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Southern California Clean Energy Innovation Ecosystem Roundtable Report

Roundtable Hosted by the University of California, LA – May 10, 2016

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Introduction

The University of California, LA (UCLA) hosted the Southern California Clean Energy Innovation Ecosystem Roundtable discussion on May 10, 2016 on the UCLA campus in Kerckhoff Hall. This roundtable discussion brought together 28 leaders from academia, local and state government, a national laboratory, non-profit groups, and industry to discuss Southern California's clean energy needs as the state and region transition to meet their ambitious climate and energy goals.

Professor J.R. DeShazo from the UCLA Luskin Center for Innovation facilitated the roundtable discussion, which was focused on identifying the region's immediate and long-term clean energy needs and challenges (challenges may be related to governance, costs, inertia, regulatory and legal restrictions, available land, technology transfer, and more), and laying the foundation for future collaborations between the participants and their associated institutions. Discussion included everything from increasing our renewable energy power, to energy storage, grid modernization, distributed energy generation and storage, energy efficiency, and energy conservation in the region.

Southern California has been a leader in the transition from non-renewable, carbon-based energy to renewable, clean energy through innovative technologies, policies, and strategies. With abundant sunlight and wind resources, and a mild climate year-round, Southern California is well positioned for a transition to renewable energy. State and local governments have set ambitious climate goals. California's Clean Energy and Pollution Reduction Act of 2015 (SB 350) set a goal of providing 50% of California's electricity demand with renewable resources by 2030. The City of LA has set greenhouse gas reduction goals of 45% by 2025, 60% by 2035, and 80% by 2050 compared to 1990 baseline emissions. San Diego recently enacted a Climate Action Plan that commits to running the city on 100% renewable energy and reducing greenhouse gas emissions by 50% by 2035.

Despite these commitments, Southern California continues to face some of the most severe air quality and climate emission challenges. Over the coming decades, population growth, rising temperatures, electrified transportation, and water needs will put increased pressure on the region's energy system. A comprehensive and multi-faceted approach is necessary to address these challenges and develop game-changing clean-energy solutions that are affordable to all residents. Collaboration and partnerships across sectors are imperative, and on a local level (LA County), UCLA's Sustainable LA Grand Challenge initiative has committed to assessing the capabilities of currently available technologies and strategies, targeting areas where new research is needed, and serving as a nexus for partnerships to transition the County to 100% renewable energy by 2050. Southern California is an ideal candidate to serve as a clean energy model for urban regions across the globe given its diversity in topography, climate zones, urban framework, and cultures. Solutions that are implemented in Southern California are eminently exportable.

The purpose of this report is to provide the United States Department of Energy (DOE) a comprehensive summary of the roundtable event, and to identify some broad conclusions and

next steps for the Southern California region with regard to a clean energy pathway. All of this is being considered within the context of Mission Innovation (http://mission-innovation.net), whose goal is to accelerate innovation in clean energy and to make clean energy affordable around the globe.

Roundtable Summary

Convening of the Roundtable

(Discussion from the roundtable event is captured below in italics)

Dr. Jayathi Murthy is Dean of the UCLA Henry Samueli School of Engineering and Applied Science. She has a Ph.D. in mechanical engineering from the University of Minnesota, an M.S. from Washington State University and a B. Tech from the Indian Institute of Technology, Kanpur. Her research interests include nanoscale heat transfer, computational fluid dynamics, and simulations of fluid flow and heat transfer for industrial applications.

Dean Murthy welcomed the Department of Energy Deputy Secretary and all of the participants to UCLA to participate in the roundtable discussion. She commented that many distinguished faculty at UCLA are working on energy challenges, with experts in various fields – from storage, to renewable energy generation to water. UCLA is a key part of the energy conversation and contributes significantly to progress. She stressed the importance of working together across the energy ecosystem since innovation is always the result of a long collaboration among numerous stakeholders. Dean Murthy described UCLA's concerted effort to address the energy challenges of the region through their Sustainable LA Grand Challenge, which was launched in 2013 with the goals of reaching 100% renewable energy, 100% locally-sourced water, and enhanced ecosystem and human health in LA County by 2050.

Introduction to Mission Innovation and Regional Partnerships

Dr. Elizabeth Sherwood-Randall, Department of Energy Deputy Secretary.

From left to right, Dr. Albert Carnesale, Deputy Secretary Dr. Sherwood-Randall, Dean Murthy, and Mr. Randy Britt. Photo credit: John Vande Wege.

In her opening remarks, Dr. Sherwood-Randall recognized the pioneering role of California, stating that Mission Innovation was launched in this spirit. The commitment of twenty countries to Mission Innovation should ensure reinvigorated funding for clean energy. At the Paris Climate Talks (COP21) in 2015, many nations agreed to ambitious but achievable targets. As part of

Mission Innovation, the US will seek to increase federal investments in clean energy technology research to USD $12 billion by 2020, up from USD $6.4 billion in 2016. The Deputy Secretary mentioned that the DOE estimates that USD $13.5 trillion will be invested in clean energy between now and 2030, so private investment and institutional partnership are key to incorporating differing perspectives to energy development. She acknowledged that the University of California system is the only institutional partner in the Breakthrough Energy Coalition. The Deputy Secretary said that the DOE is working to fund technology innovation through a variety of means, including funding to CalTech for student innovation competitions worth $40 million, the LA Cleantech Incubator (LACI), and the 4C Seed to Scale 2016 program. She emphasized that the DOE looks to California for innovative renewable energy ideas and anticipates continued collaboration in the future, and that California will serve as a model to build partnerships across the country. California's ambitious goals, set early, of 33% of energy from renewable sources by 2020 and 50% by 2030 create an urgency driver. This in turn drives the market for technology. The Deputy Secretary concluded by saying under the Mission Innovation initiative, the DOE will facilitate regional partnerships, because the best solutions are based on regional needs, with policies tailored to these specific needs. Between 8 and 10 Regional Clean Energy Partnerships are envisioned with a total of $110 million in funding for the partnerships.

Setting the Clean Energy Stage in Southern California

Dr. JR DeShazo is a UCLA Professor of Public Policy, Urban Planning, and Civil and Environmental Engineering, and Director of the Luskin Center for Innovation. He also is a Professor and Vice Chair of the Department of Public Policy in the Luskin School of Public Affairs, where he is an expert in economics, public finance, and organizational governance. Dr. DeShazo holds a Ph.D. in Urban Planning from Harvard University and a M.Sc. in Economics from Oxford University, where he was a Rhodes Scholar. His recent research focuses on local public finance, regulatory reform, climate change policy, and solar energy policy.

Dr. DeShazo served as the roundtable discussion moderator. Dr. DeShazo stated that regional and municipal leadership is critical in energy development, and UCLA and other experts across the state are ready to meet the challenges and ambitious goals set by the city of Los Angeles (LA), LA County, and California policy makers. He went on to introduce the next speakers who helped to set the stage for the roundtable discussion through brief presentations on the state of energy, research, and development in the region and state.

1. State of Energy in LA

Matt Petersen is the Chief Sustainability Officer (CSO) of the City of LA. As the first CSO for the City of LA, he focuses on helping Mayor Garcetti create 20,000 green jobs in LA, creating a more sustainable and livable city and neighborhoods, and holding every city department responsible for cleaner air and water. Mr. Petersen was the founder and is currently a board member of Global Green USA, and also serves on the board of Habitat for Humanity of Greater LA. He is a

member of the Council on Foreign Relations, and is an advisor on energy and environment to the Clinton Global Initiative.

Mr. Petersen said that the LA Mayor released the first Sustainable City pLAn in 2015, which has ambitious and time-bound targets. The pLAn addresses the three pillars of sustainability: environment, society, and economics. An important component of the pLAn is to decrease the unemployment rate through clean energy innovation and drive investment in these technologies. In reviewing the progress since 2015, the city has exceeded targets on electric vehicle (EV) chargers, with over one thousand publicly available in the city. But the city is moving slower on utility-level solar goals, with just 182 MW of installed capacity currently. The pLAn also introduces the city's first building benchmarking ordinance, which places LA ahead of statewide energy codes. LA is on track to be the most sustainable city in the nation if the city reaches its goals. But collaboration between policy makers, industry and technology innovation are key.

2. State of Energy in California

Angelina Galiteva was appointed by California's Governor and confirmed by the State Senate to the five-member Board of Governors of the California Independent System Operator (ISO) Corporation in 2011 and again in 2014. ISO is responsible for the reliable operation of the power grid in the state of California and for the efficient operation of the electricity market, including the integration of renewable energy project as mandated by State Law. Ms. Galiteva actively works to structure and advance the implementation of cutting edge energy policies that reflect the increasing role of renewable energy as well as the growing interconnection between renewables, storage, mobility, distributed energy, water storage and desalination technologies worldwide. She is also the founder and Chair of the Board for the Renewables 100 Policy Institute and serves as the Chairperson for the World Council for Renewable Energy. Both organizations are dedicated to the successful deployment of renewable energy technologies and the policies that support them on a global scale. Ms. Galiteva, is also a Principal at NEOptions, Inc., a renewable energy and new technology product design firm focused on developing innovative solar powered solutions. Her industry experience includes serving as Executive Director of the LA Department of Water and Power and head of its Green LA, Environmental Affairs and New Product Development Organization. While at the largest municipal utility in the USA, she was responsible for strategic positioning and the environmental compliance departments. Ms. Galiteva is an attorney and holds a J.D. and LLM Degrees, specializing in Environmental and Energy Law.

Ms. Galiteva stated that the California grid is currently operating with about 46% renewable energy, and that the grid can easily support 60-70% renewable generation without a technical breakthrough. The only hindrance is a lack of vision and regional integration. The grid must become regional - we have a disjointed grid system and more integration is needed. An example of successful integration is Europe, where the grid is regionalized across country lines, allowing for the transition to renewables while maintaining the base load.

3. State of Clean Energy Technologies

Dr. Eric Hoek is a Professor in the UCLA Department of Civil and Environmental Engineering, and co-founder and CEO of Water Planet. Water Planet develops and markets membrane-based water purification and separation product solutions and services. As an engineering professor his research and teaching span water treatment, desalination, membrane technology, and nanotechnology. His early research and inventions led to the formation of NanoH2O (nanoh2o.com), now LG Water Solutions. Later research and consulting activities led to the formation of Water Planet (waterplanet.com). Dr. Hoek collaborates with Global Classrooms for Peace (globalclassroomsforpeace.org) to improve sanitation and water issues for villages and settlements on remote islands of Fiji.

Dr. Hoek briefly spoke about his research focusing on the energy-water nexus, on water reuse, treatment of wastewater and desalination. Water Planet, a startup stemming from Hoek's research, is a company working to cut energy use through more efficient water purifying membranes. Dr. Hoek mentioned the importance of supporting faculty so they are able to quickly take prototypes to market, and in the example of Water Planet, Hoek took leave from UCLA to focus on the company. In fact he took leave three times for different startup companies.

Dr. Rajit Gadh is a Professor in the UCLA Department of Mechanical and Aerospace Engineering. He is the Founder and Director of the Smart Grid Energy Research Center (SMERC) and Founder and Director of the UCLA WINMEC Consortium. Dr. Gadh has a Ph.D. from Carnegie Mellon University, a Masters from Cornell University, and a Bachelor degree from IIT Kanpur, all in engineering. His current research interests include modeling and control of Smart Grids, wireless monitoring and control of distribution and consumer-premise power grids, EV aggregation, modeling and control, optimized EV charging under grid and local constraints, Grid-to vehicle, Vehicle-to-grid and Grid-to-home architectures, automation and home area network for Demand Response, Micro-grid modeling and control, and, wireless-sensor and RFID middleware architectures.

Dr. Gadh said that smart grids are vital for energy efficiency. Some new technologies being developed include using EVs as batteries for distributed energy storage. Currently the UCLA campus serves as a living laboratory for this work, and hosts 217 prototype EV chargers for this project.

Dr. James Liao is the Parsons Foundation Professor and Chair in the UCLA Department of Chemical and Biomolecular Engineering. He is a pioneer in Metabolic Engineering, Synthetic Biology, and Systems Biology. Dr. Liao received his B.S. degree from the National Taiwan University and Ph.D. from the University of Wisconsin-Madison. His research has focused on metabolism, including its biochemistry, extension, and regulation. His current projects include engineering proteins and biochemical pathways for CO2 fixation and production of fuels and chemicals with the ultimate goal of using biochemical methods to replace petroleum processing and to treat metabolic diseases.

Dr. Liao remarked that CO2 is a harmful by-product of current energy generation, but we can't stop producing it, so we have to figure out how to convert it to something useful. He is working on three ARPA-E funded projects for CO2 conversion, including converting CO2 into liquid, converting captured greenhouse gas (GHG) to liquid fuel using solar power, and engineering plants to increase CO2 fixation.

Roundtable Participant Introductions

Mr. Yaniv Tepper is a Co-Founder of the Angeleno Group, LLC, which is a pioneer in providing growth capital for next generation clean energy and natural resources companies. He oversees the Group's investment activities in renewable energy, waste management, and energy efficiency. Mr. Tepper has been a speaker and lecturer on topics including asset allocation, sector diversification, and alternative investing, and an author in major financial publications. He holds a B.S. in Mechanical Engineering from UC Berkeley, and M.S. degrees in Civil & Environmental Engineering and Management from M.I.T.

Mr. Tepper stated that clean energy investments are profitable – an example is the company TPI composites that retooled an old Maytag refrigerator plant to a wind-turbine blade production facility and increased revenues.

Dr. Bruce Dunn is the UCLA Nippon Sheet Glass Professor in the Department of Materials Science and Engineering. His research involves the synthesis of inorganic and hybrid organic-inorganic materials and characterization of their electrical, electrochemical and optical properties. One of the principal themes of his research activities is the use of sol-gel methods to synthesize a number of the materials studied in the group. This synthetic approach enables the preparation of materials that incorporate a wide variety of organic and biological dopants and are capable of developing unique microstructures and properties. Dr. Dunn's current research focuses on Electrochemical, Bio-hybrid, and Biomolecular materials.

Dr. Dunn explained that he is working on research into faster charging batteries, connecting nano-battery storage technology with transparent solar (e.g., solar windows on buildings).

Dr. Yang Yang is the UCLA Carol and Lawrence E. Tannas Jr. Endowed Chair in Engineering, and a Professor in the UCLA Department of Materials Science and Engineering. His notable contributions to the field of organic photovoltaics (OPV) are an enhanced understanding of polymer morphology and its influence on device performance; the invention of the inverted organic solar cell, the inverted tandem solar cell, photovoltaic polarizers for LCD applications, and transparent OPV devices. Together with Solarmer Energy Inc. (spun-off from UCLA) and Professor Luping Yu at the University of Chicago, he has taken part in the creation of several world record cells in OPV. In addition to organic solar cells, his group is also involved in the development of liquid-processable CIGS/CZTS photovoltaics; achievements include an approximately 11.2% PCE using a CISS absorber layer deposited from a solution-phase precursor system. Recently, Dr. Yang entered the field of perovskite solar cells, and demonstrated 19.3% power conversion efficiency by interface engineering and improved crystal growth process.

Dr. Yang stated that he conducts research in the future of solar panels - flexible and "transparent" solar panels that can be integrated into buildings and vehicles and applied to windows.

Mr. Bill Corcoran is the Regional Campaign Director of the Sierra Club's highly successful Beyond Coal campaign. He provides strategic guidance for all aspects of the campaign's work in the West and Southeast to end the use of coal in the electricity sector and replace it with clean energy, as well as stopping proposed coal export terminals on the West Coast. A graduate of UCLA, Mr. Corcoran serves on the boards of the Zen Center of LA, the Western Clean Energy Campaign, the Interwest Energy Alliance, and the Tejon Ranch Conservancy.

According to Mr. Corcoran, de-carbonization should be the highest priority.

Dr. G.P. Li is a professor at the University of California, Irvine (UCI), with appointments in three departments: Electrical Engineering and Computer Science, Chemical Engineering and Materials Science, and Biomedical Engineering. He serves as division director of the California Institute for Telecommunications and Information Technology (Calit2) and director of the Integrated Nanosystems Research Facility in The Henry Samueli School of Engineering. He received his bachelor's degree in electrical engineering from National Cheng Kung University (NCKU) in Taiwan, and his master's and doctorate degrees, also in electrical engineering, from UCLA. Dr. Li has been involved in several startup companies as a co-founder or member of the technical advisory board. Currently, he directs TechPortal, a technology business incubator housed at the UCI division of Calit2, which supports and nurtures young companies and university researchers commercializing their technologies. His current research interests focus on developing technologies for efficient energy utilization and consumption, and e-health.

Dr. Li said that operationally, UCI is the most efficient campus in the UC system. At UCI labs use about 33% of total campus energy, and therefore serve as a living lab for energy efficiency projects. He believes that the 'internet of everything' is a useful technological advancement, because consumers must have the ability to manage personal energy usage.

Mr. William Torre is the Program Director for Energy Storage Systems at the University of California, San Diego and oversees research on developing energy storage and integration of renewable generation. This work includes energy storage demonstration projects that test and demonstrate advanced energy storage technology to improve the performance of microgrid operations and renewable generation. He is also involved in developing advanced power system controls and data acquisition for microgrid applications, including phasor measurement units. Mr. Torre's energy research also involves electric transportation and utilization of automated demand response and vehicle to grid control to optimize overall microgrid operation and efficiency.

Mr. Torre stated that he conducts research on solar generation and energy storage and works with Cleantech San Diego, a clean energy industry group.

Dr. Jonas Peters is the Bren Professor of Chemistry in the Division of Chemistry and Chemical Engineering, and the Director of the Resnick Sustainability Institute at Caltech. He received a Ph.D. in inorganic chemistry from MIT, and a B.S. in Chemistry from the University of Chicago. Dr.

Peters' current research interests include multi-electron redox reactions of small molecule substrates using late first row transition metals, dicopper cores as multi-electron redox shuttles and photochemical reductants, electrocatalytic hydrogen evolution at positive potentials, and the zwitterionic approach to catalysis mediated at late transition metal centers.

Dr. Jonas stated that he researches how to convert sunlight into fertilizer in a joint center for artificial photosynthesis. (The Deputy Secretary said that there is a need to get inventors thinking about how to get products to market.) Dr. Jonas also briefly discussed Caltech's FLoW program, which has been operating since 2011 with an initial grant from DOE. The program seeks to accelerate cleantech innovation through fostering student entrepreneurship. The program received a second award from DOE in 2015 (Cleantech UP) to continue the program for three more years. The students and mentors in the FLoW program benefit from relationships with the DOE national labs, the DOE's National Incubator Initiative for Clean Energy (NIICE), the Electric Power Research Institute and DOE's National Renewable Energy Laboratory.

Dr. Gary Stern is the Director of Energy Policy at Southern California Edison (SCE). He has been an executive at SCE for over fifteen years, where he started by performing econometric evaluations of demand side management programs. From there he progressed into resource planning analysis, and worked extensively on the restructuring of California's electricity market during the mid to late 1990's. He headed a group that monitored the electricity market, which discovered the market manipulation by Enron and others, and brought the failures of the market to the attention of regulators and legislators, and worked on getting billions of dollars back in refunds. After that crisis he worked on meeting the future needs of SCE customers, through planning and strategic analysis of the electricity environment in which the company operates. Currently as head of the regulatory policy organization that leads case management and policy development for regulatory activity involving the California Public Utilities Commission, California Energy Commission, California Independent System Operator and Federal Energy Regulatory Commission.

Dr. Stern highlighted the need for advancement in electrified transportation, and the need to develop greater efficiency through distributed energy. (The Deputy Secretary mentioned that new tech creates vulnerabilities to the grid from new threat vectors that must be addressed; machine-to-machine technology is needed.)

Dr. Abhijit Mukherjee is an Assistant Professor of Mechanical Engineering at the California State University in Northridge, and the Director of the Energy Research Center. He earned a Ph.D. from UCLA, and Master degrees in Mechanical Engineering from UCLA and Villanova University. Dr. Mukherjee's research focuses on the numerical and experimental study of the liquid-vapor interface with applications in boiling, condensation, combustion and multiphase flows. His other areas of interest include Renewable Energy and Fuel Cells.

Dr. Mukherjee said that he works on applied research in portable solar energy generation, portable desalination and distributed energy.

Dr. Sandrul Ula is the Managing Director of Winston Chung Global Energy Center, a new research center at the University of California, Riverside, Bourns College of Engineering. He is also a Research Faculty at the College of Engineering Center for Environmental Research and Technology (CE-CERT) and part of the Southern California Research Initiative for Solar Energy (SC-RISE). He works on research, development and outreach aspects of electrical energy storage, power transmission and distribution, smart grids, solar photo-voltaic (PV), solar thermal, concentrated PV (CPV) and concentrated solar (CSP), as well as wind energy. During 2004-05 he served as the Energy Advisor to the Governor of Wyoming, the largest energy producing state in the country. He was the liaison between the Governor's Office and the newly formed Wyoming Infrastructure Authority whose mission is facilitating development of electric power generation and transmission from Wyoming. Over the years he had advised various Electricity and Energy ministers/officials of Bangladesh Government on energy planning and management. While at the University of Wyoming (UW), Dr. Ula served as Professor of Electrical Engineering and founding Director, Wyoming Electric Motor Training and Testing Center. He received his Ph.D. degree in Electrical Engineering from the University of Leeds, UK.

Dr. Ula explained that he runs test beds for batteries, including zero-net energy building research and distribution grid-level testing.

Dr. Douglas Rotman is the Energy Program Manager at Lawrence Livermore National Laboratory (LLNL). He began his LLNL career working across atmospheric chemistry, climate and energy. Dr. Rotman has served as group leader for Atmospheric Chemistry, deputy division leader in the Atmospheric Science Division, program leader for Energy and Environmental Programs and Program Director for Energy and Environmental Security. His research interests include energy systems research, integration of new technologies onto smartgrid systems and climate analysis at the global and regional scale for improved formulation of climate change adaptation strategies. Dr. Rotman holds a Ph.D. in Mechanical Engineering from UC Berkeley.

Dr. Rotman stated that he focuses on high performance computing for grid management and cyber security.

Dr. Albert Carnesale is Chancellor Emeritus and Professor at the University of California, LA (UCLA). He was Chancellor of the University from July 1, 1997 through June 30, 2006, and now serves as Professor of Public Policy and of Mechanical and Aerospace Engineering. His research and teaching focus on public policy issues having substantial scientific and technological dimensions, and he is the author or co-author of six books and more than 100 articles on a wide range of subjects, including national security strategy, arms control, nuclear proliferation, the effects of technological change on foreign and defense policy, domestic and international energy issues, and higher education. Dr. Carnesale holds a bachelor's degree in mechanical engineering (Cooper Union), a master's degree in mechanical engineering (Drexel University), and a Ph.D. in nuclear engineering (North Carolina State University).

Dr. Carnesale said that his career was marked by the Cold War. He was pivotal in the international work on nuclear non-proliferation and remarked that clean energy, climate change

and transforming transport and energy systems to be sustainable are the equivalent challenges of our generation.

Mr. Randy Britt is the Director of Sustainability at Parsons Corporation based in Pasadena. In this position, he is responsible for the development of sustainability programs, energy conservation projects, and renewable energy projects for Parsons commercial and public clients throughout the world. His experience includes in depth management of energy conservation and sustainability building audits and managing energy management systems installations and operations. Mr. Britt is currently working on energy efficiency, LEED certification, and renewable energy project management for municipal agencies and private sector businesses throughout the U.S. and the Middle East.

Mr. Britt said that Parsons does ground-breaking work on developing resilient and sustainable projects across the world, particularly in building out smart grids. An example of a cutting edge project that Parsons is leading is the LEED Platinum airport in Mexico City, which will be the first of its kind.

Mr. Michael Kadish is the Executive Director of GRID Alternatives for Greater LA (GLA), which installs solar electric systems for low-income families with assistance of volunteers and job trainees. He has been the Executive Director of GLA since 2013 and previously served on its Board of Directors. Mr. Kadish has over fifteen years of experience in public affairs, non-profit consulting, communications, clean-tech, and politics. His advocacy work includes the successful passage of clean energy legislation on both the local and federal levels. He holds a Bachelor Degree from Columbia University and a Masters Degree from Harvard University Kennedy School of Government.

Mr. Kadish stated that clean energy solutions do not mean anything if they are only applied in high-income areas and not in lower-income regions of LA. And that the cost of grid maintenance must be dispersed across all energy users, not just those who cannot afford solar panels on single-family homes. He emphasized that technical job training is key to quickly building a workforce to scale up renewable energy installation and to give low-income people ownership in the energy transformation of our city. (Deputy Secretary added that community colleges can create training programs and industry partnerships.)

Mr. George Minter is the Regional Vice President for External Affairs and Environmental Strategy for Southern California Gas (SoCalGas), the nation's largest gas utility. He is responsible for the Company's external affairs, communications, public policy and energy and environmental affairs functions. Mr. Minter is a long time public policy professional specializing in energy and environmental matters, policy development, communications and political advocacy. He is an Honors graduate of the University of California at Berkeley.

Mr. Minter explained that SoCal Gas is working on pathways to remove pollution and CO2, as gas has a role to play in the transition to a clean energy and low carbon future.

Mr. Erik Steeb is the Chief Programs Officer at the LA Cleantech Incubator (LACI), where he runs Portfolio Company programs with an eye toward scaling breadth, quality and capacity. In

addition, Erik focuses on expanding LACI's Satellite programs. He brings a wealth of relevant experience to LACI and Cleantech LA. He is Executive Director of the Western Division of the Cleantech Open, and sits on the executive committee of the First Look West DOE University Clean Energy Challenge. Through these organizations, Mr. Steeb works with more than 100 early stage companies each year, honing their business strategies, connecting them with investors, customers, business partners, and advisors. He is also co-founder and managing director of Segue Consulting, providing interim operations, marketing, finance and executive office leadership for early to mid-stage companies in cleantech and high-tech. Prior to his move to cleantech, Mr. Steeb held senior management roles in high-tech marketing, sales and business development, most recently with Intel Corporation. He holds a BS in Electrical Engineering from the Georgia Institute of Technology and an MBA from UCLA's Anderson School of Management.

Mr. Steeb said that LACI aids economic development through green tech, and positions LA as the city leading the green tech revolution.

Ms. Tami McCrossen-Orr is the Policy Advisor for Environmental and Land Use Planning at LA World Airports for AECOM. She holds a dual Bachelor of Arts in Economics and Diplomacy & World Affairs from Occidental College and a Juris Doctor from Loyola Law School. Ms. McCrossen-Orr has experience in all phases of commercial disputes and litigation including pleadings, discovery and discovery motions, depositions, dispositive motions, pre-trial, trial, and post-trial motions.

Ms. McCrossen-Orr said that LAX is the largest power consumer in LA, but with ambitious (USD $7 billion) plans to modernize. Between 2010 and 2015, the airport decreased energy use by 35%, mainly by switching all lights to LEDs and by installing a new central power generation plant that is more efficient.

Open Discussion and Concluding Observations

After the roundtable introductions a discussion ensued about the local needs to foster technical innovation. The group agreed that California needs continued solar subsidies to level the playing field against subsidized fossil fuels and to facilitate utility-scale solar and wind development. Additionally, the group discussed the need for both large-scale and small-scale storage solutions, but, as the technology does not exist yet, smart grids are the place to start in terms of efficiency.

Additional work needs to be done on reconciling the desire for virtual net metering and the utility companies' need to cover the costs of grid repair and maintenance. Negotiations are also needed for the cost of third party access to utilities.

The group also reinforced Southern California's strengths as a hub for a regional energy innovation center, given that there are different scale communities that can function as test beds. Furthermore, existing integration and collaboration between innovation centers has potential to create systems that are greater than the sum of their parts.

Roundtable Discussion Questions

The goal of the roundtable discussion was to facilitate discussion identifying the region's clean energy needs and challenges as they relate to the state and region's ambitious climate and energy goals and to identify next steps on our pathway to clean energy in Southern California. During the allotted time we were able to learn about how each of the participants and their affiliated organizations could contribute to a concerted effort to transition the region to clean energy. There were several roundtable discussion questions that were not adequately addressed during the roundtable discussion due to time constraints. Therefore, roundtable participants (or representatives from their organizations) were provided an opportunity to respond to these thought questions online a couple of weeks after the roundtable event. Below are several important though questions specific to Southern California's clean energy ecosystem and the responses from a number of roundtable participants. Note that only copy edits were applied to the responses below.

1. What are our immediate clean energy needs to meet California's goal of getting 33% of our energy from renewable sources by 2020 and 50% by 2030? What unique challenges do we face in the Southern California region in meeting these goals?

William Torre, UC San Diego

The San Diego region is well on its way toward achieving the goal of 50% renewables in California by 2030. Load and generation patterns that are representative of the California Independent System Operator (CAISO) "Duck Curve" are already evident in much of the region's renewable-rich territory. As distributed generation continues to surge, the region will require the ability to provide low cost, efficient ways to store and dispatch many types of renewable generated electrical energy. The state's Renewable Portfolio Standard brings significant changes to the utilities' bulk generation mix. Stabilization of this growing capacity will require new technologies in order to effectively operate the grid. Because a substantial portion of this renewable generation will consist of distributed and variable renewable generation from wind and solar, both bulk and distributed forms of energy storage will be needed. Development of new low cost highly efficient forms of energy storage, as well as sophisticated forecasting, management and dispatch systems are needed. UC San Diego is working with one of the State's largest solar generating facilities to incorporate solar forecasting algorithms that render significant improvements in operations. Clearly, expansion of this and other programs to optimize system operations of major renewable generation facilities will need to be highly integrated with the greater grid operating systems.

It is also important that new and enhanced automated systems for “in front of” and “behind the meter” applications are developed to control the generation of power and modulate power consumption (demand management, demand response and dispatchable load). The roles of these new systems are intended to significantly improve control of the demand side of the supply-demand equation, which facilitates matching the generation supply and increasing overall efficiency. These new Distributed Energy Resource Management Systems (DERMS) will need to be developed using rationally developed interoperability standards and will interface with customer end use devices, power grid utility devices, generation resources, and intersect with the transportation sector through the control of EV charging/discharging (see discussion below). In general, DERMS integration efforts are likely the single most important near term focus area because the ability of these systems to perform discrete and scalable control at or near the DER systems will significantly reduce stress on an already aged and cost constrained grid system. The State’s growing PEV population has the potential to play a significant role in this process.

It is important to also keep in mind that, longer term, climate science indicates that much deeper reductions in overall CO2 emissions are going to be needed by the 2050-time frame. It is therefore important to consider how decisions will be made to incorporate 50% renewable energy by 2030. This will determine the conditions for achieving the deeper reductions that will have to be made afterwards, and to frame the research, development, demonstration & deployment agenda appropriately.

Bob Musselman, on behalf of LA Cleantech Incubator

The only classic "renewable technologies" that can meet this demand are solar and wind, and the generation technologies are well developed. But these technologies will not suffice without utility scale storage. The only utility scale storage developed to date is concentrating solar power using “power towers” or “troughs” with large-scale thermal fluid bulk heat storage. Two large-scale plants have been developed in California, but have gained little traction with environmentalists or investors. Therefore, the energy “needs” are for further development and/or adoption of large scale energy storage, and upgrade of transmission of energy from sources (central California for wind, desert areas for solar) to large demand centers such as LA, San Diego and San Francisco. A third alternative for energy generation is safe, more efficient nuclear such as being developed in the form of small modular reactors (SMRs) by companies such as General Atomics and Nuscale. However, this would require a political re-definition of “renewable energy.” A unique challenge for Southern California is electric grid transmission upgrades to get renewable energy from sources to large demand centers.

Doug Rotman, Lawrence Livermore National Laboratory

Improved grid planning and renewable forecasting tools would allow us to better integrate intermittent sources and better understand the growing interactions between the transmission and distribution systems. Also, the expansion of geothermal power would give us more base load renewables to integrate with wind and solar.

City of LA

LA is on track to meet 33% renewables by 2020, but needs to go further on local solar to meet the City's goals. The City is working on properly aligning incentives to attract local solar investment and increase access to low-income residents.

Abhijit Mukherjee, California State University, Northridge

Distributed generation and storage. Consumers should be encouraged to meet the renewable goals by modifying homes, offices, commercial establishments, etc. A challenge is that Southern California is a highly populated area with diverse groups and conflicting interests.

Neil Fromer, on behalf of the Resnick Sustainability Institute, Caltech

From a fundamental science perspective, the challenges of a 33% renewable grid are actually quite in hand. Developing and deploying pilot projects to increase reliability with a larger fraction of renewable generation is needed, but are generally beyond the work going on at Caltech. In Southern California on that shorter timeframe, the biggest challenge is the sudden loss of the San Onofre Nuclear Generating Station (SONGs), which has led to increased gas fired power, and the utilities (SCE largely) now have the opportunity to develop pilot projects that fill in the capacity and the grid support functions of SONGs using renewable resources.

The 50% goal is a bit loftier, and there is a whole host of fundamental science and engineering investigation that needs to take place to optimize the grid for larger penetrations of renewable. Some of this is increasing efficiency/reducing cost of solar systems and especially of battery storage (of all scales). Also a focus on the deployment of EVs and the charging infrastructure for them. The biggest research challenges to meeting the 50% goal will come around adding smart, adaptive control of demand side resources in order to help keep the system stable. Lab research is still being done on how much of this is possible, and that needs to be supported with applied research that eventually leads to field trials and pilots.

Rajit Gadh, UCLA

We have to use solar energy and other renewable and clean energy as sources for deferrable loads, such as Electric Vehicle (EV) charging with EVSmartPlug technology and WINSmartEV infrastructure. Solar energy supply is ample in Southern California, but the EV and other load demand does not conform well to the solar generation profile. Proper energy storage and user scheduling are needed.

George Minter, SoCalGas

While the focus has been on renewable ELECTRICITY -- 33% and 50% -- the purpose is to reduce emissions (reduce carbon content of energy) and reliance upon depletable resources. We need to think about gas supply in the same way as we have focused on electric supply for the past 30 years. There are many sources of renewable gas – in fact the Air Resources Board's Short Lived Climate Pollutant plan is focused on biomethane to atmosphere – which is a big climate problem

(methane has higher GWP than CO2). California is now focused on capturing its biomethane – and to do so means we need to move it as an energy resource into the gas system for delivery to customers. That effectively is renewable gas replacing fossil gas – increasing the renewable percentage of our gas supply. In the state's inventory of methane, over 85% comes from the human production and waste chain – waste treatment, landfills, dairies, agriculture operations and woodland waste.

Existing biomethane resources can displace 15-20% of the state's current fossil gas volumes. Purpose grown crops – another pathway envisioned by the ARB, if dedicated to biomethane, can displace another 15-20% of fossil gas – bringing gas supply upwards to 40% renewable.

Then there is new Power to Gas technology (P2G) that uses excess renewable electricity produced during times of low demand, which can be directed through water in an electrolysis process to produce hydrogen, which is essentially stored energy that can be blended into the gas pipeline system or "methanated" (a Sabatier or "shift" reaction with captured CO2) and delivered as gas for heat, or for power at a later point in time. This adds additional renewable gas volumes to continue the "decarbonization of the pipeline". P2G is a promising electric to gas storage technology that has a broader application and potential than mere battery storage.

We also need to deploy immediately available near zero technology, like fuel cells in our stationary applications; and ultra-low NOx truck engines in our heavy-duty transportation sector ("near zero" or "electric equivalent" heavy duty engines are available NOW).

Gary Stern, Southern California Edison

We are well on our way toward 33% by 2020 with no significant challenges or impediments likely to interfere with that goal. We appear to be off to a good start towards 50% by 2030, despite the fact that California's definition of counting RPS, unlike any other State, does not include rooftop solar, which is rapidly expanding. Our one potential challenge is the operational impacts of adding what will likely be predominantly solar power based on current economics. These challenges, well described by the CAISO as the "duck curve" include times of excess generation compared to load in the middle of the day, particularly in Spring when loads are low and hydro power from snow melt exacerbates the excess generation, and the evening ramp as the sun sets and the solar power rapidly goes away while lighting needs add to system demand. Moving from the high generation period to a low solar power period strains the system.

Angeleno Group

Although California is highly progressive with regards to renewable energy, distributed solar, both for residential and commercial end-users, needs to be installed at a higher velocity in the near future. Utility scale solar projects continue to be constructed at a reliable rate, but putting the impetus behind more distributed generation assets can help California tap into unutilized capacity and achieve its renewable energy goals.

Angelina Galiteva, California Independent System Operator

Ensuring that we can reliably and cost effectively integrate the renewables coming on to our system. There is no silver bullet, but various efforts like appropriate time of use pricing, flexible capacity, reliability services provided by renewables, and regional integration will be key. This is especially true for Southern California as solar has seen significant growth and created opportunities in the middle of the day for storage based technologies (both stationary and mobile).

2. How will Southern California reduce petroleum use in cars and trucks by 50% by 2030? What are the challenges specific to Southern California in reaching this goal?

William Torre, UC San Diego

More convenient and efficient charging infrastructure, associated control systems, and regulatory reform is needed to foster higher penetration of EVs. Development of smart charging and vehicle to grid (V2G) capability in EVs and associated electric charging infrastructure in addition to making charging more available and affordable will also help to meet the renewable generation goals referred to in question one above. Smart charging similar to the 26 EV chargers installed and under test at UC San Diego can provide a way to provide more affordable vehicle charging, but also improve overall power grid reliability and increase use of renewable generation through dynamic pricing.

Bob Musselman, on behalf of LA Cleantech Incubator

The obvious answer is accelerated adoption of EVs. EV adoption requires the following: 1) Continued subsidies at the Federal and State level, along with perks such as High Occupancy Vehicle (HOV) lane access; and 2) As EV battery technology improves and charging times are shortened, the demand for very high charge rates at charging stations will put pressure on higher amperage delivery at local charging stations, a challenge for local utilities for which there is little compensation for infrastructure (larger local transformers) improvements. An alternative is energy storage at the charging stations themselves so that the station can accept lower steady state amperages and then dispense energy to EVs at a higher rate on demand. That will require a different employment of batteries or flywheel energy storage. Reducing petroleum use in trucks is a larger problem. One scheme proposed by Grid Logistics, AECOM, and Hyperloop is the use of underground tunnels moving cargo containers from the ports of LA and Long Beach to inland freight terminals using electric railcars underneath existing highways.

Doug Rotman, Lawrence Livermore National Laboratory

Nothing really new here – we just need to do more and better – expansion of electric cars and renewably produced hydrogen fuels for large trucks.

City of LA

With EV's becoming more affordable and with state and federal rebates in place, we must meet the availability of EV's with availability of charging stations. Biggest challenge for passenger vehicles is range anxiety, yet most EVs have sufficient range for most drivers' needs. We are learning how to remove infrastructure barriers and utilize incentives by leasing 100 EVs at LAPD, and sharing those lessons. The biggest challenge for electric trucks is market confidence on behalf of producers. Cities and state can help by committing to electric trucks and buses and send a signal to the market that demand is there.

Abhijit Mukherjee, California State University, Northridge

Heavily invest is public transportation. A robust public transportation system is required, especially in Southern California. Changing people's habits will be the key.

Neil Fromer, on behalf of the Resnick Sustainability Institute, Caltech

The state has put a strong emphasis on electrification of vehicles, but there are real concerns about our ability to meet a high level of penetration of EVs by 2030, while also continuing to reduce emissions from the electricity production. From a fundamental science and engineering perspective, the biggest goals that should be addressed are the development of advanced transportation batteries and charging infrastructure, and the development of renewable liquid or gaseous fuels. Renewable hydrogen generation as a fuel source is certainly feasible by 2030, and renewable methane/methanol/other hydrocarbon fuels might not be commercially ready by that point, but the continued development of such technologies is imperative if we are going to hit this goal.

Rajit Gadh, UCLA

Encouraging the adoption of clean energy vehicles, such as EVs, Plug-in Hybrid Electric Vehicles (PHEVs), etc., to shift the dependence of transportation energy consumption from fossil fuel to clean sources is the way to move away from petroleum run cars and trucks. Accordingly, to support large-scale adoption of EVs and PHEVs, EV Supply Equipment (EVSE) providing different types of renewable and clean energy should be installed in places easily accessible to the drivers of clean vehicles. For Southern California, investing in the deployment of more EVSE will facilitate the penetration of clean vehicles, in both residential and commercial areas.

George Minter, SoCalGas

Again, in our transportation sector – and not just buses and trucks, but also rail and marine – natural gas, and renewable gas, is the alternative to reduce carbon and reduce polluting emission like PM and NOx. As light and medium duty vehicle go electric and fuel cell – for heavy-duty transit and public fleets an engine is now available that is at "electric equivalent" tailpipe standards; and transit and public fleets are now ordering such engines. These are 90% cleaner than today's engines. Next year a similar "near zero" engine for heavy-duty trucking will become available. In the LA area 80% of the polluting emissions are from the Heavy Duty Transportation

sector – all of these applications can move from diesel and bunker fuel to natural gas and renewable natural gas to reduce both criteria pollutants (under Clean Air Act) and GHGs (under AB 32) -- Buses, Trucks, Off-road equipment (construction), Rail and Marine.

Gary Stern, Southern California Edison

From the electricity sector perspective (SCE is an electricity company) our focus is on accelerating the growth of transportation electrification to the extent possible. Our primary contributions will be charging infrastructure, education, and electricity rates that when designed to track the costs of providing electricity, should provide a much lower fuel cost than petroleum. As solar power grows and daytime electricity becomes low cost, long dwell time charging infrastructure for daytime charging will need to be greatly expanded to meet the anticipated demands as lower cost EVs become, hopefully, ubiquitous. Meanwhile progress on trucks, buses, and other petroleum using transportation must also be addressed with electrification (or other non-petroleum) solutions.

Angeleno Group

Incrementally changing driver habits, whether it's from a government, business or consumer perspective is a big challenge. However, Angeleno Group has seen a trend of smarter transportation practices that can play a promising role in reducing petroleum usage of cars and trucks in Southern California. From applying data analytics to traffic signals in Los Angeles, to enterprises partnering with fleet logistics companies and the proliferation of crowd-sourced cars and trucks, Southern California is on the road towards better transportation efficiency, which will hopefully lead to fewer cars on the road. Telogis is a Southern California based company that Angeleno Group has identified and invested in that supports this thesis. Telogis provides vehicle telematics and fleet management solutions that help businesses manage their mobile assets to increase route efficiency and reduce fuel consumption.

Angelina Galiteva, California Independent System Operator

Electrify transportation. With price discovery like what is provided in the CAISO markets, vehicles can charge at the appropriate times and use renewable energy. Additionally, providing hydrogen fuel solutions that are based on utilizing low cost surplus renewable energy will also be an increasingly viable option.

3. What are some of the feasible pathways for doubling the efficiency of existing buildings by 2030 and making heating fuels cleaner? What are the challenges specific to the Southern California region in reaching this goal?

William Torre, UC San Diego

The population of built environments in California is highly diversified. Many of the newest residential and commercial/industrial property developments constructed under CA Title 24 have significant improvements over the prior generations of buildings. In general, retrofits focused on these earlier generations of buildings have the potential to yield a large portion of this statewide goal to double efficiency. Climate zone appropriate measures must be ratified. A holistic approach to energy supply and consumption needs to be considered including both the electric power consumption and heating and air conditioning requirements. Much greater efficiencies can be achieved through combined heat and power applications. Renewable rooftop generation can be combined with energy storage to supply locally stabilized power, and advanced fuel cells (in some cases using renewable bio-methane) can provide electric energy production and the associated heat product can be used for both heating and cooling (absorption chillers). UC San Diego has recently demonstrated the feasibility with its 2.8 MW fuel cell by capturing the heat product and coupling it using an absorption chiller to produce chilled water. This system yields 350 tons of air conditioning capacity on campus, supplying most of the energy needed to condition two hospitals and their associated research laboratories. Effective implementation of combined heat and power potentiates double the overall efficiency, and with more research focus the goal of 50% energy reduction is highly realistic.

Bob Musselman, on behalf of LA Cleantech Incubator

Several technologies have been developed to improve the efficiencies of refrigeration and air conditioning systems by cleaning both the inside and outside of heat exchanger tubing, removing scale and improving heat transfer. Improvements in instrumentation and IoT technologies will allow for more specific monitoring of HVAC and refrigeration systems for optimized control and higher efficiencies. Additionally, building integrated photovoltaics (BIPV) can be used more extensively in new construction, which will yield efficiencies nationwide, but especially in Southern California.

City of LA

Removing all barriers to energy data is the first step toward energy efficiency. AB 802 is trying to address this, but it will be critical that implementation goes smoothly. To double energy efficiency, all large buildings in the state should undergo an energy audit and implement the recommended retrofit measures that pay for themselves in five years or less. Smaller buildings and single-family homes can forgo the audit and simply install selected retrofits. A key challenge will be financing. Allowing utility programs to align with state or local mandates will help owners comply. Advocating for PACE and on-bill financing will also help.

Abhijit Mukherjee, California State University, Northridge

Identify consumers who are wasting energy and motivate them to change. Most people are wasteful in nature, but they don’t know it.

Neil Fromer, on behalf of the Resnick Sustainability Institute, Caltech

See some of the renewable fuels discussion, above, but given the climate and environment of Southern California, the heating and cooling loads for buildings should be manageable with much less energy if smarter systems are put in place to passively control living and working spaces. Some of these ideas are quite mature, but there are many opportunities to develop new insulation materials or window/roof coatings that can play a large role in improving building energy management as well as urban heat islanding. In addition, the grid control infrastructure designed to meet high renewable electricity penetration can utilize building HVAC systems as a schedulable distributed resource that can be managed actively to adjust demand. These research areas need fundamental and applied project to develop them further.

George Miynter, SoCalGas

The above approaches describe new natural gas pathways that can help us increase our energy efficiency in buildings and also reduce the carbon content of heating fuels – "make our heating fuels cleaner". Governor Brown, in announcing the need to "make heating fuels cleaner" in his 2015 State of the State address, understood that we need to decarbonize the gas sector, as we will be using combustion – especially for heavy duty engines and for heating and other manufacturing processes in our commercial and industrial sectors. Biomethane development is key. So is developing purpose grown crops toward biomethane away from ethanol. So is Power to Gas technology. But also critical is the siting of highly efficient and low emission gas technology for this sector – particularly the building sector. Combined heat and power applications significantly increase our building efficiency by providing both heat and power on site, increasing efficiency of electric generation by eliminating line loss inefficiencies, but also by using the same energy resource to provide for heat requirements. Also critical is deployment of fuel cells that provide electricity and heat with virtually no emissions. Running these applications on renewable gas brings their carbon profile to near zero, zero, or even below zero – cleaner than electricity, given only a 50% RPS factor for electricity!

Gary Stern, Southern California Edison

One of the primary impediments to improving the efficiency of existing buildings for the Investor Owned Utilities has been the paradigm that only provided funding and goals for savings beyond existing codes and standards. With legislation that passed in 2015, we are in the process of developing programs to target "to code" savings, which will expand the potential for efficiency from existing buildings.

Angeleno Group

Energy storage is an area that Angeleno Group feels will be transformative for energy efficiency in existing buildings. Predictive energy software combined with the cost down trend of lithium-ion batteries is a simple way to deliver energy savings. To enable increased installations of these systems will require commercial building owners to recognize the value proposition of automating their energy management. Stem, one of Angeleno Group's portfolio companies, has

developed data analytics combined with energy storage that learns a building's energy profile to deliver energy when it matters most. The Stem system lowers energy bills with no change to operations and delivers actionable insights for building operators.

Angelina Galiteva, California Independent System Operator

Creating programs that are impactful and verifiable to reducing peak and overall demand is critical to reaching our goals. Fuel switching to renewables presents a large opportunity to decarbonize the economy while still providing reliable service. For Southern California, transportation electrification and the pricing signals and infrastructure to support its growth will be important areas to focus on.

4. How can we accelerate clean energy innovation in Southern California? What are the major obstacles to providing affordable clean energy to consumers and creating additional commercial opportunities in clean energy?

William Torre, UC San Diego

Accelerating clean energy innovation will require two major accomplishments: 1) Increased level of energy related research and demonstration projects. To achieve the State, Federal and International goals in Southern California and nationwide, for that matter, requires a drastic emphasis on innovation, which, in turn, will require additional investment in feasibility assessments, road-mapping and core focused research. Studies have shown that the energy sector has received a small portion of the overall investment in research. Acceleration of the clean energy sector will require renewed emphasis on research and demonstration projects. 2) Support for accelerating the transition of innovations developed in research environments toward commercialization. More support is needed and emphasis placed on moving new innovation from the laboratory to deployment and testing in the field at an accelerated pace. Many new innovative technologies in the clean energy sector are dying on the vine because they cannot pass through the "valley of death" to demonstration and eventual commercialization, more support and investment by DOE is needed in this area. UC San Diego is participating in a Regional Energy Cluster in San Diego by providing a test bed utilizing its microgrid and living laboratory as a platform for emerging energy technologies to test and demonstrate. DOE Mission Innovation could support this type of effort.

The major barriers to providing clean energy include much needed regulatory reform and streamlined rules for interconnection and implementation by local utilities. The regulatory rules were set and based on supporting vertical integrated utilities with a rate structure to support monolithic implementation and control of the system. As the paradigm shifts away from centralized plants toward distributed renewable clean generation, regulatory reform is needed to

allow and encourage emerging technologies to capture full benefits and revenues. This will, in turn, result in increased investment and accelerated implementation of clean energy. The interconnection rules and tariffs implemented by local utilities were developed and implemented based on increasingly obsolete rules that do not reflect the needs and capabilities of increasingly modern population of control and energy systems. These largely arcane paradigms need to be modified and streamlined to allow the ability to install new clean energy technologies without waiting months to years to follow through the filings and process required for interconnection by local utilities.

Bob Musselman, on behalf of LA Cleantech Incubator

Accelerating innovation requires incentives for both development and adoption. Public-private initiatives such as the LA Cleantech Incubator, grants, and other sources of funding are key to the innovation side. Subsidies provided by utilities, but funded by government, are key to adoption.

Bruce Dunn, UCLA

We need better integration of clean energy generation (wind, solar) and storage. The ability to put storage in homes to be used at night or at low wind times will be a disruptive technology that will, in turn, greatly increase the demand for renewable sources.

Doug Rotman, Lawrence Livermore National Laboratory

We are only beginning to tap the power of High Performance Computing (HPC) to enable greater innovation. HPC does not take the place of experiments, testing, and demonstrations – but, much broader use of HPC can help explore areas of new thinking and can enable thinking “beyond what we think is possible”. An emphasis should be placed on enabling small businesses (not just multi-national companies).

City of LA

Market adoption of new technologies always has a slow start. The SoCal utilities have a large role to play in helping the technologies penetrate residential and commercial markets. State and local policies also have a key role to play (e.g. CA storage mandate is a great example). Removing code barriers to allow new technologies is an important piece. Getting the technology (e.g. storage, auto DR appliances) into homes is difficult and will require proactive intervention/outreach. The challenge remains on how to scale up demonstrations (e.g. LADWP smart grid pilot, UCSD microgrid).

Abhijit Mukherjee, California State University, Northridge

The technology is there; we need implementation and job creation. It will start from investing in educational institutions as models.

Neil Fromer, on behalf of the Resnick Sustainability Institute, Caltech

Perhaps the solution is to create pilot projects or new energy technology “zones” within the

Southern California area to more rapidly prove out technologies. More resources are necessary for prototyping, piloting and testing new energy projects, and supporting translational science out of the lab and into the marketplace as quickly as possible.

Rajit Gadh, UCLA

Acceleration of clean energy innovation in Southern California will require the participation of both energy providers (e.g. utilities) and energy users (e.g. customers). To bring both sides together, a solution that is grid-and user-friendly is needed. Therefore, the priority should be the development of intelligent applications that will provide customers the option to integrate renewable energy generated in their homes to the grid. Current obstacles to overcome include: 1) lack of pricing strategies that encourage customers with renewable energy generation capabilities to participate in the energy market; 2) lack of advanced and integrated control strategies for EVs, solar generations, etc., to guarantee energy delivery efficiency and high level of customer satisfaction.

George Minter, SoCalGas

One thing is that we need to move from ideological positioning in our policy development and regulations – to focus on the goal – which is emission reductions. We need to allow technologies to develop – and to be deployed – that can achieve our goals – in the timeframe needed. Electrification of all energy end uses is NOT the goal. It may be a means to a goal – in numerous applications. But so is near zero or electric equivalent combustion technology, also in appropriate applications. We need to turn our economic incentives towards technology deployment. We have a 90% cleaner combustion engine. It needs to be deployed over the next 15-20 years to achieve the benefits it can deliver – especially when our scientific assessment (by ARB) is that electric of fuel cell alternatives are not ready for another 15-20 years. What prevents us from actually achieving goals is ideological pre-disposition that we know the answer – causing us to miss the solutions facing us.

We also need public incentives – such as those utilized over the last 30 years to decarbonize our electric sector – to now be turned towards incenting deployment of near zero combustion technology and de-carbonization of our gas sector. And that means biomethane development and Power to Gas development.

Angeleno Group

Nurturing energy institutions at UCLA, USC, and Caltech, and incubators like the LA Cleantech Incubator can accelerate clean energy innovation rooted in Southern California. More initiatives by utilities can also be a major catalyst towards this goal. Utilities occupy a dual role of being the customer for energy technology companies and also the channel for consumers and commercial opportunities to adopt more clean energy.

Angelina Galiteva, California Independent System Operator

At the CAISO, we produce locational prices every five minutes. If the market can see these prices, they can bring forward cost effective and innovative clean energy solutions that provide operational value to the end-use consumer. Over time, this will "flatten" the duck curve and reduce costs that are driven by high peaking demands.

5. What are some of the human resources that we have/need to transition to a clean energy economy in LA? What is needed in terms of workforce development?

William Torre, UC San Diego

More investment is required in education, specifically in the areas of Electric Power Engineering, Environmental Engineering and Material Science. We need more scientists and engineers to study and develop new innovative low-carbon energy technologies. We would suggest that major new technology centers dedicated to the development of new innovative low-carbon energy technologies should be developed and invested by DOE within the university sector, connected to a strong translation to move discoveries into demonstrations that can then be deployed at scale.

Bob Musselman, on behalf of LA Cleantech Incubator

SoCal business and MBA programs should offer courses on project finance, rather than just corporate finance. There are many programs that assist in recruitment of armed forces veterans with technical/engineering backgrounds, but none do a very good job of it.

Bruce Dunn, UCLA

UCLA has the opportunity to train the next generation workforce in clean energy technology. Investments have been made in terms of developing courses and curricula. More can be done. For example, an internship program with Southern California clean energy industry would provide students and employers additional opportunities. In addition, academic programs must continue to evolve to meet the needs of the clean energy economy.

Doug Rotman, Lawrence Livermore National Laboratory

Training in advanced manufacturing is necessary – all the way from informed technicians, to work and advance manufacturing processes, to deep innovation in new materials and advanced manufacturing technologies. We also need training in cyber security as we integrate and grow electrical and communication systems. We should focus on inclusion of all communities, engaging High Schools, Community Colleges, and 4-year institutions.

City of LA

We need to retain and attract more human capital to LA to lead the cleantech revolution and transform the market. By focusing on the Sustainable City pLAn targets, we not only can help create markets and drive local solar goals forward, we can increase housing affordability and increase mobility options for residents. We also need to include training and create a green job pipeline, so we can beat our goal of 20,000 green jobs in LA. Trainings will need to be focused not only on cleantech, but covering energy efficiency as well, including energy auditors, electricians, retro-commissioners, energy managers, and operating engineers.

Abhijit Mukherjee, California State University, Northridge

Invest in education, and retrain people working in fossil fuel based plants or systems and in car dealerships.

George Minter, SoCalGas

We need more Scientists and Science education. We need more Engineers – mechanical and energy engineers and more engineering education. We need more combustion and emission reduction research and trained personnel to advance such research and its applications.

Angeleno Group

Los Angeles is home to some of the greatest engineering schools in the country and to a thriving start-up scene. An ecosystem to support these engineers and entrepreneurs will allow them to further develop their businesses and tomorrow's energy innovation, and thus enable them to attract more capital.

Angelina Galiteva, California Independent System Operator

The zero net energy goal for new construction beginning in 2020 will be a crucial incentive to accelerate consumer awareness and accelerate technological innovation. Generally consumers are becoming more aware of their energy use and are driving clean energy production, especially at the distributed local level. Having the workforce to support such an expansion would be a win-win. However, even lower electricity costs from renewable resources can increase economic activity and improve health.

6. How do we ensure that energy innovation and new energy technology development initiatives are inclusive and encourage all Southern Californians to engage?

William Torre, UC San Diego

An outreach program in conjunction with the new technology centers should be considered. These outreach programs should interact directly with the local Southern California communities.

UC San Diego is currently engaged in such a program under the CEC EPIC Advanced Energy Community, where UCSD is working directly with a local community group to develop a plan for a clean energy community in a disadvantaged neighborhood of San Diego. This type of effort provides a hands-on demonstration in the field of innovative clean energy technology and, if successful, can be used as a template for engagement, implementation and educational objectives throughout the Southern California region.

Bob Musselman, on behalf of LA Cleantech Incubator

The media is pretty good at reporting tech/internet innovations, but not very good at reporting engineering/energy innovation. Perhaps because there is little public demand for that kind of reporting. Not sure how to solve that problem, but public engagement requires engaging with the public and that must involve the media.

Bruce Dunn, UCLA

Continue to sponsor workshops and roundtables so that all stakeholders become more familiar with one another's areas of expertise. This will aid in the integration required among the different stakeholders for new initiatives. For new energy technology, there needs to be support of advanced research ideas coming out of the universities that are especially directed at Southern California. Equally as important is the need to find ways to continue the development of these nascent technologies to facilitate their moving beyond the university stage. Finally, all of us need to re-double our efforts at communication so that Southern Californians are cognizant of opportunities for clean energy.

City of LA

Programs that lower the cost or financing that minimizes upfront costs are key. Education and outreach also key – lack of information is a major initial barrier.

Abhijit Mukherjee, California State University, Northridge

Invest in community colleges to start the change.

Neil Fromer, on behalf of the Resnick Sustainability Institute, Caltech

The more regional pilot projects can be supported and can require local participation, the more we can build an inclusive program. The utilities also can play a role in ensuring this process addresses all aspects of their customer base.

Rajit Gadh, UCLA

New energy technologies should engage users to interact with the technology, offer easy feedback, as well as an easy way to collect user input. This will enable all Southern Californians to personally experience the technology advancement and witness its positive impact on their lives, the environment, and the economy. Achieving this will lead to a healthy feedback improvement cycle.

George Minter, SoCalGas

Multi-sector stakeholder engagement.

Angeleno Group

Availability and access are crucial for engagement. Angeleno Group's investment into Renew Financial is proof that robust financing options for energy efficiency upgrades and renewable energy can unlock support from commercial and residential customers for energy technology initiatives. Renew Financial's financing solutions help efficiency and renewable energy contractors grow their business while promoting energy independence for their consumers in Southern California.

Angelina Galiteva, California Independent System Operator

In addition to what was stated above, policy drivers, long term planning and a strong commitment to renewable energy development, deployment and new technology integration will be important.

7. What are the "next steps" in accelerating clean energy innovation in Southern California?

William Torre, UC San Diego

Next Steps: 1) Develop regional centers for advancement of research and innovation of clean energy. 2) Provide support for education programs that train scientists and engineers in the clean energy sector. 3) Establish regional energy clusters that support transition of innovative clean energy technology to demonstration and commercialization. 4) Begin an effort to change regulatory and interconnection rules to reflect the changing energy sector and implementation of new clean energy technology.

Bruce Dunn, UCLA

Additional workshops are essential for us to communicate our expertise and articulate a vision for the future.

Abhijit Mukherjee, California State University, Northridge

Generate public awareness, with a focus on the commuters, and encourage public transport.

Rajit Gadh, UCLA

More renewable energy resources, including data and equipment, should be made available for researchers to facilitate development of new ideas and technologies.

George Minter, SoCalGas

Convene a stakeholder task force to assess immediate deployment of existing technology with the best emissions reduction outcome for both NOx (Clean Air) and GHG (Climate Change). Build support for South Coast Air Quality Management District (SCAQMD) and San Joaquin (SJ) Valley and Air Resources Board (ARB) Clean Air programs. The state's Mobile Source Strategy, its Sustainable Freight Strategy and its SIP (State Implementation Plan); as well as the SCAQMD and SJ Valley Air Quality Management Plans (AQMPs) -- all call for massive outlay of incentives to deploy clean energy and emissions technologies to the tune of an additional $1 Billion per year out to 2030 ($15 Billion). We need to build non-partisan, multi-sector stakeholder support for such an ambitious and necessary commitment.

Angeleno Group

Southern California needs up-to-date modern infrastructure to support energy innovation in the coming years. This would include a more robust grid, additional smart meters and more resilient transmission and distribution lines. Southern California's aging infrastructure needs an investment to be primed to handle an influx of renewable energy and energy storage.

Angelina Galiteva, California Independent System Operator

Create strong effective partnerships between Agencies, Utilities, grid operators, academia, civic society and NGOs.

8. What are some of the relevant research initiatives at your organization, and what role might your organization play in Mission Innovation (Mission Innovation aims to reinvigorate and accelerate global clean energy innovation with the objective to make clean energy widely affordable.)

William Torre, UC San Diego

UC San Diego conducts a significant level of research in the clean energy technology area. UC San Diego has top scientists, engineers and faculty who study and conduct research in the clean energy sector. UC San Diego has focused research and demonstration of innovative clean energy technologies in all aspects, including PV solar, energy storage, fuel cells, EVs, and distribution and automation. In addition, the concepts that have been developed have been implemented on its self-sustaining campus microgrids, one of the largest and most advanced microgrids in the US. Because UC San Diego owns its own generation and electric distribution system, new technologies can be tested live on the power grid, which is crucial to the successful demonstration and transition of new energy technologies to commerciality. This is demonstrated

in the 2.8 MW bio-gas fed fuel cell (largest commercial fuel cell) which provides 8% of the campus base load, the 2.5 MW/ 5 MWhr energy storage system (largest electric energy storage system at any university in the world), first combined heat and power fuel cell serving the campus heating and air-conditioning. UC San Diego was selected by DOE ARPAe as one of two sites nationwide to test new advanced energy storage chemistries, from the cell level to full MW systems. UC San Diego has developed the existing labs and infrastructure to support the major advancement needed for innovation in the clean energy sector.

City of LA

The City of LA can use its position to help get the message out. We also collaborate with cities around the world and can use an international forum to promote initiatives. We will also work hard to attract investment.

Abhijit Mukherjee, California State University, Northridge

CSUN is a leader is renewable energy and we serve as a role model for other institutions across CA.

Rajit Gadh, UCLA

At UCLA, the Smart Grid Energy Research Center (SMERC) has developed and tested various demand response (DR) and energy management system (EMS) technologies. SMERC, funded in part by a $120 million DOE-LADWP Smart Grid Regional Demonstration Grant, has designed, implemented, and tested the Automated DR (ADR) testbed within the WINSmartGrid™ framework on the UCLA campus.

Focusing on the charging behaviors of EV drivers, SMERC has developed a scalable scheduling framework on top of WINSmartGird™ with centralized control algorithms and mobile applications that are capable of capturing EV drivers' charging preferences. Time of Use (TOU) pricing strategies based on the wholesale price signals from the California Independent System Operator (ISO) are implemented in the EV charging system with customer preferences. In our online energy scheduling system, pricing strategies and renewable generations take random customer behaviors into account.

The SMERC developed WINSmartGrid™ is a network platform technology that enables wireless monitoring, connection, and control, via a Smart Communications Hub, of appliances such as washer, dryer, HVAC device, and plug-in automobile. Based on WINSmartGrid™, SMERC has developed an advanced Open ADR-compliant network system with a three-layer service architecture, i.e. Edge-ware, Middleware and Central-ware. The protocols and communication standards in this advanced system architecture include the following: (1) Wired and wireless network protocols for communication with the central controller, e.g., HTTP protocol based on TCP/IP over wired Ethernet or wireless WiFi/4G LTE link; (2) Communication protocols for interaction with the distributed energy controllers, e. g., IEC61850, BACnet, DLMS, Zigbee, etc.

George Minter, SoCalGas

Low emission combustion research; Engine technology research; Biomethane development research; Power to Gas research; BioGas Conditioning Tariff (to clean up gas for pipeline injection); Compression; Service Tariff (to support CHG refueling by public sector); Potential for LNG liquefaction service; Potential for Hydrogen, or Power to Gas production service.

Angeleno Group

Angeleno Group provides growth capital for next generation clean energy and natural resource companies. As promising companies emerge from Mission Innovation, Angeleno Group can help these companies at their inflection point of growth to transition from commercialization to scale.

Angelina Galiteva, California Independent System Operator

Would love to do that under a separate cover with additional partners and tangible examples if possible.

Appendix I – Roundtable Agenda

Southern California Clean Energy Innovation Ecosystem Roundtable

May 10, 2016, 12:30 – 3:00 pm (lunch at 11:45am)

Kerckhoff Hall State Rooms, UCLA Campus

Hosts: UCLA Dean, Henry Samueli School of Engineering and Applied Science, Dr. Jayathi Murthy and Associate Vice Chancellor for Environment & Sustainability, Dr. Mark Gold

Special Guest: Department of Energy Deputy Secretary, Dr. Elizabeth Sherwood-Randall

Moderator: Director of the Luskin Center for Innovation, Dr. J.R. DeShazo

11:45 am	Lunch
12:30 pm	Convening of the Roundtable, UCLA Dean, Henry Samueli School of Engineering and Applied Science, Dr. Jayathi Murthy
12:40 pm	Introduction to Mission Innovation and Regional Partnerships, Department of Energy Deputy Secretary, Dr. Elizabeth Sherwood-Randall
12:50 pm	State of Energy in LA, Chief Sustainability Officer, City of LA, Matt Petersen
1:00 pm	State of Energy in California, Member, California Independent System Operator Board of Governors, Angelina Galiteva
1:10 pm	State of Clean Energy Technologies, Professors Eric Hoek, Rajit Gadh & James Liao
1:20 pm	Moderated Roundtable Discussion, led by Dr. J.R. DeShazo
	Participant Introductions

Goals: Identifying the region's immediate and long-term clean energy needs and challenges*, and laying the foundation for future collaborations between roundtable participants and their associated institutions.

Sample questions leading the discussion:

- What are our immediate clean energy needs to meet California's goal of getting 33% of our energy from renewable sources by 2020 and 50% by 2030? What unique challenges do we face in the Southern California region in meeting these goals?
- How will Southern California reduce petroleum use in cars and trucks by 50% by 2030? What are the challenges specific to Southern California in reaching this goal?

- What are some of the feasible pathways for doubling the efficiency of existing buildings by 2030 and making heating fuels cleaner? What are the challenges specific to the Southern California region in reaching this goal?
- How can we accelerate clean energy innovation in Southern California? What are the major obstacles to providing affordable clean energy to consumers and creating additional commercial opportunities in clean energy?
- What are some of the human resources that we have/need to transition to a clean energy economy in LA? What is needed in terms of workforce development?
- How do we ensure that energy innovation and new energy technology development initiatives are inclusive and encourage all southern Californians to engage?

2:30 pm Next steps: summation of discussion and discussion of potential future collaborations moving forward

3:00 pm Roundtable Ends

* Note: Challenges may be related to governance, costs, inertia, regulatory and legal restrictions, available land, technology transfer, and more.

Appendix II – Roundtable Participants

FIRST NAME	LAST NAME	TITLE	AFFILIATION	DEPT/DIVISION/OFFICE
Randy	Britt	Director	Parsons Corp	Sustainability
Austin	Brown	Senior Policy Analyst	Executive Office of the President, Office of Science & Technology Policy	Energy Research and Development, Environment and Energy
Albert	Carnesale	Chancellor Emeritus and Professor	UCLA	Department of Public Policy; Department of Mechanical & Aerospace Engineering
Bill	Corcoran	Western Regional Director	Sierra Club	Beyond Coal Campaign
JR	DeShazo	Professor and Director	UCLA	Department of Public Policy; Luskin Center for Innovation
Bruce	Dunn	Professor	UCLA	Department of Materials Science & Engineering
Rajit	Gadh	Professor	UCLA	Department of Mechanical & Aerospace Engineering
Angelina	Galiteva	Board Member	California Independent System Operator	Board of Governors
Mark	Gold	Associate Vice Chancellor for Environment & Sustainability	UCLA	Office of the Vice Chancellor for Research; UCLA Grand Challenges
Eric	Hoek	Professor and CEO	UCLA	Department of Civil & Environmental Engineering; Water Planet
Michael	Kadish	Executive Director	Grid Alternatives LA	
Scott	Kitcher	President and CEO	CleanTech OC	
GP	Li	Professor and Director	UC Irvine	Department of Electrical Engineering & Computer Science; California Institute for Telecommunications & Information Technology; Integrated Nanosystems Research Facility
James	Liao	Professor	UCLA	Department of Chemical & Biomolecular Engineering
Tami	McCrossen-Orr	Policy Advisor	AECOM	Policy Advisor for Environmental and Land Use Planning at LA World Airports

FIRST NAME	LAST NAME	TITLE	AFFILIATION	DEPT/DIVISION/OFFICE
George	Minter	Regional Vice President	Southern California Gas Company	External Affairs and Environmental Strategy
Abhijit	Mukherjee	Professor and Director	California State University, Northridge	Department of Mechanical Engineering; Energy Research Center
Jayathi	Murthy	Dean	UCLA	Henry Samueli School of Engineering and Applied Science
Jonas	Peters	Professor and Director	CalTech	Department of Chemistry; Resnick Sustainability Institute
Matt	Petersen	Chief Sustainability Officer	City of LA	Office of LA Mayor Eric Garcetti
Douglas	Rotman	Program Director	Lawrence Livermore National Laboratory	Energy and Environmental Security
Elizabeth	Sherwood-Randall	Deputy Secretary	US Dept of Energy	Energy
Erik	Steeb	Chief Programs Officer	LA Cleantech Incubator	
Gary	Stern	Senior Director	Southern California Edison	Regulatory Energy Policy
Yaniv	Tepper	Managing Partner and Co-Founder	Angeleno Group	Renewable energy, waste management and energy efficiency
William	Torre	Program Director	UCSD	Energy Storage Systems
Sadrul	Ula	Managing Director	UC Riverside	Winston Chung Global Energy Center
Yang	Yang	Professor	UCLA	Department of Materials Science & Engineering

Appendix III – UCLA's Clean Energy Ecosystem

UCLA's Clean Energy Ecosystem

In 2013, UCLA Chancellor, Gene Block announced the Sustainable LA Grand Challenge, a campus wide research initiative with the ambitious goal of transforming LA County to the first sustainable megacity. Unlike research initiatives of the past, Sustainable LA organizes faculty and researchers from across disciplines around a common goal. Specifically, the goals are to transition LA (LA) County to 100% renewable energy and 100% locally sourced water, while enhancing ecosystem health and human health and well being by 2050.

In December 2015, we released the Sustainable LA Five-Year work plan, which summarizes the challenges unique to LA County, our reasoning for choosing these goals, and over 100 research recommendations that must be completed in the next five years for us to develop a comprehensive implementation plan by 2020 that will provide a pathway for sustainability by 2050. Twenty-eight faculty from across campus contributed to the development of the work plan, including faculty from engineering, life sciences, physical sciences, public health, law, public affairs, humanities, social sciences, and architecture and arts. This was truly a multi-disciplinary effort that set the foundation for much future interdisciplinary collaboration.

We believe that the complex problem of sustainability requires diverse expertise. We also recognize that UCLA cannot do this alone – we must partner with other academic institutions, government, utilities, industry, NGOs, and community groups to solve this multifaceted problem and reach our goals. We are working on building and fostering the necessary partnerships to integrate and ultimately implement the research findings stemming from the work prescribed in the research plan.

Sustainable LA is one way in which UCLA coordinates the incredible clean energy research that is happening across campus. UCLA has a long history of excellence in energy-related research, including record-breaking solar cell efficiency and reliability research, cutting-edge energy storage and hybrid supercapacitor innovations, advanced development of alternative fuels to power electricity and transportation, prominent climate change and environmental law and policy programs, progressive architecture and urban design programs that focus on energy efficiency and transportation issues, leading voices on health effects of pollution and climate change in urban spaces, a top transportation policy and planning program contributing regularly to regional practices, and prominent designers of decision support tools for policymakers and civic leaders in the area of environmental sustainability.

Over the next five years, UCLA and its partners will undertake critical energy and transportation research projects aimed at filling knowledge gaps and informing the optimum energy transition plan for LA County. First, we will develop a long-term plan for a local energy portfolio that balances accessible renewable resources; energy and fuel distribution, management, and storage needs; and end-user requirements. Our multidisciplinary team will then work with

stakeholders and partners to research and develop key technologies, policies, and management strategies needed to expand renewable energy generation in accordance with that plan and the Sustainable LA Grand Challenge goals. This work will include research related to the development of an integrated electricity and fuel infrastructure and a local smart grid, as well as groundbreaking technologies and policies to integrate solar energy harvesting and storage into a wide variety of surfaces found in the built environment. In tandem, researchers focused on improving management of energy consumption will design strategies to reduce the energy intensity of transportation, promote building energy efficiency and conservation, and better manage electricity demand in the County. Additionally, UCLA's public health, policy, and environmental science researchers will work collaboratively with partners and stakeholders to evaluate the broader implications of transitioning to 100-percent renewable energy, and explore strategies to enhance public health and mitigate adverse environmental impacts during LA' renewable energy transition.

There are several existing UCLA Centers and Institutes that contribute to UCLA's energy and innovation ecosystem, and also to the goals of Sustainable LA. They include the following:

UCLA Engineering Institute for Technology Advancement is a technology development center to accelerate the transition of high-impact innovative research from UCLA to technology development and commercialization.

UCLA's Energy Innovation Lab investigates breakthrough technologies for grid-scale renewable energy generation and storage. They study how thermal energy storage systems allow concentrated solar power plants to provide energy even when the sun is not shining, as well as advanced wind turbine blade designs that improve energy capture and reduce the cost of wind energy.

UCLA's Smart Grid Energy Research Center (SMERC) is currently working on Electric Vehicle Integration (G2V and V2G), Automated Demand Response (ADR), Microgrids, and Distributed and Renewable Integration, and Energy Storage Integration.

UCLA Energy & Propulsion Research Laboratory aims to improve combustion, propulsion, and fluid flow systems to solve critical national problems, including those related to energy efficiency and aerospace propulsion.

Center of Excellence for Green Nanotechnologies at KACST & UCLA (CEGN) undertakes frontier research and development in the areas of nanotechnology in energy and nanoelectronics. CEGN tackles major issues of scaling, energy efficiency, energy generation, and energy storage faced by the electronics industry.

California Center for Sustainable Communities creates actionable science that improves the sustainability of urban systems. One research theme is focused on mapping energy and gas use across the County by census block groups and land use to determine patterns across the landscape. They recently developed a publicly available interactive LA Energy Atlas.

Luskin Center for Innovation is organized around initiatives that seek to conduct and translate world-class research and expertise into real-world policy solutions. Initiatives are linked by the

themes of sustainability, energy and environmental health justice. Current initiatives include: Sustainable Energy for California, Electric Vehicles & Alternative Fuels, Complete Streets, Smart Water Systems, Nanotechnology Environmental Health & Safety, Climate Change Planning for Local Governments, Digital Technologies, and Business and the Environment.

UCLA Institute of Transportation Studies is a leading transportation policy research centers in the U.S. and links transportation research with policy and planning practice.

Emmett Institute on Climate Change and the Environment is focused on climate change and other critical environmental issues. The Institute is leading the Public Utilities Commission Clean Energy Policy Collaborative Project—a multi-year, cross-university project designed to improve states' energy policies by analyzing interactions between climate regulatory efforts and state Public Utility Commissions (PUCs) nationwide.

Anderson School of Management Energy Management Group serves to strengthen educational pursuits, facilitate networking opportunities and enhance recruiting efforts among Anderson students, alumni and energy-industry organizations. They are interested in finance, strategy, marketing and technology development.

Appendix IV – A Preliminary Assessment of 100% Renewable Energy for LA County

100% Renewable Energy for LA County: A Preliminary Assessment

(Executive Summary, July 2016)

Richard E. Wirz*, Karthik Nithyanandam, Parker Wells

UCLA, Department of Mechanical & Aerospace Engineering

*Energy Representative, Sustainable LA Grand Challenge Steering Committee (wirz@ucla.edu)

Abstract: The results of this feasibility study show that it is possible to achieve LA County's 2050 energy needs by using only a small fraction of the region's accessible renewable energy resources. The solution requires the generation, distribution, and storage of both renewable electricity and fuels to meet end-user, water, and transportation energy needs, while supporting a healthy regional ecosystem. To achieve this goal, many significant technological and policy challenges must be addressed – several of which are identified herein as near-term "Research Directions". As such, this study serves as a preliminary technological assessment to stimulate the development of a long-term 2050 plan for a sustainable energy portfolio for LA County and region.

Introduction & Approach:

The University of California, LA (UCLA) launched its first Grand Challenge: Sustainable LA, Thriving in a Hotter LA (Sustainable LA) – an ambitious campus-wide research endeavor to transition LA (LA) County to 100% renewable energy[1], 100% locally sourced water, and enhanced ecosystem and human health by 2050 through innovations in science, technology, and policy. With regard to the energy goal, the objective is to power all of the County's energy and transportation needs from renewable energy resources in the LA region. This study aims to assess the 2050 renewable energy potential for the LA region[2] and to present potential pathways for achieving the Sustainable LA 100% renewable energy goal by considering regional

[1] According to the State of California, "**renewable energy**" includes the following, subject to certain state regulatory requirements and conditions: biodiesel, biogas, biomass, conduit hydroelectric, digester gas, fuel cells using renewable fuels, geothermal, hydroelectric incremental generation through efficiency improvements, landfill gas, municipal solid waste, ocean wave, ocean thermal, tidal current, photovoltaic, small hydroelectric, solar thermal, and wind (CEC, 2012).

[2] The "**LA region**" is defined by the City of LA, LA County, and the greater LA metropolitan Area, including surrounding counties in Southern California.

energy, transportation, and water needs; renewable energy resources in the region; and responsible approaches that promote a vibrant local ecosystem and community.

This feasibility study considers two basic questions associated with achieving the Sustainable LA Grand Challenge goal of 100% renewable energy in LA County by 2050.

> Question 1: Can the LA region fulfill 100% of its energy (electricity and fuel) requirements with local renewable resources?
>
> Question 2: What are the primary technological challenges associated with achieving 100% renewable energy by 2050?

These two feasibility questions are addressed and discussed here at a high-level. Energy usage data and projections are used to construct realistic and fringe-case demand scenarios for a fully renewables-powered LA in 2050. These scenarios are used to compare the energy supply and energy demand for the LA of the future. The different electricity demand scenarios, combined with projected costs of renewable generation and storage sources are then used to develop approximate breakdowns of how each technology will contribute to the LA County energy landscape in a cost and logistically responsible scenario.

Energy Demand (LA County) & Energy Supply (LA Region):

The forecasted average hourly total power demand (in Gigawatts, GW) for LA County in 2050 is an aggregate of the end-use demand [CEC, 2014], the electricity demand to produce clean water [Christian-Smith et al., 2012; Semiat, 2008], and transportation fuels. These power demand projections account for regional population growth, expected increases in per capita energy consumption, and assumes a reasonable level of end-user efficiencies, i.e., “Negawatts”. For these conditions, the average hourly total power demand (shown in Figure 1) is projected to be 14.4 GW, with 69% going towards end-use, 5% towards water, and 26% towards transportation.

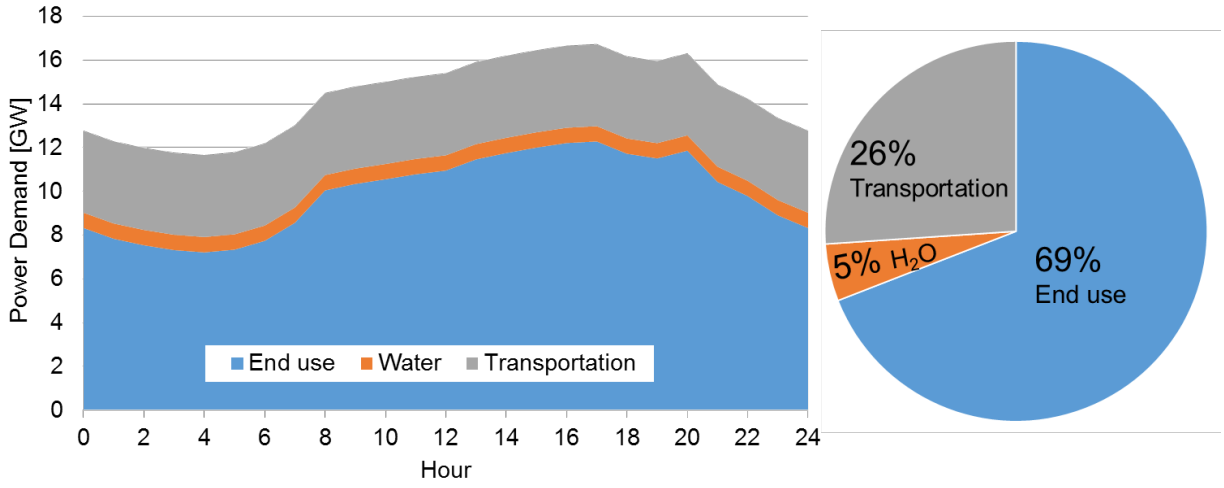


Figure 1: Total average hourly power demand for LA County in 2050

Demand levels in Figure 1 are representative of the energy scenarios that combine both renewable electricity and fuels. For LA County to achieve the 100% renewable energy goals by 2050, it is important to integrate renewable fuels to accommodate transportation vehicles moving within and through the County. Renewable/sustainable fuels can also replace natural gas currently used for industrial and residential purposes. For example, a comparison of the potential of the various feedstocks in meeting the 2050 transportation demands of LA County is presented in Table 1. The low ethanol yield per acre of cultivation for corn, sugar cane, and poplar, compounded by the potential conflict between food and fuel production, suggests a need to develop more advanced non-agricultural biofuels, such as algal strains with reduced water needs. Other fuel sources may include biomethane capture, and power-to-gas (P2G) technologies.

Table 1: Comparison of various feedstocks for ethanol production

Source	Ethanol equivalent yield (Gallons per acre-year)	Land area required (million acres)	Percentage of LA county/ LA region/CA
Corn	400	6.9	225 / 31.6 / 6.6
Sugarcane	800	3.5	112 / 15.8 / 3.3
Poplar	1500	1.83	60 / 8.4 / 1.8
Algae	5000	0.55	18 / 2.5 / 0.5

By 2050 the total maximum percentage that regional hydro, wind, and geothermal combined can reasonably contribute to meeting LA County's projected average daily energy demand is only slightly more than 15%. Solar is by far the biggest renewable energy resource for the LA region and can easily provide the remaining 85%. As shown in Figure 2, over half of the solar energy resource must be stored to meet the demand profile from Figure 1. For most of the LA region, and particularly for the less populated areas, solar energy is a highly predictable energy resource that can be made dispatchable on a nearly diurnal cycle, and for multi-day durations if necessary.

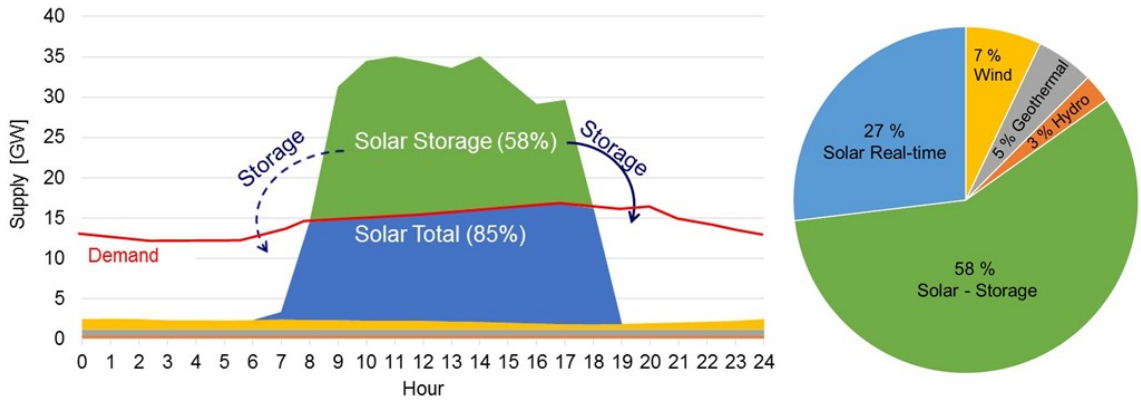


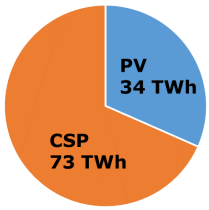
Figure 2: Energy supply scenario for LA County in 2050

From Figure 2, we determined that the annual energy required from solar in LA County is ~107 TWh per year. Only 34 TWh, or 32% of this energy could be supplied from distributed rooftop solar photovoltaics (PV). To meet the remaining solar demand, LA County will have to rely on centralized concentrated solar power (CSP) and PV plants that can provide both the capacity and dispatchability needed for a robust and reliable energy solution. The levelized cost of electricity (LCOE) for PV integrated with battery storage is currently 28-30 cents/kWh [Nykvist and Nilsson, 2015], compared to LCOE of 12-14 cents/kWh for CSP integrated with thermal energy storage (TES). This difference is due to the comparatively high cost of the batteries required for PV energy storage. The US Department of Energy (DOE) projects a credible pathway for a reduction in the LCOE of PV+battery and CSP+TES to approximately 14 cents/kWh and 6 cents/kWh, respectively by the year 2020 [DOE SunShot, 2011]. Therefore, we are recommending PV+battery primarily for distributed rooftop generation throughout LA County, with CSP plants that are built in compatible areas of the LA region providing the remaining solar energy supply (68%). We also suggest the use of dry-cooling approaches, as is currently done by many modern CSP plants to lessen water consumption.

Table 2 shows a preliminary assessment of the solar energy contribution necessary from both solar PV and CSP to meet LA County energy requirements by 2050. A key observation from Table 2 is that LA County could meet its solar energy requirement (Figure 2) from CSP by developing less than 18% of the land in the region that is compatible for CSP development (this is only 0.3% of the total land area in the region). Compatibility is based on various practical considerations, including: topography (slopes must be less than 3% grade), proximity to transmission lines and roads, ecological sensitivity, federal/state protected habitat status, and other considerations [Hernandez et al., 2015].

Table 2: Solar supply scenario of LA County power demand in 2050

Required Solar (TWh/y)	107
LA County **PV** (TWh/y)	34
LA region **CSP** (TWh/y)	73
Area required for CSP (km^2) in the LA region	235
% of compatible area in LA region required for CSP	17.5 %
% of total area in LA region required for CSP	0.3 %



Conclusions & Research Directions:

This study provides a preliminary assessment of LA County's energy requirements and the potential for renewable energy technologies to meet the County's energy demand in 2050. We conclude that LA will be able to meet its 2050 energy needs through 100% renewable energy resources. These resources will come from a combination of distributed and centralized generation and storage of electricity and fuel. Solar energy (PV and CSP) integrated with low-

cost, dispatchable energy storage will play the most significant role in reaching 100% renewable energy. With such a comprehensive change envisioned for the LA region, action is required not only from scientists and technologists, but from policymakers, climate scientists, urban planners, and other professionals. UCLA's Sustainable LA Grand Challenge must serve as a leader in advancing the necessary research required to reach these goals, and continue to foster collaborations and partnerships throughout the region to develop a pathway to renewables that thoughtfully considers the findings from this study and social, cultural, and political challenges unique to the region.

Based on the findings of this feasibility study, our recommended Research Directions include:

1. Ecosystem friendly conservation and efficiency "Negawatts".
2. Renewable fuel technologies for transportation and industrial/residential end-users.
3. Low-cost/high-performance energy storage (e.g., thermal batteries) for grid-scale solar energy storage.
4. Storage and management for distributed energy generation.
5. Energy efficient technologies for water reuse, wastewater treatment, and brackish water desalination.
6. Innovations at the Energy, Water, and Ecosystem Nexus to promote responsible development in all areas.