceptance, which translates to long permitting processes and sometimes battles that stop the process altogether.

What can be done to solve this dilemma? Multi-stakeholder processes, such as the one facilitated in Europe by RGI, which enables dialogue between grid operators, NGOs and at least some opponents to grid development, are essential.

Discussion

Following the panelists' introductory remarks, Battaglini engaged them in a series of questions and answers, followed by questions from the audience. The following are highlights from this discussion.

How did TenneT decide to invest in a transmission grid connecting Germany and Norway?

TenneT CEO Ben Voorhorst explained that the success of connecting the Netherlands to the Nordic transmission system, which took only 7 years to be paid off, had already illustrated the societal cost benefits of this type of investment. Germany similarly connecting to Norway can help manage the wind power in the north and offshore wind off the northern coast in which there is heavy investment.

Boris Schucht, CEO of 50Hertz, added that a similar grid connection is under implementation between Norway and Germany.¹⁷

New Interconnectors

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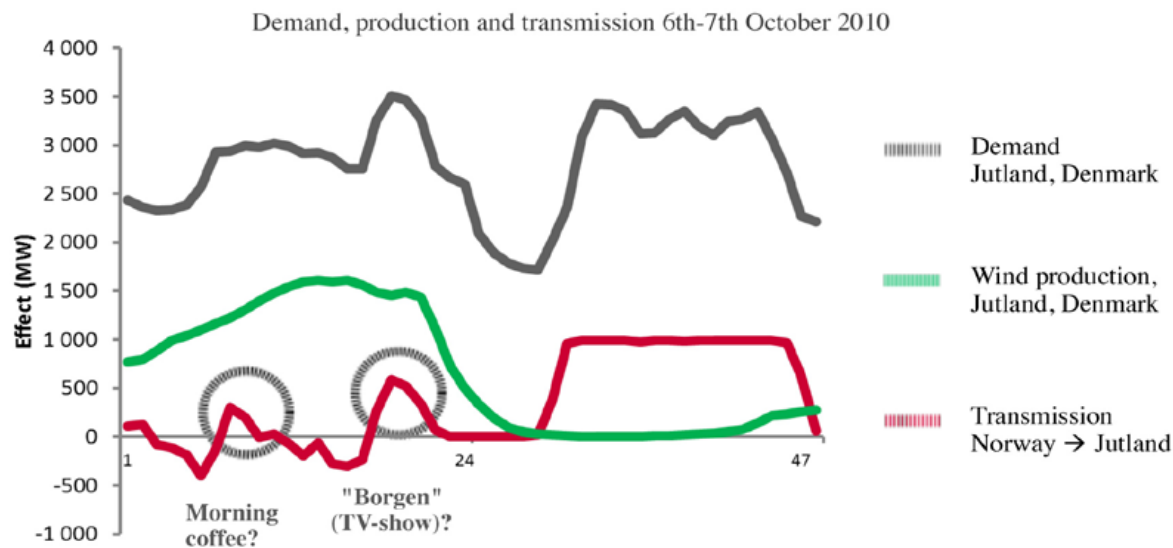
How does Norway help Denmark by complimenting its variable wind supply to meet demand?

Statnett CEO Auke Lont presented a slide which illustrated how, over the course of two days in December 2010, Norway helped Denmark to stabilize its electricity supply. On the first day, there was wind in Denmark, and Norway's hydropower just helped cover Danish peak demand. On the second day, there was no wind in Denmark, and Norwegian hydropower covered the load.

Security of supply and climate solutions

- Power flow between Norway and Denmark

Statnett



Such cooperation not only ensures secure supply, but is also a good business model because the pricing on the flexible and competitive power exchange reacts effectively to supply and demand. It is additionally a good climate model because Norway's hydropower has enabled Denmark to turn off its coal power plants and replace the capacity with renewables.

How is the transmission connection between Norway and Germany expected to create financial value for each country?

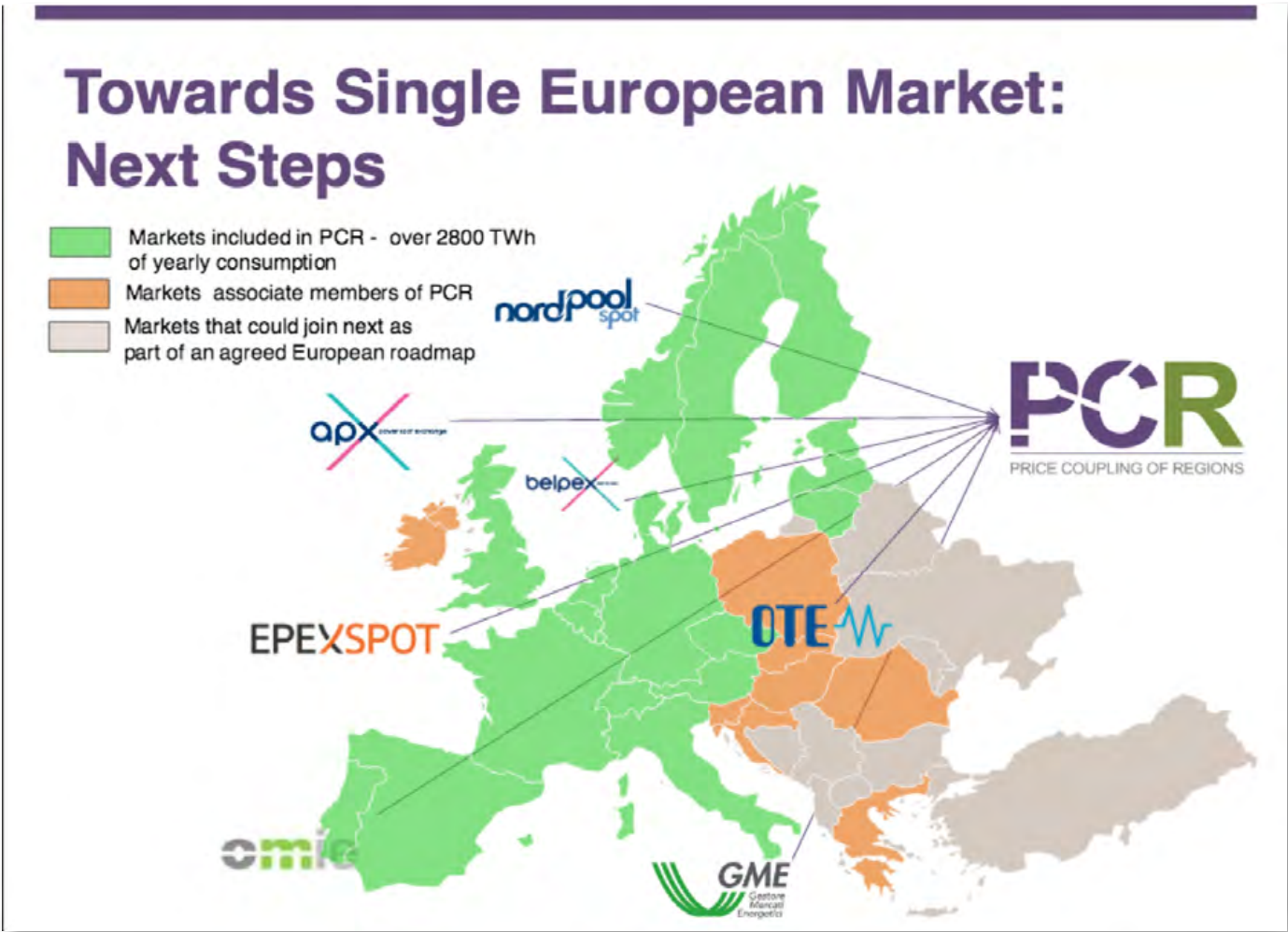
"Scandinavia is the natural battery for Central Europe," said Schucht. "The volume of Norway's and Sweden's lakes together are (equivalent to) 118,000 terawatt hours. That is one fifth of German (annual) consumption."

Germany and Norway have their own electricity price zones that are coupled, he explained, so “there are times when prices in Germany are cheaper, and Norwegians buy in Germany and keep the water up in the mountains.” And then there are times when Norwegian prices are lower, and it makes sense for Germany, instead of starting a lignite power plant, to buy cheap hydropower from Norway. The savings on both sides make it possible for these transmission connections to be paid off in a few years.

How does the human element factor into regional grid cooperation?

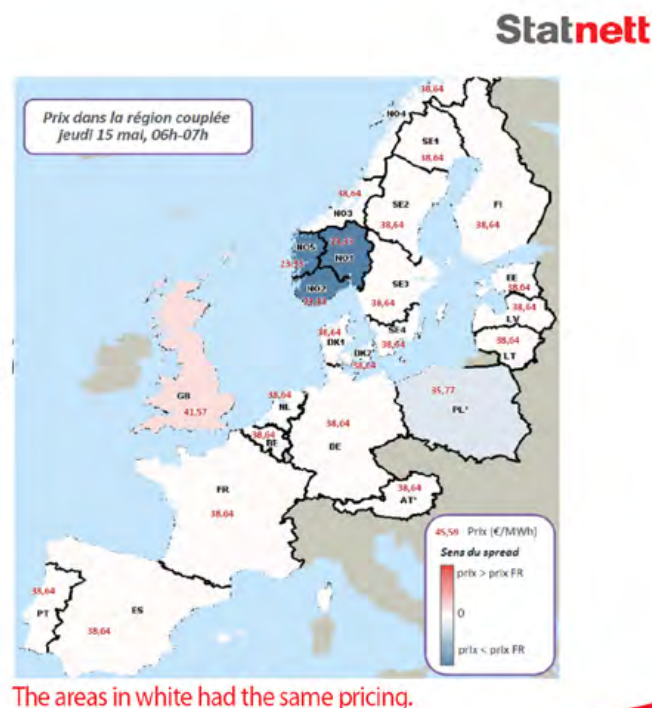
Moderator Antonella Battaglini pointed out that while grid operators often bring up technological solutions to easing regional cooperation, the human side also remains important. She asked Joerg Spicker of Swissgrid to speak to this.

Spicker explained that in Europe, transmission grid operators don’t operate the power market, as is the case in California. A network of power exchanges does.



These exchanges have developed price calculation algorithms and simultaneously allocate capacity and calculate prices for the day ahead and partly for the intraday market.

The same price from North Cape to Gibraltar on May 5 2015



While at times this set up leads to market integration across all or nearly all of Europe, this comes with a hidden “price,” explained Spicker, because the power traders’ commercial flows sometimes deviate from the technical flows, which sets up a challenge for grid operators. For example, Switzerland may technically get an unscheduled flow of wind energy from the northern countries when the wind blows up there, but not commercially because that wind power gets sold somewhere else. Likewise, Italy’s power from the sun regularly technically flows into the Swiss grid but may get sold on the market to another bidder.

To manage this discrepancy, European TSOs have been developing “security cooperation,” said Spicker, in which they all have a common grid model that they operate, each does day ahead grid calculation in their own control center, and then they have a teleconference to work out issues. This requires not just technical knowledge, but understanding of different cultures, languages, and generations. Swissgrid sends staff to CAISO to learn even more different ways of doing things.

In other words, the human factor remains of paramount importance to finding and implementing solutions.

Audience Question 1: Has Norway replaced Switzerland as “the battery of Europe?”

Spicker explained that Norway’s pumped storage mainly serves northern countries in Europe, while Switzerland primarily serves the South – for example, supplying as much as 50% of Italy’s electricity needs. “No spaghetti without Switzerland,” he quipped.

Audience Question 2: What role will storage play in your grids?

The panelists offered three different perspectives:

Boris Schucht shared his view that “it is not black and white.” While he sees batteries coming into the market for frequency control as an example of near term use, he believes most investment in Europe is more of a “marketing” effort by distribution system operators to show proof of concept. Power to gas, in which over-generation of wind power is used to make hydrogen or methane and injected into the gas grid, is another example of a storage solution that is in the testing phase. However, Schucht reiterated that for the transmission grid, he believes central Europe is unlikely to need these storage solutions in significant quantities until there is 70% renewable electricity in the transmission grid, which is not expected for another 15 years. Until then, interconnectivity between regions and using existing pumped storage will be more cost effective. That said, batteries coupled with solar PV for private home use may continue to gain traction sooner.

Joerg Spicker shared that while Europe does indeed have pumped storage in place, a study looking out ten years showed that if solar power generation reaches 40%, about a billion dollars could be saved on grid expansion by installing large amounts of battery storage at only three strategic locations where the grid tends to get congested. This has raised interest in this direction and also the possibility of making the storage – which would amount to 200-300 megawatts – mobile because the congestion locations change seasonally.

Auke Lont added his opinion that well functioning markets with accurate price signals to all market participants, with the addition of IT to help integrate the demand side, can go a long way before investment in battery storage is necessary.

How do you see these developments translating into consumer retail benefits in the next 5–10 years?

Ben Voorhorst cited benefits already seen from his point of view, including price equalization throughout Europe and increased competition. As shares of renewables increase, he added, regional integration and market improvement can help reign in consumer price increases resulting from high capital investment costs of this transition.

Also, he shared that with the right market mechanisms in place, demand response has some of the greatest potential to stabilize the grid in rare weather conditions that could otherwise critically strain the grid, as Europe transitions to high shares of renewable electricity sources. Establishing the necessary, well functioning market requires a long period of time for various players, from households to small businesses and industry, to learn how to respond to market signals. Supporting this process should be a priority of regulators and policymakers, as it can enable the system to handle a very large amount of renewables.



CAISO Stakeholders Symposium Panel

Transition to a Low Carbon Grid: European Perspectives Part II



Panelists: Alparslan Bayraktar, Chairman of International Confederation of Energy Regulators (ICER) & of European Regulators Regional Association (ERRA), Board Member, Energy Market Regulatory Authority (EMRA) Turkey | Andrew Burgess, Associate Partner at Ofgem | Patrick Graichen, Executive Director at Agora Energiewende | Luigi Michi, Head of Strategy and Development at Terna | Eicke Weber, Director of Fraunhofer ISE

Moderator: Michael Liebreich, Founder and Advisory Board Chair of Bloomberg New Energy Finance

The second international panel shifted focus primarily to what the regulatory concerns and solutions are, as European countries adopt ever increasing shares of renewables in the electricity grid. The panel also offered a review of recurring themes brought up over the course of the two-day Symposium.

The panelists' opening remarks are summarized as follows:

Patrick Graichen, Agora Energiewende

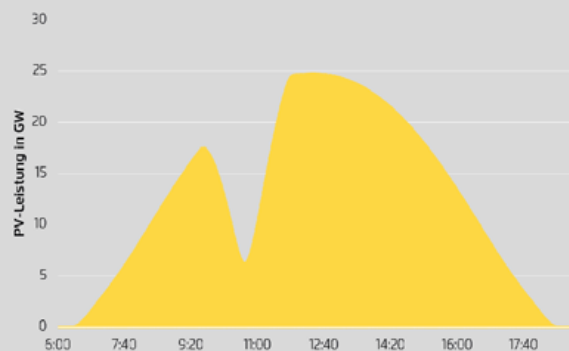
How regulators can prevent over-generation from being a problem.

Graichen reiterated that over-generation doesn't need to be a problem, if markets are set up to encourage flexibility. He shared a chart illustrating what Boris Schucht recounted in his Keynote address, namely that the market responded well to the highly volatile availability of sunshine during the solar eclipse, ensuring that the right the amounts of supply were present from the right sources to keep the grid stable.

How Germany coped with the partial solar eclipse in March 2015

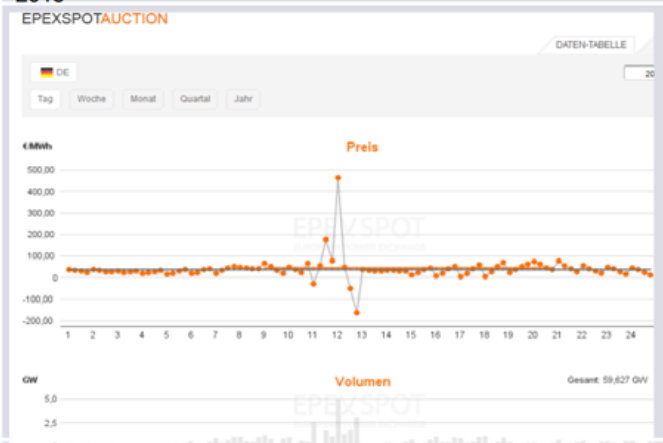


Solar power production on March 20, 2015



Agora Energiewende (2015): Die Sonnenfinsternis 2015

Prices and volumes traded on the Intraday market, March 20, 2015



www.epexspot.com

Dr. Patrick Graichen | Sacramento | 23 October 2015

2

The lesson, Graichen emphasized, is that many entities must participate in the power market, both on the demand and supply sides, and they must "feel their marginal cost." If regulatory systems support this dynamic, he concluded, they will enable flexibility. Specific measures that Germany has taken to encourage the right price signals have so far included allowing for a wide range of pricing from -500 to 3000 euros/MWh, as well as ensuring ample liquidity by including renewable generators in the day-ahead market.

Graichen added that in California, the large numbers of wastewater treatment plants could be a great source of flexibility, as long as they are participating on the same market as other energy players.

Alparslan Bayraktar, ICER*International regulatory perspective*

As Chairman of the international regulator network ICER, Bayraktar brought a perspective that reaches beyond Europe to regions across the globe. He shared that while different regions on various continents may be tackling their own challenges, two main issues are driving energy discussions all over the world: security of supply and climate change. In every region, there must be adequate planning to ensure supply security, and to address climate change, people must figure out new ways of getting and using energy.

The objectives of regulators are clear: to establish competitive, financially viable, stable transparent energy markets that ensure reliable, affordable, environmentally sustainable energy supplies to consumers. It is not, however, easy to achieve.

Regulators can start by asking themselves a series of questions. Echoing themes heard throughout the tour, these questions include:

- How can we make the energy system more resilient and flexible, while maintaining security of supply?
- How do we provide sustainable development through efficient climate change measures?
- How do we create efficient regional market conditions that support industry competitiveness, reliability, and secure supplies?
- How do we increase renewable energy penetration?
- What are the impacts of local prices on energy system flexibility and security?

At the end of the day, Bayraktar shared that he believes we have to end up with harmonized solutions that are effective, economically viable, and politically and publicly acceptable. The European Union's energy policy is attempting to do this with its focus on sustainability by means of implementing renewable energy, efficiency, and competitiveness through market integration on a continental scale. This is no small task, conceded Bayraktar, with 23 different languages to work with and varying levels of market liberalization among participating countries.

To reach these goals, the EU is focusing on using existing infrastructure more efficiently, improving market design, efficient infrastructure planning and implementation, as well as harmonizing guidelines and network codes and monitoring to ensure best outcomes for consumers.

Other areas where regulators can play a substantial role include:

- implementing end user efficiency measures
- developing strong grid networks within and between regions, in order to connect national systems as well as to connect large and prosumer generators to the grid
- providing consumers with information, opportunities for energy savings, protection, and a wider range of choices
- advancing energy storage and smart grid solutions to promote a wider range of market participants, flexibility, and grid reliability

Finally, regulators must focus not only on technical innovation, which is certainly important, but also on social engagement and improving regulators' competency. Educating and engaging the full range of stakeholders with transparent information and dialogue is critical to overcoming resistance and identifying pathways forward. Also important is cooperation among regulators from different sectors – e.g. not just energy, but land use, finance, and environmental protection.





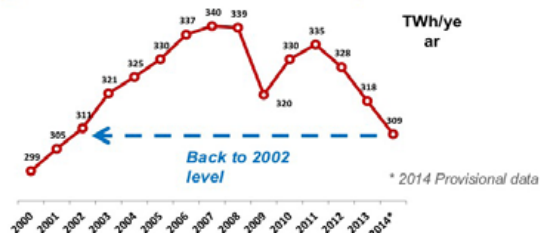
Luigi Michi, Terna

The Italian energy framework evolution

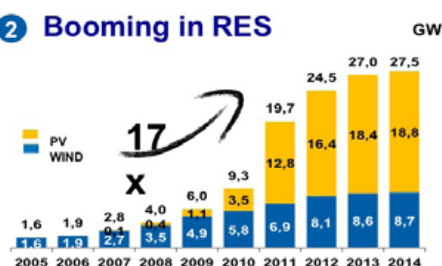
Michi focused his comments on a series of “no return” changes to Italy’s electricity system over the past decade. For one, following the financial crisis, power demand dropped and in 2014 was at the lowest level since 2002. In addition, Italy accumulated a substantial overcapacity of supply. Due to generous incentives, renewable electricity soared to nearly 30 gigawatts of installed capacity, about two thirds of which are solar and most of the rest wind. Simultaneously, while the old oil generating fleet has almost entirely been retired, massive overinvestment in new natural gas generation from around 2004-2012 triggered by misinterpretation of day ahead market signals resulted in about 30 gigawatts of natural gas capacity that has been increasingly sitting idle, with the new combined cycle

Italian energy framework evolution

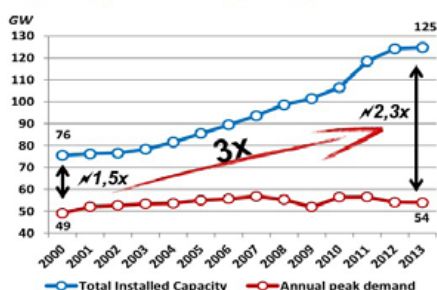
② Post crisis demand drop



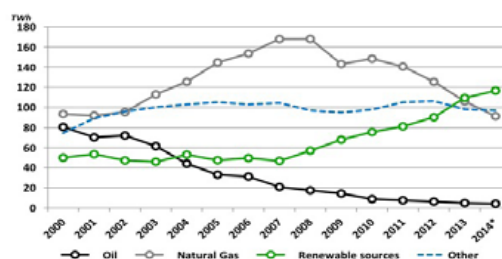
② Booming in RES



② Huge overcapacity...



② ...and a tremendous change in generation mix



➤ Idle gas driven power stations

Generation 2014* vs 2008: **-46%**

➤ Old plant mothballing

Generation 2014* vs 2000: **-95%**

* 2014 Provisional data

units now facing the probability of being shut down.

Although Italy's electricity system is still largely gas driven, natural gas generation is declining, while intermittent renewables are ramping up. This presents a challenge to the TSO, but Michi says he learned over the course of his week in California that almost all TSO/ISOs are going after the same goal: to ensure grid safety and stability while guaranteeing the highest level of renewable integration. And the TSO/ISOs general widespread effort could really make things happen. "The great thing I discovered," he declared, "is I am sharing all the same issues (as) the other TSOs and ISOs, and the only difference is the number of remedies and tools" and the extent to which each should take action.

One helpful tool Italy has in its favor, Michi shared, is the stable presence of large hydropower dating back to the 1960s, plus 7000 pumped storage facilities (see blue line marked "other" in the graph on the lower right hand corner in the above chart.), together with a significant number of last generation CCGT power stations which help to provide flexibility. And flexibility, he emphasized, is definitely the crucial key factor for the future.

Andrew Burgess, Ofgem

The UK Regulatory Perspective

Burgess, an Associate Partner at Great Britain's independent electricity and gas regulator Ofgem, focused his opening remarks on economic regulation, what he perceives to be the role of the regulator, and relevant efforts at Ofgem.

Generally, regulators are "trying to make imperfect markets work in the consumer's interest," said Burgess, as well as "to improve competition, to deal with monopoly elements, and to make sure that the market rules are fit for purpose." Regulators must be careful to match the course of action to the need. "Sometimes doing nothing as a regulator is the best thing to do. Sometimes it's absolutely the worst thing to do." Likewise, intervening can be the right or wrong thing to do depending on the situation and consequences.

"Just as the world is changing... and getting smarter, regulation needs to get smarter."

– Andrew Burgess, Ofgem

How has Ofgem been trying to get smarter?

First, they reviewed regulation of network monopolies, that is, the transmission operators, the system operators, and the distribution companies, and came up with a new framework titled RIIO, which stands for Revenue equals Incentives plus Innovation plus Outputs.¹⁸

¹⁸ For more on Ofgem's RIIO model, please see: <https://www.ofgem.gov.uk/network-regulation-riio-model>
Slightly different arrangements currently apply to the system operator.

Under this framework, the companies receive revenue for an eight-year period, by the end of which they must deliver outputs, but they are free to decide how and when they deliver those outputs, within reason.

Mechanisms are also in place to stimulate innovation, such as competitions for network companies to engage with third party, non-energy sector players to test innovative solutions. To address the bias toward return on capital investment for innovative solutions, they are considering network company operating and capital expenditures together.

Ofgem additionally published a position paper on flexibility.¹⁹ Areas of focus include demand response on the commercial and industrial sides, the regulatory framework and access to market for storage and for aggregators, as well as how the roles of the distribution and transmission networks and system operator ought to evolve to meet all the new challenges and how network tariffs might change in light of flexibility.

Lastly, the regulator conducted a consultation in which they asked a broad range of stakeholders to offer feedback on non-traditional business models and whether there were obstacles in the regulatory or legal system that were stopping them from entering the market and being able to provide consumer services.²⁰ While at the time of the Symposium, Ofgem was still going through the immense response received, Burgess shared that flexibility was a recurring theme.

The message was that regulators need to balance ensuring that rules are kept under review and allow for new entry, while maintaining investor certainty.

Michael Liebreich followed up Burgess' comments by noting that a key difference between Germany and the UK is that in Germany, there is a general acceptance that the energy transition is happening and a good thing, and stakeholders tend to collaborate on moving forward, whereas the UK, somewhat like the US, is very polarized on the issue. He asked Burgess how that impacts his organization's freedom to operate and try new things.

Burgess responded that while Ofgem's regulators need to be conscious of the political environment, they are not impacted on a high level, due to the politically independent nature of the organization and its mission to help consumers. That said, the degree to which government actions, such as incentivizing renewables, are stable or volatile can influence investment choices, so the more certainty from the political level, the better for everyone involved.

¹⁹ See: <https://www.ofgem.gov.uk/publications-and-updates/position-paper-making-electricity-system-more-flexible-and-delivering-benefits-consumers>

²⁰ See: <https://www.ofgem.gov.uk/publications-and-updates/non-traditional-business-models-workshops>

Prof. Dr. Eicke Weber, Fraunhofer ISE

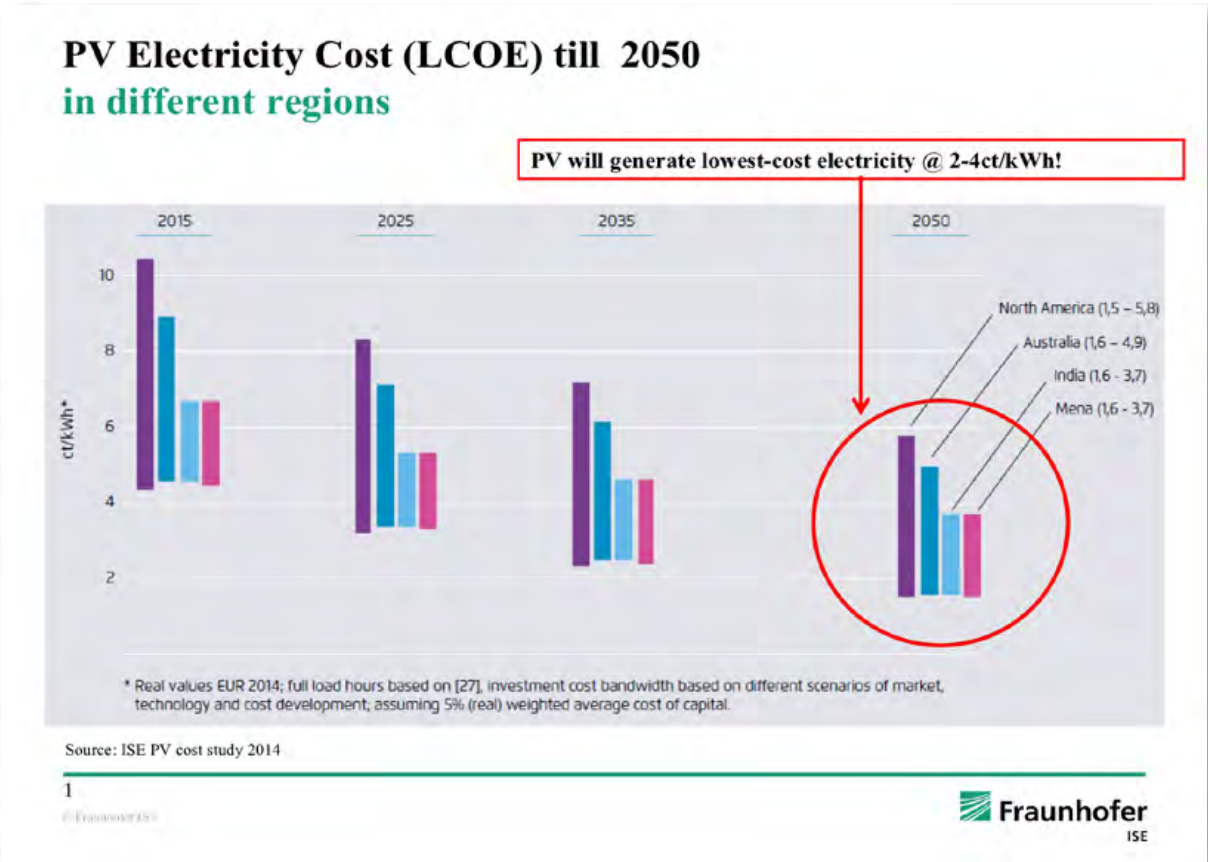
The Future of Solar Energy

Prof. Dr. Weber opened by sharing that in addition to the issues of supply security and climate change already mentioned as driving the global energy conversation is the fact that transitioning to a renewable energy system is “simply the most economical way to go.”

To illustrate, he shared a slide with data combining Fraunhofer ISE’s knowledge of technology development and of the solar PV electricity price degression curve from 2014 to 2050.

In 2015, solar PV electricity in sun rich conditions cost as little as approximately 5 or 6 cents/kWh, and by 2050, this cost is forecasted to drop to as low as 2 cents/kWh.

Only perhaps old hydropower plants will be that cheap, said Weber. Even as an optimist on solar, he added, he always underestimated over the past decade how quickly the prices would come down.



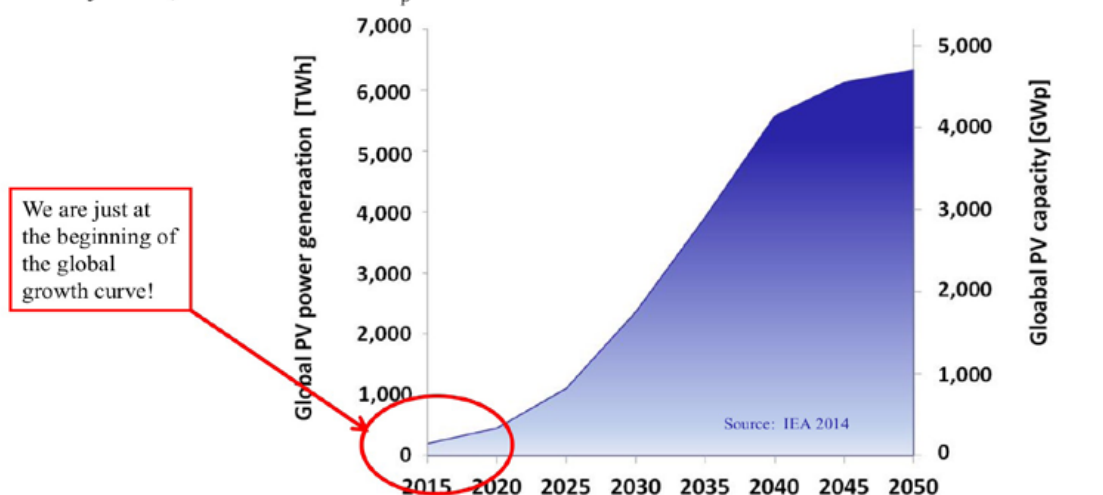
Weber argues that with solar increasingly proving to be such a safe, cost-effective energy choice, it will become ever harder to justify, for example, the UK’s plan to build a new, large nuclear power plant that requires a guaranteed price of 11 cents/kWh with inflation adjustment for the next 35 years that will drive the price up even higher.

Because of its environmental and economic attributes, as well as its flexibility and scalability, solar PV installations are expected to continue to rise over the next decades. Weber cited a prediction from the traditionally conservative International Energy Agency (IEA) that there will be nearly 5000 gigawatts of installed capacity by 2050, although he explained that this is if PV covers only 5% of the world's energy need, which he believes is an underestimation.

Weber predicts that the world will see closer to 30,000 gigawatts of solar PV installed by 2050. Given that today, there are less than 200 gigawatts of solar capacity, the biggest growth is yet to come.

PV Market Growth (IEA 2014)

- Rapid introduction of PV globally is fueled by availability of cost-competitive, distributed energy
- In 2050 between 4.000 and 30.000 GW_p PV will be installed!
- By 2015, less than 200 GW_p have been installed!



2

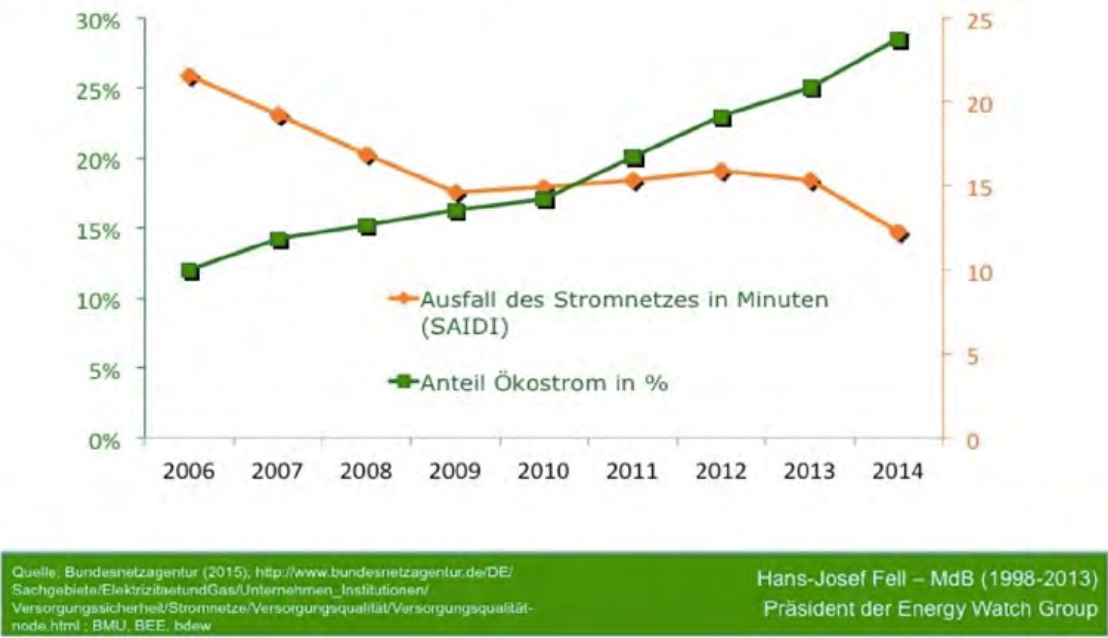
© Fraunhofer ISE

Weber questioned which countries will be prescient enough to know where we are headed. He criticized Germany, for stopping its PV market in recent years, despite having been the global frontrunner on solar PV adoption. "We are down to a 1 gigawatt market," he lamented.²¹ The United States and China are seeing PV growth, he observed, although he added that the latter is fairly saturated. Weber reported that the world market, which is currently at 50 gigawatts of annual production, is expected to double to 100 gigawatts/year by 2020, which means over the next five years, we will need to add the same amount of production capacity as was built over the past twenty years. Weber says that we are, therefore, at the dawn now of "the second wave of photovoltaics."

²¹ In previous years, before the feed-in tariff prices were drastically reduced, Germany installed far greater amounts of solar PV annually. For example, in 2012, 7.6 gigawatts of new capacity were installed, in 2011, 7.5 gigawatts were installed, and in 2010, 7.4 gigawatts were installed. <http://www.reuters.com/article/us-germany-solar-idUSBRE90406C20130105>

Lastly, he reaffirmed that fears of grid instability with higher penetrations of renewables have so far not been justified. He shared data showing that in Germany, disruptions on the distribution grid actually decreased from 2006 to 2014, while the share of renewable electricity, most of it from intermittent sources, more than doubled. What we should be more worried about is the problem of stranded assets for those who are overinvesting in conventional generation.

Grid stability with growing amounts of fluctuating RE:
Grid in Germany today more stable than in 2006!



Discussion

Is coal killing the German Energiewende?

To kick off the interactive discussion, Liebreich invited Patrick Graichen to respond to a common belief that comparatively low carbon natural gas has been tending to get pushed out of the market in Germany instead of dirty coal.

“There are lots of myths all around,” according to Graichen, one of which is that the Energiewende is driving up CO₂ emissions in Germany.

What’s happened in all of Europe, he explained, is that because coal is so cheap, because gas prices have not been falling in Europe as they have in the US, and because the EU emissions trading scheme is not delivering, in countries where there is both coal and gas, coal is outcompeting gas.

“The good news,” he added, is that the tide is turning, and “emissions are decreasing. 2014 emissions in Germany are down again,” and the same is true all over Europe. He believes that while increasing renewables is part of Europe’s job, the other is to eliminate coal.

Graichen commended the UK for establishing a CO₂ price floor of 18 £ (approximately \$23) per tonne, a significantly higher amount than the European Union’s current CO₂ price, which has been averaging around only 8 euros (a little over \$8) per tonne. He said that the UK’s domestic price floor, which is added on top of Europe’s price, is about where we need to be on CO₂ pricing, stating that with \$30 per tonne of CO₂, we would see considerable CO₂ reductions taking place.

How will the UK deal with the planned inflexible block of new nuclear power, given the rising amounts of intermittent solar and wind?²²

While no one on the panel was willing to defend the plan of building the new UK nuclear power plant, Burgess did emphasize that if it is implemented, regulators will need to be sure the system is able to cope with this challenge and to figure out how to deal with the contradicting needs of nuclear power, which might in the future require more transmission grid infrastructure to export the power away from the facility, and of flexible renewables, which require less grid infrastructure. This will necessitate getting a wide range of industry views and ensuring that the framework is flexible enough to deal with different situations.

²²
The UK is moving forward on building a new nuclear power plant Hinkley Point C, with several others being planned. See: <http://www.energy-uk.org.uk/energy-industry/nuclear-generation.html>

How do we encourage innovation and flexibility without destroying investor confidence, which requires long term certainty?

Burgess shared that we can't know what all the new market entries will be, and regulators should not foreclose these solutions. Within the UK's regulatory framework, there are uncertainty mechanisms that ensure that where there is uncertainty and an upfront decision can't be made, the regulator states what they would do under changed circumstances.

Liebreich challenged the panel to think of whether, rather than trying to perfect the job of regulating, stopping might work better. He brought up the example of the 1980s telecom industry, in which the industry conceded that anticipating all the services was impossible and promised to be open to new market entrants and to allow the market to develop to the greatest extent possible, essentially getting out of the way. Could this hold clues for how to regulate the energy transition?

Burgess responded that he agrees regulators should not leap to regulate every new market entrant. At the same time, a challenge in the UK and elsewhere, he added, is that there are "existing industry and commercial rules that have been developed with the existing market structure, so doing nothing means that those market rules will get in the way of new entry. So the basic job is removing the undue barriers in those market rules and then hoping that new entry comes in, and if it doesn't, being prepared to look again at some of those rules to make sure things do happen."

Bayaktar acknowledged that regulatory barriers are a major concern, recalling that when the audience at the 2013 BNEF Summit he attended in New York was polled on what the biggest obstacle was to energy investment, the majority answered regulatory risk. He added that with experts like the IEA concluding that massive investment is needed over the coming decades to address climate change and ramp up renewables – indeed more than what countries are currently cumulatively pledging to – encouraging robust investment is critical. Regulators are the ones who attract private capital, so "we need to have a concerted effort to remove the barriers and to reduce this political and regulatory uncertainty...The regulator sometimes doesn't understand the real market dynamics...so I think it is better not to intervene very often and to create a more level playing field for the market players," he stated.

Michi added that from the TSO perspective, there is a concrete possibility of successfully enabling a large fleet of renewables coming into the market while maintaining investor confidence. To achieve this balance, he asserted that two guidelines must be followed: First, interconnections must be strengthened, and second, the market must be properly designed to more closely respond to real time requirements and to give renewables full opportunity to participate with the right short-term signals. Some long-term market signals, he added, are also important to encourage people to make the right investment decisions.

Therein lies the challenge – how to “square the circle” of getting the electricity system reacting on the minute basis, while allowing for the long-term contracts and commitments needed to attract investment in infrastructure.

Concluding remarks

To conclude, Liebreich encourage the panelists to share any points that had not yet been touched upon.

Prof. Dr. Weber stressed that the kind of exchange experienced on the EU-CA Energy Regions in Transition Tour and on the 2014 Learning and Collaboration Tour to Germany that he helped Renewables 100 Policy Institute organize for California energy leaders, is of great importance. It helps frontrunners like California and European countries to strengthen each other in the face of international pressure and incumbent stakeholders who are worried about losing their business models. Such exchanges of best practices on technical, administrative, and regulatory solutions, and the political and societal support this builds ought to happen on a recurring basis.

Bayraktar added that empowering women is key to achieving all the goals discussed throughout the Symposium. ICER is developing an initiative to increase the participation of women in the energy field across the board, from industry to regulation to politics, and he invited all women at the conference to get involved.²³

Graichen added that a question that was not addressed and should be next time is what our regulations and new tariff structures should be in a world where solar power is only a couple cents per kilowatt hour, and there is lots of homegrown electricity. “Regulators should not even think about regulating against that, but rather (should be) embracing it” and figuring out how this new world can work.



²³ For more information, see www.icer-regulators.net or www.naruc.org

CAISO Headquarters Tour

The delegation concluded their tour with a visit to the CAISO headquarters, located in Folsom, CA. There, they witnessed first-hand how the CAISO manages a large Balancing Area with a fleet of 750 utility-scale generators and an increasing amounts of renewable and distributed generation to maintain reliability across an expanding footprint of operation. They also learned how market operators run the integrated forward market and optimize the dispatch of generation every fifteen minutes to serve real-time demand. Of equivalent interest, delegates toured the CAISO business offices which, as much as the renewable fleet of generation it operates, reflects the CAISO's commitment to environmental stewardship

Starting with the facility, the LEED Platinum, state of the art headquarters is a relatively new facility into which the ISO relocated in 2012 after outgrowing their prior headquarters that could no longer serve their technology and security requirements. At the time, the CAISO had the opportunity to custom-design new offices to meet the multiple objectives of environmental responsibility, need for an advanced control room to support reliable grid operation with the latest cutting edge tools and superior situational awareness, compliance with rigorous new physical and cyber-security requirements of the U.S. Department of Homeland Security (DHS) and the North American Energy Reliability Corporation (NERC), the need for a work environment that provides comfort and productivity to attract and retain a world-class workforce, and accomplish all of this within a tight and publicly scrutinized budget. The result is a showcase of sustainability and operating efficiency.





Outdoor features include 750 kilowatts of solar panels covering carports and rooftops, preferred parking for low-emitting fuel-efficient vehicles and carpools, and a dozen EV charging units with more being planned. Underground aquifers are replenished with reclaimed water, and grey water from sinks help to supply the irrigation needed for drought-tolerant landscape. The facility also uses Thermal Energy Storage, wherein a 250,000 gallon thermal storage tank holds water that is chilled during off-peak periods and used to cool the building during business hours. Indoors, controllable energy efficient task lights at workstations save energy, an underfloor ventilation system with individual workstation controls channels chilled air for individualized employee comfort, windows cover the entire span of north and south facing exterior walls to provide natural lighting, and specially-designed window shading devices disperse sunlight to all interior workspaces and meeting rooms and reduce heat gain.

The new facility enabled the CAISO to lower its electricity usage by 60%²⁴, and its water usage by more than 80%²⁵. Moreover, the LEED platinum facility also meets all the safety and security requirements for facilities deemed critical infrastructure by the U.S. Department of Homeland Security, demonstrating that sustainability, security, and employees comfort can coexist.

The majority of CAISO’s 585 employees work in the Folsom headquarters. Of those, approximately 25 work in the CAISO’s secondary facility in Southern California, located approximately 650 km to the south of its Folsom headquarters. Those remote staff will soon relocate to a new backup facility located 35 km to the north of the Folsom headquarters in a move that creates cost savings while simultaneously continuing to provide the functional redundancy and physical separation required of a backup facility.

.....
24 *Watts per square foot reduced from approximately 7.7 to 3.2*
25 *Gallons per year reduced from approximately 1.23 million to 0.8*



The highlight of the visit was the tour of the CAISO control center, one of the most modern in the world. There, the CAISO operates 42,000 kilometers of transmission lines and optimizes the dispatch of 65 gigawatts of generating capacity through the only organized energy market in the western United States. The delegation witnessed how advanced computing software and hardware evaluate and clear thousands of bids for energy and capacity, every 15 minutes, using a full network model with over 5,000 nodes representing the current grid and topology (including all outage information) to produce a security-constrained economic dispatch. Among its many other state-of-the-art features, the CAISO control center in Folsom piloted the first renewables dispatch desk in the country, which enables the grid operators to better integrate large amounts of renewables. High-tech visual displays allow operators to quickly take in vast amounts of information, and the Energy Management System (EMS) is the most advanced in the industry.

Delegates became acquainted with sophisticated tools designed to ensure reliability and visibility. With an extensive array of high-speed synchro-phasors collecting data dozens of times per second, complementing the existing array of hundreds of thousands of field sensors transmitting data from Remote Telemetry Units (RTUs) and Remote Intelligent Gateways (RIGs) every four seconds, CAISO operators enjoy superior situational awareness and flexibility to display that data. Using the data historian and display tool PI, the CAISO can quickly develop or refine displays allowing operators to convert raw data into actionable information and visualize the data any way they might require.

The need for additional data has multiplied in recent years in response to new requirements from the North American Energy Reliability Corporation requiring greater data exchange and situational awareness of operations by neighboring Balancing Authorities. Similarly, the Energy Imbalance Market, joined by participants from 6 neighboring states (with more contemplating participation) sees each new participant providing real-time data from tens- and hundreds of thousands more data points.



Key Takeaways

During the tour, three major themes recurred among the grid operators present:

- **Larger electricity markets** result in lower costs and are better able to accommodate more renewables;
- **Balancing Area consolidation** improves reliability and increases efficiencies, thereby reducing costs.
- **More transmission is essential**, in order to share resources and support larger markets.

The following is the broader list of key takeaways from the delegation discussions that are recommended to inform future planning:

1. **California and European countries are facing many common challenges in their efforts to decarbonize the grids and share growing and widespread optimism about identifying and implementing solutions.**

The main foundational takeaway was that although different regions and nations have varying regulatory, legal, geographic and cultural landscapes and approaches, transmission grid operators, regulators, and policymakers in both California and Europe are essentially dealing with many common identifiable challenges, as they plan the power grid of the future. The majority of Delegates also agreed that whereas skepticism was the rule only a few years ago, there now seems to be an overwhelmingly positive attitude about finding effective solutions to the challenges of operating an emissions-free energy system. As one European TSO summed up, he started the tour thinking that the energy transition is full of “challenges” and ended seeing instead that it’s instead full of “opportunities.” The main opportunities identified are elaborated upon below.

2. **Expanding a regional approach to grid operation is strongly needed to successfully decarbonize the transmission grid.**

One of the most persistent big ideas emerging from the Tour discussions was that systemic regional grid integration and collaboration is strongly needed to decarbonize the electricity system. Repeatedly, participants from multiple sectors shared that a well-coordinated regional strategy with a wider geographic footprint presents a major opportunity to more efficiently and cost effectively operate a grid that relies on high percentages of renewables.

The concept of regionalism is nothing new in Europe. For example, regional grid cooperation dates back to the 1960s in Norway as a solution to supplying cost-effective reliable power, and today, the Nordic Exchange is a well functioning market that includes all Nordic countries and also collaborates with neighboring countries. Likewise, in the late 1980s, Europe decided that an internal single European market would be more cost-effective for consumers, which prompted the beginning of a European Union policy to work toward a competitive, fully interconnected single internal energy market.²⁶ Despite 23 languages, the Europeans manage to balance the common market that has so far been established.

Such thinking is not unique to Europe. CAISO staff similarly emphasized that regional collaboration will be the most cost effective solution to integrate high penetrations of renewables in California.

With strengthening and expanding regional cooperation come many issues to address along the way on both sides of the Atlantic, including resolving questions of governance, harmonizing discrepancies between commercial and technological flows of electricity, building public acceptance, ensuring climate protection, and ensuring economic benefits.

All participants agreed they would collectively benefit from periodic review, adjustment and exchange of experience around their efforts to expand regional collaboration. Specific efforts on which to focus include the EIM and Regional Energy Market in California and the single internal energy market and in the European Union.

3. Upgrades must be made to grid infrastructure to ensure maximum efficiency.

The need for technical upgrades to grid infrastructure was also discussed. To prevent congestion on the grid and ensure that electricity is efficiently and cost-effectively transmitted, grid infrastructure must be planned, coordinated and optimized with a long term view that focuses on integrating renewables and advanced grid technologies on a regional basis.

4. Deeper inter-regional and international collaboration is needed on specific best practices for technically integrating renewable energy sources and complementary new market players onto the grid.

While regionalism is key, there are still many technical questions regarding how to most efficiently integrate renewables and other new - sometimes disruptive - technologies like storage and smart technologies into the grid. All agreed that to succeed in this common goal, renewables and complementary technologies need to be “good citizens” of the grid that enable flexibility.

²⁶ For more details on the EU's efforts toward a single internal energy market, please see: <https://ec.europa.eu/energy/en/topics/markets-and-consumers/single-market-progress-report>

To encourage smooth grid integration of clean energy technologies, we need to ensure:

- all resources are dispatchable
- accurate forecasting of resource availability
- renewables are used instead of fossil fuels to integrate renewables
- best use of existing infrastructure
- resource diversity
- investment in long term solutions (e.g. utility scale storage)
- avoidance of stranded assets, including efficient ways to prevent curtailment of renewables
- development and application of smart technologies, such as integrated communications technologies (e.g. demand response technologies, energy management technologies) and sensing and measurement technologies (e.g. PMUs, advanced metering). Digitizing of operations will increasingly be part of better managing new sets of data and analytics.

Clearly different countries and regions have varying degrees of experience with integrating a fast paced schedule of variable resources, as well as different strengths. Different approaches can also broaden perspectives. Learning from one another's analyses and experiences stands to enable everyone to make better decisions.

5. Further collaboration is also needed to identify, track, and strengthen business models of the future, which will require greater horizontally and vertically integrated planning.

Integration, coordination and visibility on the grid are going to be increasingly important on a horizontal (regional, wider footprint), as well as vertical (entire supply chain of the distribution networks down to the consumer's meter) level, as new customer-owned technologies installed on the distribution system have a growing ripple effect on transmission grid operations. Examples of such new technologies include distributed power generation, such as that from rooftop solar arrays, efficiency technologies, and storage. As these new sources impact daily utility/distribution company operations, new business models will be needed to enable fluid information and data exchange across the board.

6. Regulators and policymakers around the world must strengthen their capacity to respond to rapidly developing clean electricity technologies and consumer demand.

As we implement the grid of the future, all participants recognized that the political, policy and regulatory frameworks will either make or break this effort. There was strong consensus that creating frameworks that support rather than inhibit the energy transition being successfully executed by all stakeholders, including commercial and residential consumers, all sizes of producers, and local communities, is one of the biggest challenges in every region around the world. Striking the right balance is made all the more difficult by the typical slow pace of regulatory and government processes compared to technology development and consumer readiness. To overcome this critical challenge, regulators and policymakers must strengthen their capacity to respond to rapidly developing clean electricity technologies and consumer demand. Five key principles were identified as particularly important to apply:

- **Make long-term clean energy and climate goals and keep them in clear view.**
- **Maximize long-term frameworks to support those energy and climate goals, and minimize stop and start policies and regulations.**
- **Build flexibility into regulatory frameworks, so they can quickly adjust to a future with many unforeseeable innovations and developments.**
- **Ensure that energy markets are transparent, accountable, competitive, even playing fields open to a broad spectrum of participants, including prosumers.**
- **Continue to strengthen dialogue between regulators and stakeholders, in order to identify lessons learned and best practices, and to prevent conflicts down the road.**

“The communication and (inter-regional) cooperation between all stakeholders... not only regulators, but also industry (and) consumer groups is very...important. This trip is very much addressing these needs...At the end of this week, I can say it (was) worth it because... we are in an age of change, of innovation,...(and) the most difficult part (is) the regulators, the public administrations...We should be more open to understand what is happening and how it will affect the energy markets...and I think (this tour) was the right place to see these developments.”

– Alparslan Bayraktar, Chairman, International Confederation of Energy Regulators (ICER), Chairman, Energy Regulators Regional Association (ERRA)

7. **The energy transition specifically requires two sets of policy and regulatory mechanisms: one to transform the energy system, and the other to ensure efficient and reliable running of the energy system.**

The energy transition around the world requires two basic sets of policy and regulatory solutions: One to encourage transformation of the energy markets and investment in the required new technologies, and another to enable the actual running of the system. While an all-renewables based system could possibly someday be purely market driven, most regions are not there yet. Therefore, incentives and fee structures that ensure ongoing investment in transforming the system must in the meantime continue to be in place. At the same time, operating and continuing to develop an efficient, flexible power market that can deliver reliable, cost effective energy to consumers must remain a primary mandate for all grid operators. All participants agreed that no one has the silver bullet, but that continued exchange would up everyone's know how and likelihood of success.

8. **Stakeholders must be engaged in transparent transmission grid planning from the start.**

Engaging stakeholders early on is an important aspect of a successful initiative, including making the transmission grid ready for a decarbonized energy future. Fine-tuning such practices and learning from each other's experience will help all improve transparency and make educated decisions.

9. **The energy transition is cross-sectorial, and further collaboration and exchange among frontrunners is needed to better understand, navigate, and indeed create this new energy playbook.**

While pathways for reaching 30-40% renewable electricity goals are becoming more common and better understood, the playbook for how to go beyond this to fully decarbonize not just the electricity grid, but the entire energy system is in the midst of being written, with no one having all the answers yet. One thing clear to all participants is that along the way, the electricity market is increasingly integrating with other energy sectors, such as transportation, heating and cooling. Moreover, the energy sector is increasingly integrating with other industrial sectors, such as buildings, water, and telecommunications. Anticipating these developments and positioning market and regulatory rules to support their integration is needed to help accelerate the transition to a zero carbon grid. Collaboration and knowledge exchange between regions and countries, as well as between sectors, is essential to ensure a faster and more successful effort.

10. The international multi-stakeholder dialogue on the Tour needs to be institutionalized into a long-term, regular exchange.

By the end of the Tour, there was broad consensus that the tour was an unusual and highly useful gathering of minds from many sectors and that this multi-stakeholder, international exchange ought to be more of a beginning than an end. Nearly every participant shared that institutionalizing this exchange into an established, high-level process for sharing experience, knowledge and technology solutions on a regular basis would be an important step toward the common goal of transitioning to a post-carbon energy system. Suggestions for the structure included a mix of formal exchanges, such as that which took place at the CAISO Stakeholders Symposium, as well as less formal meetings, such as the kinds of roundtables that took place on the tour, working groups on specific issues, and virtual meetings and teleconferences to enable more frequent long distant dialogue. Many participants additionally expressed interest in eventually including other regions that are working on their own energy transition efforts, such as China, India, Brazil, South Africa, and other U.S. states.

“I think it is extremely useful to build..on what we have created and to make it...a continuous process because...the tasks and the problems change,...and we can share experience, we can share best practices. This will be a process that will take us another twenty, thirty years, and I think what we’ve created here (should) really continue and be a strong exchange...” – Prof. Dr. Eicke Weber, Director of Fraunhofer Institute of Solar Energy Systems (ISE)

“There needs to be a continuation of this dialogue. It doesn’t make sense to come here every two or three years, and vice versa. That’s not enough. We need to do this on a regular basis, maybe in some shape or form institutionalized. Getting together as the CEOs or the operative people is very important.”

– Joerg Spicker, Head of Market Operations, Swissgrid

“I have already learned a lot during this trip to California...No one of us has the silver bullet nor the master plan. That’s why it’s so important to learn from each other.” – Boris Schucht, CEO, 50Hertz

Conclusion

The Tour provided a unique opportunity for European and California energy leaders from multiple sectors to identify challenges and opportunities related to decarbonizing the electricity system, a collective effort with far reaching global value.

Among the critical areas of focus were expanding regional cooperation, integrating renewables and other disruptive technology market entrants, developing new business models, new cross-sectorial relationships (e.g. between energy, transportation, water, building environment, etc.), and implementing related regulatory frameworks.

Whereas only a few years ago, discussions on such issues may well have been fraught with doubt and apprehension, the tone on the Tour was optimistic and positive. While not shying away from the tough questions, Delegates shared a general sense of confidence that these questions can be tackled.

The consensus by the end of the Tour was that a widespread initiative building on the work with the EU-CA Energy Regions and Transition Tour will be key to success. This work is currently lacking and would be relevant and necessary not only for the Tour participants, but also for new large entrants into the energy marketplace, such as Brazil, Indonesia, Russia, China, India, Eastern Europe, and other US states, as they transition to a lower carbon energy system.

The need for such a comprehensive initiative was underscored by the Paris COP21 Agreement and the international call to keep temperatures well below 1.5 to 2 degrees Celsius above pre-industrialized levels by 2050. This urgent global priority must include a front and center focus on the grid infrastructure, both existing and that which is planned for the future. Only by optimizing grid related technology, governance, regulatory frameworks, and markets will we be able to globally transition to the greenhouse gas neutral energy systems necessary to protect our climate, with the speed, reliability, efficiency, investment, and low costs required.

Attachments

Attachment A

Glossary of Technical Terms

Attachment B

List of Delegates & Organizers

Attachment C

Agencies With Jurisdiction Over California Electricity

Attachment D

Tour Schedule

Attachment E

Side By Side Comparison of Key Climate & Energy Targets in European Union & California

Attachment F

Comparison of Key Electricity Data in European Union & California

ATTACHMENT A – GLOSSARY OF TECHNICAL TERMS

Ancillary Services – Refers to a variety of services, other than generation and transmission, that help ensure grid stability and security, such as frequency control, spinning reserves and operating reserves. The Federal Energy Regulatory Commission (FERC) identifies the following 6 types of ancillary services: scheduling and dispatch, reactive power and voltage control, loss compensation, load following, system protection, and energy imbalance.

Control Power Market – Control Power refers to the power that transmission system operators (TSOs) in Germany keep to maintain stable and reliable supply. Demand for control energy is created when total power generated on the transmission system varies from the actual load (due to unforeseeable weather fluctuations in the case of renewable energies). Primary control, secondary control, and tertiary control reserve are procured by the respective TSOs within a non-discriminatory control power market (www.regelleistung.net) in accordance with the requirements of the Federal Cartel Office.

Duck Curve – The CAISO defines this commonly used expression, which stems from one of its forecasting models, as follows: “Net load is the difference between forecasted load and expected electricity production from variable generation resources. In certain times of the year, these curves produce a ‘belly’ appearance in the mid-afternoon that quickly ramps up to produce an “arch” similar to the neck of a duck—hence the industry moniker.”ⁱ

Renewable Curtailment – The practice of turning down renewable power generation, generally to relieve congestion on the grid. Economic curtailment refers to when generation is turned down automatically in response to market conditions. Manual curtailment typically refers to when a plant operator manually turns down generation in response to a request from the grid operator.

Secondary Voltage Control – Secondary voltage control (SVC) was introduced in some European countries to improve power system voltage security and operation. It is a closed loop system dedicated to keep the voltages of some load buses, called pilot buses, constant.

ⁱ See: https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

LIST OF EUROPEAN DELEGATES & TOUR ORGANIZERS

EUROPEAN DELEGATION

1. Alparslan Bayraktar – Chair, International Confederation of Energy Regulators (ICER) & European Regulators Regional Association (ERRA) / Board Member, Energy Market Regulatory Authority (EMRA) Turkey

ICER is a voluntary framework for cooperation between energy regulators from around the globe. ERRA is a voluntary organization comprised of independent energy regulatory bodies primarily from the Central European and Eurasian region, with Affiliates from Africa, Asia the Middle East and the USA. EMRA is an independent authority responsible for the regulation and supervision of the Turkish electricity market

2. Andrew Burgess - Associate Partner, Ofgem

Ofgem is the Office of Gas and Electricity Markets in Great Britain. They are a non-ministerial government department and an independent National Regulatory Authority, recognised by EU Directives. The department's principal objective when carrying out their functions is to protect the interests of existing and future electricity and gas consumers.

3. Olivier Feix – Chief Communication Officer, 50Hertz

50Hertz is responsible for the operation, maintenance, planning, and expansion of the 380/220 kilovolt transmission grid throughout the northern and eastern part of Germany, running approximately 10,000 km and reliably supplying power to around 18 million people.

4. Patrick Graichen, Executive Director, Agora Energiewende

Agora Energiewende is a non-profit think tank and policy laboratory that develops scientifically based and politically feasible approaches for ensuring the success of the German Energy Transition, aka “Energiewende.”

5. Hervé Laffaye – Deputy Chief Executive Officer, RTE

Rte, an independent subsidiary of partially publicly-owned Électricité de France (EDF), is the sole transmission system operator for high and extra-high voltage electricity in metropolitan and continental France. With nearly 105,000 km of lines, RTE's grid is the biggest in Europe.

6. Harry Lehmann – General Director, German Federal Environmental Agency (UBA)

Since its founding in 1974, the UBA has been Germany's main environmental protection agency. Dr. Lehmann's Division's sphere of responsibility encompasses sustainable development strategies, climate protection, energy, traffic and noise pollution.

ATTACHMENT B – LIST OF DELEGATES & ORGANIZERS

7. Auke Lont – CEO, Statnett

Statnett is the state-owned transmission system operator in the Norwegian energy system, operating about 11 000km of high-voltage power lines and 150 stations all over Norway.

8. Henrik-W. Maatsch – Policy Advisor Climate and Energy, World Wildlife Fund (WWF) Germany

The global non-profit WWF, which works in over 100 countries, and has branches in many nations, is one of the world's largest conservation organizations.

9. Luigi Michi – Head of Strategy and Development, Terna

Terna is the Italian Transmission System Operator, whose main shareholder (30%) is the State, and is actually the biggest independent TSO in Europe, managing and operating more than 80,000 high voltage (HV) power lines

10. Jörn Rauhut – Department International Energy Policy, German Federal Ministry for Economic Affairs and Energy (BMWi)

The central priority of economic policy - and therefore of the Federal Ministry for Economic Affairs and Energy - is to lay the foundations for economic prosperity in Germany and to ensure that this prosperity is spread broadly throughout the population.

11. Boris Schucht – CEO, 50Hertz

50Hertz is a privately held TSO responsible for the operation, maintenance, planning, and expansion of the 380/220 kilovolt transmission grid throughout the northern and eastern part of Germany, running approximately 10,000 km and reliably supplying power to around 18 million people.

12. Joerg Spicker, Head of Market Operations, Swissgrid

Swissgrid is the publicly held operator of the Swiss transmission system with responsibility for the operation, security and expansion of the 6700 km long high-voltage grid.

13. Ben Voorhorst – COO, TenneT

TenneT is a leading European electricity transmission system operator with activities in the Netherlands and in Germany.

14. Eicke Weber – Director, Fraunhofer Institute for Solar Energy Systems (ISE)

With a staff of about 1200, Fraunhofer ISE is the largest solar energy research institute in Europe.

15. Christoph Wolff – Managing Director, European Climate Foundation

The European Climate Foundation (ECF) – a ‘foundation of foundations’ – was established in early 2008 as a major philanthropic initiative to help Europe foster the

ATTACHMENT B – LIST OF DELEGATES & ORGANIZERS

development of a low-carbon society and play an even stronger international leadership role to mitigate climate change.

16. Edoardo Zanchini – Vice President, Legambiente

Legambiente (League for the Environment) is a non-profit association based in Italy, with a mission to make the environmental culture the center of a new kind of development and diffused well-being. Important values for the association are the improvement of environmental quality, the fight against all forms of pollution, a wise use of natural resources, the construction of a more balanced relationship between human beings and the nature.

ORGANIZERS

Renewables 100 Policy Institute (US)

Matthias Bank, Outreach and Media Director
Angelina Galiteva, Founder, Board Chair
Diane Moss, Founder, Director

The Renewables 100 Policy Institute is a US non-profit organization founded in 2007 with a mission to study and accelerate the global transition to 100% renewable energy in ways that are most efficient, cost effective, reliable, ecological, and economically beneficial for the most people.

Renewables Grid Initiative (EU)

Antonella Battaglini, CEO
Stephanie Batjer, Project Manager
Theresa Schneider, Senior Project Manager

The Renewables Grid Initiative (RGI) is a unique collaboration of NGOs and TSOs from across Europe. They promote transparent, environmentally sensitive grid development to enable the further steady growth of renewable energy and the energy transition. RGI members originate from a variety of European countries, consisting of TSOs from Belgium (Elia), France (RTE), Germany (50Hertz, Amprion and TenneT), Italy (Terna), the Netherlands (TenneT), Switzerland (Swissgrid), Norway (Statnett) and Spain (REE); and the NGOs BirdLife Europe, Climate Action Network (CAN) Europe, Fundación Renovables, Germanwatch, Legambiente, Natuur&Milieu, the Royal Society for the Protection of Birds (RSPB) and WWF International. RGI was launched in July 2009.

Description of Energy Agencies Mentioned in Report With Jurisdiction Over California Electricity Industry

The following are the entities mentioned in this report with some type of jurisdiction over California's electricity industry.

State Level

California Public Utilities Commission (CPUC)

The CPUC regulates privately owned electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation companies in the state of California. Among other bodies regulated by the CPUC are investor-owned electric utilities (IOUs) operating in California, including Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), San Diego Gas and Electric Company (SDG&E), together which serve over two-thirds of the total electricity demand throughout California. The CPUC has jurisdiction over regulating distributed generation by the IOUs.

www.cpuc.ca.gov

California Energy Commission (CEC)

The CEC leads California's energy policy research, analysis and planning. The agency has seven primary responsibilities: Forecasting future energy needs; promoting energy efficiency and conservation by setting the state's appliance and building energy efficiency standards; supporting energy research that advances energy science and technology through research, development and demonstration projects; developing renewable energy resources; advancing alternative and renewable transportation fuels and technologies; certifying thermal power plants 50 megawatts and larger; and planning for and directing state response to energy emergencies.

www.energy.ca.gov

California Independent System Operator (CAISO)

The California Independent System Operator (CAISO) oversees the operation of 80% of California's and a small part of the state of Nevada's transmission lines, as well as facilitates the competitive wholesale power market in which its electricity industry members participate. An independent non-profit public benefit corporation, the CAISO is the only independent grid operator in the western US. It states that it "grants equal access to 26,000 circuit miles of power lines and reduces barriers to diverse resources competing to bring power to customers." The CAISO also forecasts electrical demand every five minutes, "accounts for operating reserves and dispatches the lowest cost power plant unit to meet demand while ensuring enough transmission capacity is available to deliver the power." Whereas distributed generation is regulated by the CPUC, the CAISO is regulated by the FERC because interstate transmission lines fall under the jurisdiction of federal commerce laws.

<http://www.caiso.com/>

Federal Level

Federal Energy Regulatory Commission (FERC)

The Federal Energy Regulatory Commission is an independent regulatory agency within the U.S. Department of Energy with a mission to “assist consumers in obtaining reliable, efficient and sustainable energy services at a reasonable cost through appropriate regulatory and market means.” The agency regulates the transmission and sale for resale of natural gas in interstate commerce; regulates the transmission of oil by pipeline in interstate commerce; regulates the transmission and wholesale sales of electricity in interstate commerce; licenses and inspects private, municipal and state hydroelectric projects; oversees related environmental matters; and administers accounting and financial reporting regulations and conducts of jurisdictional companies.

<http://www.ferc.gov/>

U.S. Department of Energy (DOE)

The Department of Energy's mission is “is to ensure America’s security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions.”

energy.gov

ATTACHMENT D – TOUR SCHEDULE

Tour Schedule

October 19 – Arrival

Welcome reception hosted by Carroll, Burdick, & McDonough

Day 1 - October 20 – Silicon Valley: innovation & new technologies and their impact on the energy transition

Tour of the Tesla facility

Discussions about innovation in battery technologies, e-mobility and balancing options for the system

Luncheon with Silicon Valley technology companies.

Focus on new technologies that enable deployment and grid integration of renewables. Includes representatives from Google, Sunpower, EtaGen, and others.

Roundtable Discussion hosted Stanford University

Agenda:

Q&A/discussions during/after presentations. Goal to have informative discussions on both sides.

2:00-2:10 Stanford Welcome

2:10-2:30 Overview of Energy 3.0 and Bits & Watts

2:30-3:00 EU Delegation - Discussion of challenges being faced by EU grid operators. To include two presentations, one from the policy perspective and one from the grid operator perspective by a grid operator Executive Officer in the Delegation.

3:00-4:30 Presentations by Stanford/SLAC on research relevant to EU grid challenges with roundtable discussion

4:30-5:00 Opportunities to engage with Stanford: Energy 3.0 and Bits & Watts

5:00 Campus Tour followed by Reception & Dinner

Day 2 - October 21 – San Francisco, Sacramento

Two Hour Roundtable Discussion hosted by the CPUC

Agenda:

9:30 AM: Introductions

9:50-10:10 AM: California Presentation on Regulatory Solutions to Increased Renewable Penetration

10:10-10:30 AM: EU Presentations: Policy and Technical Response to Increase Renewable Penetration

10:30-11:15 AM: Roundtable Discussion

11:15-11:30: Informal Discussion and Networking

Roundtable Lunch hosted by Bloomberg New Energy Finance (BNEF)

Discussion moderated by BNEF Founder and Advisory Board Chair Michael Liebreich

Day 3 - October 22 – 23 Sacramento

CAISO Annual Energy Symposium

The Symposium has become the largest gathering of electric industry executives in the US and in particular the West Coast, attracting participation by 600 business leaders and policymakers. This event enables discussion on important issues impacting the bulk power grid and markets. Formal Delegate participation is detailed in the body of the report. See Symposium Schedule for details on the Agenda, including Delegation participation:

<https://www.caiso.com/Documents/2015StakeholderSymposiumAgenda.pdf>

Day 4 - October 23 Folsom

1:30-3:30
PM

Tour of CAISO Headquarters/Control Room

ATTACHMENT E – COMPARISON OF CLIMATE & ENERGY TARGETS

SIDE BY SIDE COMPARISON OF KEY CLIMATE & ENERGY TARGETS IN EUROPEAN UNION & CALIFORNIA				
Greenhouse Gas Reduction Targets	Targets		Status	
	European Union	California	European Union	California
	<p>2020 Climate & Energy Package 20% below 1990 levels by 2020 EU wide (binding)ⁱ</p> <p>2030 Climate and Energy Framework At least 40% below 1990 levels by 2030 (binding)ⁱⁱ</p> <p>Roadmap under discussion: - 60% by 2040, and – 80% by 2050.ⁱⁱⁱ</p> <p><i>Some member states are discussing more aggressive targets, e.g. 80-95% by 2050.</i></p>	<p>AB 32 (binding): 1990 levels by 2020</p> <p>2005 Executive Order S—3-05 (non-binding): 80% below 1990 levels by 2050ⁱ</p> <p>2015 Executive Order B-30-15 (non binding) 40% below 1990 levels by 2030^{iv}</p>	<p>1990-2013 GHG reduction below 1990 levels^v <i>Including intl. aviation:</i> 19.8% <i>Without international aviation:</i> 21.2 %</p> <p>Tonnes annual CO2 equivalent per capita (2012)^{vi} <i>Excluding land-use change and forestry:</i> 8.70 <i>Including land-use change and forestry:</i> 8.15</p>	<p>1990-2013: GHG levels up by 7.6% (from 427 tonnes of CO2 equivalent to 459.3 tonnes of CO2 equivalent)^{vii}</p> <p>down 7% from 2004 peak levels^{viii}</p> <p>Tonnes annual CO2 equivalent per capita (2012): 12.1^{ix}</p>

ⁱ http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm

ⁱⁱ http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm

ⁱⁱⁱ http://ec.europa.eu/clima/policies/strategies/2050/index_en.htm

^{iv} <https://www.gov.ca.gov/news.php?id=18938>

^v http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics; Note that EU greenhouse gas statistics refer to EU-28.

^{vi} http://cait.wri.org/profile/EU_28

^{vii} Source: California Air Resources Board (CARB); http://www.arb.ca.gov/cc/scopingplan/2013_update/first_update_climate_change_scoping_plan.pdf and <http://www.arb.ca.gov/cc/inventory/data/data.htm>

^{viii} [ibid; http://www.arb.ca.gov/cc/inventory/pubs/reports/ghg_inventory_trends_00-13_10sep2015.pdf](http://www.arb.ca.gov/cc/inventory/pubs/reports/ghg_inventory_trends_00-13_10sep2015.pdf)

^{ix} [ibid; http://www.arb.ca.gov/newsrel/newsrelease.php?id=612](http://www.arb.ca.gov/newsrel/newsrelease.php?id=612)

ATTACHMENT E – COMPARISON OF CLIMATE & ENERGY TARGETS

Renewable Energy Targets	Targets		Status	
	European Union	California	European Union	California
	<p>2020 Climate & Energy Package 20% of gross final energy consumption by 2020 – at least 10% must be transport fuel (binding)^x</p> <p>2030 Climate and Energy Framework At least 27% of gross final energy consumption must be covered by renewables by 2030 (binding)^{xi}</p> <p>Individual member states have separate targets for renewable energy (final and/or primary consumption and separate sectors), ranging up to 100%.^{xii}</p>	<p><i>(Select list of policies with trackable status)</i> SB 350 RPS requiring utilities procure 33% renewable power by 2020 and 50% by 2020^{xiii} (binding) <i>Excludes large hydropower and installations < 1 MW</i></p> <p>Go Solar California^{xiv} (non-binding)^{xv} 3 GW of small scale PV (<1 MW) by end of 2016</p> <p>585 million therms solar hot water systems by end of 2017</p> <p>Low Carbon Fuel Standard 10% lifecycle carbon reductions from petroleum based transport fuels by 2020 (binding).^{xvi}</p>	<p>(2014) 16% gross final energy consumption met with renewables.</p> <p>(2014) 28% (includes 11.8% large hydro) electricity consumption met with renewables.</p> <p>(2014) average 6% renewable energy sources in transport fuel</p> <p>(2014) 17.7 % of total energy use for heating and cooling</p> <p>Source of this column's statistics: Eurostat^{xvii}</p>	<p>(2014) 25.6% (includes 5.5% large hydro)^{xviii} total electricity consumption met with renewables</p> <p>Go Solar– target exceeded with 3.5 GW of small scale PV installed (2015)^{xix}</p> <p>Low Carbon Fuel Standard– annual targets so far being met or exceeded^{xx}</p>

^x http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm

^{xi} http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm

^{xii} See the Renewables 100 Policy Institute's Go 100 Percent project for details on member states, regions, and cities in the EU with targets in at least one sector of or surpassing 100%: <http://www.go100percent.org/cms/index.php?id=19>

^{xiii} https://leginfo.ca.gov/faces/billCompareClient.xhtml?bill_id=201520160SB350

^{xiv} <http://www.gosolarcalifornia.ca.gov/about/index.php>

^{xv} While these goals are non-binding, the program has been institutionalized via a menu of incentives, policies and regulatory frameworks, including rebate programs and net metering. See the program website for more details: <http://www.gosolarcalifornia.ca.gov/>

^{xvi} http://www.energy.ca.gov/low_carbon_fuel_standard/

^{xvii} http://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_from_renewable_sources

^{xviii} Hydropower in 2014 was negatively impacted by severe drought conditions.

^{xix} http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf, p. 15

^{xx} http://www.arb.ca.gov/fuels/lcfs/dashboard/quarterlysummary/20151211_q3datasummary.pdf

ATTACHMENT E – COMPARISON OF CLIMATE & ENERGY TARGETS

Building Efficiency Targets	Target		Status	
	European Union	California	European Union	California
	<p>2020 Climate & Energy Package^{xxi} (binding) 20% improvement in efficiency by 2020</p> <p>2030 Climate and Energy Framework^{xxii} At least 27% improvement in efficiency by 2030 (binding)</p> <p><i>Individual member states have their own targets and policies to meet or exceed EU goals.</i></p>	<p>SB 350^{xxiii} (binding) By 2030, double energy efficiency savings in electricity & natural gas final end uses of retail customers through energy efficiency and conservation.</p> <p>Zero Net Energy (ZNE) Buildings^{xxiv} (goals being integrated into state standards)</p> <ul style="list-style-type: none"> - all new residential: ZNE or the equivalent by 2020 - all new commercial: ZNE or the equivalent by 2030 <p>Executive Order B-18-12^{xxv} New state-owned buildings and renovations: ZNE, double efficiency and conserving up to 20% on energy or (non-binding)</p>	<p>2005-2013:^{xxvi} <i>Final energy consumption down 7% Primary energy consumption down 8 %</i></p> <p><i>Early estimates suggested a continuation of the decline in consumption in 2014.</i></p>	<p>1990-2013:^{xxvii} GWh savings from energy efficiency and conservation measures climbed from under 25,000 GWh to about 70,000 GWh.</p> <p><i>Electricity consumption growth: roughly 1% annual</i> <i>Natural gas consumption growth: nearly zero</i></p>

^{xxi} http://ec.europa.eu/clima/policies/strategies/2020/index_en.htm

^{xxii} http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm

^{xxiii} https://leginfo.ca.gov/faces/billCompareClient.xhtml?bill_id=201520160SB350

^{xxiv} For details, see: <http://www.energy.ca.gov/title24/2016standards/background.html> and http://www.energy.ca.gov/2011_energypolicy/documents/2011-07-20_workshop/presentations/Revised_Zero_Net_Energy_Definition.pdf

^{xxv} <https://www.gov.ca.gov/news.php?id=17508>

^{xxvi} <https://ec.europa.eu/energy/en/news/progress-made-2020-energy-efficiency-target>

^{xxvii} See: http://www.energy.ca.gov/renewables/tracking_progress/documents/energy_efficiency.pdf

ATTACHMENT E – COMPARISON OF CLIMATE & ENERGY TARGETS

Zero Emissions Transportation Targets	Target		Status	
	European Union	California	European Union	California
	The EU supports research & innovation, and the effective deployment of new green transport technologies. For example, new rules require EU countries to promote clean technologies (cars that run on electricity/hydrogen, gas-powered trucks/barges/ships) by building a minimum number of recharging and refueling stations. ^{xxviii}	<i>Executive Order B-16-201</i> ^{xxix} 1.5 million Zero Emissions Vehicles (plug-in electric and hydrogen) by 2025 (non-binding, but supported by several initiatives and pieces of legislation ^{xxx}). <i>Goal to Reduce Petroleum Use 50% by 2030</i> ^{xxxi} (non-binding)	(2010-2014) ^{xxxii} 153, 633 Total • 86, 230 BEV • 67,300 PHEV/REV • 103 FCEV <i>PHEV/REV group broken down into 50,869 gasoline PHEV, 12,613 diesel PHEV, and 3,818 REV</i> (2012) 11,038 EV charging stations ^{xxxiii}	(Jan 2016) 184,657 Plug-in electric vehicles ^{xxxiv} (2013) 179 Fuel Cell electric vehicles ^{xxxv} (2015) 44 hydrogen fueling stations available to the public ^{xxxvi} (2015) 7,687 EV charging stations ^{xxxvii}

^{xxviii} http://europa.eu/pol/trans/index_en.htm

^{xxix} <https://www.gov.ca.gov/news.php?id=17463>. The Executive Order is supported by the ZEV Action Plan:

^{xxx} A partial list of legislation supporting the Governor's Zero Emissions Vehicles target can be found here: <https://www.gov.ca.gov/news.php?id=18720>

^{xxxi} <http://under2mou.org/wp-content/uploads/2015/05/California-appendix-English.pdf>; Note: 50% petroleum reduction by 2030 was a provision that was part of the original SB 350 law, but was defeated before the mandate was passed. However, while not yet binding, this remains state policy.

^{xxxii} Source for these statistics: https://setis.ec.europa.eu/sites/default/files/reports/Electric_vehicles_in_the_EU.pdf

^{xxxiii} <http://www.averre.org/www/Images/files/EV%20Data%20Collection%20AVERE%282%29.pdf>, p.3

^{xxxiv} <http://www.pevcollaborative.org/>

^{xxxv} http://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2015.pdf

^{xxxvi} *ibid.*

^{xxxvii} *ibid.*

ATTACHMENT F – COMPARISON OF KEY ELECTRICITY SYSTEM DATA

COMPARISON OF KEY ELECTRICITY DATA IN EUROPEAN UNION AND CALIFORNIA		
Item	European Union (EU-28) <i>Statistics for member states vary widely</i>	California
ELECTRICITY GENERATION	3262 TWh (2013)ⁱ <i>Stable or trending down overall, but up in the residential sector.</i>	2933 TWh (2014)ⁱⁱ <i>Down 1% from 2013. Total consumption flat or declining.</i>
ELECTRICITY CONSUMPTION PER CAPITA	5529 kWh (2012)ⁱⁱⁱ	6823 kWh^{iv}
GENERATION BY ELECTRICITY SOURCE (as % of total TWh)	(2014)^v Conventional Thermal: 48% (mostly coal and natural gas) ^{vi} Hydro: 13% (includes pumped hydro) Nuclear: 28% Wind: 8% Other Renewables: 3% (solar, geothermal, biomass, etc.)	(2014)^{vii} Conventional Thermal: 50.9% (mostly natural gas) Hydro: 5.5% large/.09% small (includes pumped hydro) Nuclear: 8.5% Wind: 8.1% Other Renewables: 11.1% (solar, geothermal, biomass) Unspecified: 15%
AVERAGE ELECTRICITY PRICES	0.21€/kWh (2014)^{viii}	\$0.15/kWh^{ix}

ⁱ http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_and_heat_statistics

ⁱⁱ This data is based on the California Code of Regulations (Title 20, Division 2, Chapter 2, Section 1304 (a)(1)-(2)), which requires owners of power plants that are 1 megawatt (MW) or larger in California or within a control area with end users inside California to file data on electric generation, fuel use, and environmental attributes. Filings are submitted to the Energy Commission on a quarterly and annual basis. These filings cover all types of electric generation: wind, solar, geothermal, natural gas, hydroelectric, coal generators, and others. For source/details, see: http://energyalmanac.ca.gov/electricity/total_system_power.html

ⁱⁱⁱ <http://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production/assessment-2>

^{iv} http://energyalmanac.ca.gov/electricity/per_capita_electricity_sales.html - 1990-2012

^v http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_production_and_supply_statistics

^{vi} 2012 statistics, which were similar to 2013 and 2014, broke down combustion fuels by source in the EU-28 electricity mix as follows: 27% solid fuels (mostly coal), 19% natural gas, and 2% petroleum and crude oil, for a total of 48% combustion fuels in gross electricity generation. See p. 10 of: http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_production_and_supply_statistics For detailed breakdown of solid fuels: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:T1Gross_electricity_generation_by_fuel,_GWh,_EU-28,_1990-2013.png

^{vii} http://energyalmanac.ca.gov/electricity/total_system_power.html

^{viii} To illustrate the wide range of pricing in member states, the price of electricity for household consumers in Denmark (EUR 0.304 per kWh) was 3.4 times as high as in Bulgaria (EUR 0.090 per kWh). Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_price_statistics

^{ix} https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a