Institute on Science for Global Policy (ISGP)

Sustainability Challenges: Coping with Less Water and Energy

Conference convened by the ISGP and the Whittier Working Group
June 5, 2015
at the PIH Health Hospital
Whittier, California

ISGP Climate Change Arctic Program (ICCAP) — Whittier

Institute on Science for Global Policy (ISGP)

(a not-for-profit organization that does not lobby on any issue, but does promote rational thinking)

Sustainability Challenges: Coping with Less Water and Energy

A conference convened by the ISGP in partnership with the Whittier Working Group of community leaders, in Whittier, California, U.S.
June 5, 2015

An ongoing series of dialogues and critical debates examining the role of science and technology in advancing effective domestic and international policy decisions

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Introduction

Dr. George H. Atkinson
Founder and Executive Director, Institute on Science for Global Policy
and
President, Sigma Xi, The Scientific Research Society
and
Professor Emeritus, Department of Chemistry and Biochemistry and College of Optical Sciences, University of Arizona

Preface

The contents of this were taken from material presented at a conference convened in Whittier, California, by the Institute on Science for Global Policy (ISGP) on June 5, 2015, in partnership with the volunteer Whittier Working Group comprised of community leaders. The conference, ***Sustainability Challenges: Coping with Less Water and Energy***, was the second of a new series of ISGP Climate Change Arctic Program (ICCAP) conferences being held around the United States. These ICCAP conferences focus on communities that are concerned with how to mitigate and/or adapt to the anticipated impact of changing climates (e.g., drought, sea level rise, severe storms, warming freshwater). Special attention is given to how changes in climate may alter personal lifestyle choices and the collective decisions made throughout a community. ICCAP conferences attempt to significantly improve the communication of credible scientific and technological (S&T) understanding to both policy makers and to the public *writ large,* required to support progressive policies.

ISGP

The ISGP was founded in 2008 on the premise that rational debate between credible scientists and relevant stakeholders is an increasingly critical element in both the public and private sectors where policy decisions involving S&T are being made. To support effective policies, decision makers need to understand the advantages and risks associated with the often-transformational S&T advances.

The ISGP has pioneered the development a new type of international forum designed to provide articulate, distinguished scientists and technologists opportunities to concisely present their views of the S&T options available for addressing major geopolitical and security issues.

All ISGP programs rely on the validity of two overarching principles:

1. Scientifically credible understanding must be closely linked to the realistic policy decisions made by governmental, private sector, and societal leaders in addressing both the urgent and long-term challenges facing 21st century societies. Effective decisions rely on strong domestic and global public endorsements that are based on the active political support required to implement progressive policies.

2. Communication among scientific and policy communities requires significant improvement, especially concerning decisions on whether to embrace or reject specific S&T opportunities continually emerging from global research communities. Effective decisions are facilitated in venues where the advantages and risks of credible S&T options are candidly presented and critically debated among internationally distinguished subject-matter experts, policy makers, as well as private-sector and community stakeholders.

Whittier Working Group (WWG)

The WWG is comprised of leaders from the Whittier, Calif., area who volunteered to work with the ISGP concerning their shared interest in facilitating constructive, rational, and critical

debates about the climate issues facing the Whittier area. Biographies of the Whittier Working Group members are in the Appendix of this report.

ISGP Climate Change Arctic Program (ICCAP)
Of the seemingly innumerable challenges associated with science and technology being debated, those connected to "climate change" are among the most intractable. The often-irrational discourse and public uncertainty about climate change defines how complex and challenging such issues can become. While public and political disagreements rage over the existence of climate change, and certainly its relationship(s) to human activities, there are increasing physical indications that changes in climates (local, regional and global) are occurring with a rapidity and severity not anticipated by many credible scientists and societal leaders.

Under these circumstances, there is an increasingly important need to more effectively engage citizens in discussions concerning the reality of climate change and its potential significance in their lives. It is also evident that new models are required to reconcile opposing views in order to obtain practical policies that can be implemented and publicly supported.

To ensure that the societal debates of climate change issues lead to effective governmental and private-sector policies, two types of engagements are needed:

1. It is critical that well-informed, credible scientists and technologists candidly communicate the advantages and risks of practical options for addressing climate changes in the lives of citizens and their communities.

2. Citizens must be able to evaluate recommendations based on the predictions from climate change models against often expensive and difficult alterations in their personal lifestyles. Since citizens legitimately have concerns regarding the credibility of information provided to them from multiple sources, they deserve the opportunity to question specific recommendations based on their own perspectives. Formulating and implementing such policies require broad, sustained public endorsements.

Eventually, the outcomes of such candid debates depend on the degree of certainty citizens attribute to the relationship(s) between climate change and specific human activities. The extent to which citizens believe that uncertainty associated with scientific research justifies their accepting the costs and risks associated with any societal decision is the focal point of the ICCAP conferences. Because these decisions often require changes, and perhaps even retrenchments, in the lifestyles of average citizens and community-wide decisions (e.g., higher-fuel-efficiency transportation, reduced energy consumption, different choices for food and housing), sustained public support is essential to motivate policy makers to act.

***Sustainability Challenges: Coping with Less Water and Energy* conference structure**
At each ISGP conference, internationally recognized subject-matter experts are invited to prepare concise (three-page) policy position papers. Following extensive interviews by the ISGP staff with domestic and international subject-matter experts, three distinguished individuals are invited by the ISGP to prepare policy position papers describing their views of the current realities and the scientific, technological, and policy options available to decision makers in government, the private sector, academia, and the society in general. These policy position papers are distributed to all participants prior to the conference.

In Whittier, a group of 29 debaters, comprised of local scientists, academics, governmental and private-sector representatives, students, and other members of the community, was invited to critically question these experts. (Short biographies of the debaters are included in this report.)

The first part of the conference was comprised of three, 90-minute sessions, each of which was devoted to a debate of a given policy position paper. In each session, the author was given 5 minutes to summarize his views while the remaining 85 minutes were opened to all participants, including other authors and the audience, for questions, comments, and debate. Audience members could submit written questions to the moderator. The debates focused on clarifying understanding among the nonspecialists. The not-for-attribution summaries of each debate, prepared by the ISGP staff from notes and recordings, are presented here immediately following each policy position paper.

In the second part of the conference, all participants (audience members, presenters, and debaters) met in small caucus groups to identify areas of consensus and actionable next steps to be considered within government, the private sector, and civil society. Subsequently, a plenary caucus was convened for all participants. While the debates focused on specific issues and recommendations raised in each policy position paper, the caucuses focused on overarching views and conclusions that could have policy relevance both domestically and internationally.

A summary of the overall areas of consensus and actionable next steps emerging from these caucuses is presented in this report.

Areas of Consensus and Actionable Next Steps

The Areas of Consensus (AoC) and Actionable Next Steps (ANS) presented in this report summarize the essential themes raised by conference participants in response to information, debate, and discussion about drought and water usage. These statements of AoC and ANS reflect how participants responded to the policy position papers as well as their concerns on related climate/water issues.

The AoC and ANS were prepared by the ISGP and WWC following a careful analysis of the transcripts and notes from the debates and caucuses. These AoC and ANS were sent to all conference participants for review and comment, and that feedback was incorporated into the final statements in this report.

Concluding remarks

This report is designed to be used throughout society *writ large* including policy makers within citizen groups, public and private-sector organizations, as well as governmental officials wishing to learn about the common concerns of area residents regarding ***Sustainability Challenges: Coping with Less Water and Energy***.

The ISGP, a not-for-profit organization, has no opinions nor does it lobby for any issue except rational thinking. Members of the ISGP staff do not express any independent views on any topic. Rather, ISGP programs focus on fostering environments that can significantly improve the communication of ideas and recommendations derived from credible scientific understanding to decisions makers in both the public and private sectors. It is hoped that all those responsible for formulating and implementing polices will benefit from the information in this report in their efforts to effectively serving their constituents.

Conference conclusions

Area of Consensus 1
Water is both a commodity and a right. Because current policies in California undervalue water and lead to inefficient usage, water policies need to be changed to encourage more equitable and efficient distribution to all stakeholders and discourage wasteful, polluting, and/or water-intensive practices by food producers and urban users. This must be done without favoring one group over another and while protecting access to water for all, including vulnerable human populations and the natural environment.

Actionable Next Steps

- Convene an expert panel to evaluate and propose revisions to the existing system of water rights in California.
- Establish a regulated marketplace for water distribution.
- Establish easily accessible channels that ensure the public has a voice in policies set by the entity charged with overseeing new water markets.
- Invest in public outreach and community education programs about the distinctions between urban and agricultural water uses in California.

Area of Consensus 2
High priority needs to be place on integration of water and electrical technologies in California, not only for individual innovations, but also for projects and research that look at systemic sustainability and that promote existing cost-effective ways to manage energy and water use.

Actionable Next Steps

- Provide funding, incentivize investment and reallocate resources to develop and integrate advanced water and energy systems, including gray, sanitary, and storm water utilization systems, dual water systems for local property developments, a smart energy grid, passive energy design, automated meter reading for water, innovative basic research, and emerging technologies.
- Require new property development to integrate designs that reduce energy and water usage and promote retrofitting of existing structures.
- Require regulatory agencies to streamline their processes for approving updates to current energy and water distribution/supply systems, and the incorporation of innovative technologies into these systems.

Area of Consensus 3
While international organizations cannot enforce water agreements, they can play a critical role in helping articulate the frameworks by which surface and subsurface water is utilized worldwide. International organizations can set a standard for water agreements that recognizes water as both a right and a commodity, and they can assist with technology and offer informational guidance, but nation-states must formulate and enforce water agreements at a regional or national level.

Actionable Next Steps

- Charge international organizations (e.g., the United Nations) with encouraging

collaboration on water issues within multinational regional organizations (e.g., European Union, Pan-American organizations), while providing resources for collaboration (e.g., arbitration, moderation, facilitation, objective data collection, research, education, and funding), and serving as record keepers of regional compliance.

- To foster cooperation, convene international conferences that catalyze the development of, and compliance with, equitable and just water agreements, and that encourage sustainable agricultural practices among regional multinational organizations.

Sustainability Challenges: Coping with Less Water and Energy
PIH Health Hospital • 12401 Washington Blvd., Whittier, California
Flo & Frank Scott Conference Center

Conference Program

Friday, June 5

7:45 – 8:30 a.m.	**Registration** / *breakfast snacks*
8:30 – 8:45 a.m.	***Welcoming Remarks & Introduction*** **Dr. Sweta Chakraborty**, Associate Director, Institute on Science for Global Policy
Presentations and Debates	
8:45 – 10:15 a.m.	**Debate 1** **"Coping With Drought to Ensure Societal Stability and Food Security: California Encapsulates Many Global Issues"** **Dr. Jerry R. Schubel,** President and CEO, Aquarium of the Pacific, Long Beach, California, USA
10:15 – 10:30 a.m.	*Break*
10:30 – 12:00 p.m.	**Debate 2** **"When Subsidies Work and When They Don't: Food vs. Power"** **Dr. Christopher Thornberg,** Founding Partner, Beacon Economics, Los Angeles, California, USA
12:00 – 12:45 p.m.	**Lunch** *Boxed lunches served on Lowell Smith Patio*
12:45 – 2:15 p.m.	**Debate 3** **"Balancing Efficient Use With Sustainable Generation"** **Dr. Neil Fromer,** Executive Director, Resnick Sustainability Institute at Caltech, Pasadena, CA, USA
2:15 – 2:30 p.m.	*Break / move into assigned caucus rooms*
2:30 – 5:45 p.m.	**Focused group sessions** *Breakout rooms*
5:45 – 6:15 p.m.	**Closing and Adjournment** Dr. Sweta Chakraborty

Coping With Drought to Ensure Societal Stability and Food Security: California Encapsulates Many Global Issues

Jerry R. Schubel, Ph.D
President and CEO, Aquarium of the Pacific, Long Beach, California, U.S.
Bill Patzert, Ph.D
Climatologist, NASA's Jet Propulsion Laboratory, Pasadena, California, U.S.

Summary
Much of the world, like California, faces serious shortages of fresh water. Water is often scarce; water issues are complicated. Agriculture is by far the largest user of water globally, and in California it accounts for 80% of all water used. Globally and in California, people have generally settled far from water supplies. Consequently, there has been extensive and increasing intervention by humans to capture and move water for agricultural, urban, and industrial uses. Globally, most of the world's waters — surface and ground — are shared resources and no agreements or frameworks exist for managing shared water sources. It can be anticipated the availability of water in general will decrease because of climate change, as demand grows from a ballooning population, and as the need for more food grows, tensions over these shared waters are increasing. The United Nations (UN) predicts that the world will need 70% more food by 2050 to feed an additional 2.5 billion people. Agriculture already uses nearly 50% of the Earth's ice-free surface and 70% of its fresh water. We need a new "green revolution," one that grows more nutritional food on less land, using less water, less fertilizer, and less pesticides. California is a perfect laboratory to illustrate these issues. It is the seventh largest economy in the world, has the largest agricultural economy of any state in the United States and currently is faced with a serious drought. California could become a model for other states and nations facing serious drought.

Current realities
Water is essential for a stable society. It is the most extracted natural resource on Earth, and the one natural resource for which there is no substitute. Climate change will dramatically redefine the global water picture. Nearly half of all the world's population already lives in water stressed areas and these tensions are expected to increase to 60% by 2025.

The Global Situation Eighty four percent of the population lives on the driest half of Earth. This has led to extensive intervention by humans to capture and transport water. Most of the world's waters are shared resources and 50% of the world's population depends upon shared water resources. At least 274 groundwater basins straddle international borders. As water shortages increase, the potential for trans-boundary water conflicts increase. According to the UN, more than 60% of all international river and lake basins — and nearly all the international aquifers outside of Europe and North America — lack cooperative frameworks for cross-boundary water sharing. Water access is poised to be the world's next major security threat.

According to UNESCO, by 2025 1.9 billion people will live in countries with absolute water scarcity, and two-thirds of the world population will approach water stress conditions. Climate change is beginning to take a toll. Water shortages will not only be a less-affluent country issue — Spain, South Korea, Australia, and even the U.S. already face challenges. Rapidly growing cities constitute major centers of water demand and major water losses with some leakage rates reaching 30%-50%. Improved water management is needed to ensure global security.

The California Situation In California, as in much of the world, the people are not where the water is. Most California water is in the north, while most of the people are in the south. California has developed an elaborate system to capture, store and distribute the water from where it is located to where it is needed. California has the largest agricultural economy of any U.S. state and accounts for 60% of all the state's water use. Once the linchpin of the California

economy, the state's agriculture sector accounts for only 2% of its economy, driving a call for a reevaluation of the state's water distribution. California could be an excellent laboratory for developing solutions for the present and coming global water crisis.

California currently is in a long-term drought — the worst since record-keeping began more than 135 years ago. California has had droughts throughout history, but a ballooning population, a rapidly growing agricultural economy, and diversification of the California's economy has dramatically increased the demand for water. One hundred years ago, California's population was fewer than 2 million. Today it is near 38.5 million and is projected to reach 47.7 million by 2040. On January 20, 2015 more than 77% of the state was in the two worst categories of drought — "exceptional" and "extreme," according to the National Oceanic and Atmospheric Administration (NOAA) Drought Monitor. The drought is exacerbated by some of the warmest years on record, with the 2013-2014 winter being the warmest on record. California's average temperature was 61.5°F, 4.1°F above the 20th century average, beating the previous record set in 1934 by 1.8°F (NOAA).

The high temperatures and the lack of precipitation took a toll on California's major water storage mechanism: snow pack in the Sierra Nevada. The 2013-2014 snowpack was less than 15% of normal volume. On April 1, 2015, it was at 5% of the historical average. In January 2015, the state's major surface reservoirs averaged 37% of capacity. Groundwater levels are also falling, some as much as 1-1.5ft/month. With higher temperatures, humans and nature use more water.

Scientific opportunities and challenges
Attention should be focused on developing drought-resistant crops and on new approaches to ocean desalination that are less energy intensive. While many scientific and technical solutions exist, the challenge is to get them adopted. Often this means changing attitudes and behaviors, and developing sustainable economic models. These issues must be addressed by a coalition of scientists and engineers, economists, politicians, and even spiritual leaders. Organizing these seemingly disparate forces is where we should put our emphasis.

Policy issues
International

- The single most important issue is development of international frameworks for sharing surface and sub-surface water bodies, particularly in areas of political unrest. (UN must lead)

California
California and the world need the next "green revolution" — one that increases crop yields using less water, less fertilizer, and less pesticides, while also producing crops that have greater nutritional value. In the meantime, California needs to (i) improve irrigation to increase efficiency and reduce losses; (ii) choose crops that match the climate, available water, and soil type; (iii) price water appropriately; and finally (iv) revise outdated water laws. The last will be a major challenge, but is necessary.

Southern California imports about 70% of its water: 50% from the Delta, 20% from the Colorado River. Both sources will continue to decline with climate change. The balance comes primarily from groundwater and much of that is overdrawn.

Some steps to reduce water demand in Southern California:

- Reduce urban indoor water use by 15% to 20% permanently. (Each city must take the lead.)
- Reduce outdoor water use significantly through mandatory restrictions with fines.

(Reductions mandated by the state and enforced by cities.)

- Price water appropriately to reflect its value. Use tier pricing to reflect high use while protecting those least able to pay. (May require legislation)

- Provide funds to cities to eliminate significant leaks. (State Legislature)

- Inventory groundwater resources so both surface water and groundwater can be managed together more effectively. (state in collaboration with water districts).

- Create a comprehensive public education program — a campaign — to help people understand where our water comes from, where it goes, and the changes in behavior we need to make on a permanent basis. (state in partnership with cities)

These emergency measures need to be institutionalized.

Some state-wide strategies:

- The state should explore all ideas for reducing demand and increasing supply.

- State water allocations should reflect uses most important to the health and safety of Californians, to the state's economy, and to nature.

- The State Water Board, the Governor's Office, and the Legislature should continue dialogue to ensure that allocations reflect these priorities. Discussions should be expanded to include a representative cross-section of stakeholders. Agriculture deserves particular scrutiny.

In addition to reducing demand, we should increase the amount and reliability of the water supply.

Some steps to increase the reliability of supply

- Place a greater emphasis on local water supplies through:
    - Expanded use of water recycling. (cities)
    - Capture and storage of stormwater. (cities)
    - Expanded use of greywater systems. (cities)
    - Use smart meters to monitor water use and detect leaks. (cities and state)
    - Expanded use of permeable pavement to capture stormwater. (cities and state)
    - Desalination of saline and brackish waters (cities and state)
    - Ensuring adequate investment in infrastructure to eliminate water loss. (cities and state)

- Clean-up and manage groundwater for sustainable use. (state and water districts)

- Improve reliability of the State Water Project. (state)

- Conduct targeted research critical to improving management of the state's water. (state and water districts)

The challenges of dealing with a warming climate and the high probability of more frequent, more intense, and longer droughts are daunting. All challenges carry with them opportunities. Californians have the natural, intellectual, and fiscal resources to adapt to "the new normal"

while conserving a high quality of life for which California is known. In doing so, the state can become an example for other parts of the nation and the world facing similar situations. Seizing this leadership opportunity would result not only in a more resilient state, but also a sustainable economy.

References

Coping With the California Drought Crisis; Report of an Aquatic Forum of the Aquarium of the Pacific, December 2014
www.aquariumofpacific.org/mcri/info/coping_with_the_california_drought_crisis

*** A policy position paper prepared for presentation at the conference on Sustainability Challenges: Coping with Less Water and Energy, convened by the Institute on Science for Global Policy (ISGP), on June 5, 2015, in Whittier, California, U.S.*

Debate Summary

The following summary is based on notes recorded by the ISGP staff during the 90-minute not-for-attribution debate of the policy position paper prepared by Dr. Jerry Schubel (see above). Dr. Schubel initiated the debate with a 5-minute statement of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Dr. Schubel. Given the not-for-attribution format of the debate, the views comprising this summary do not necessarily represent the views of Dr. Schubel, as evidenced by his policy position paper. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate Conclusions

- Conservation and efficiency strategies that increase existing sources of water (e.g., increasing storage capacity, improving and expanding water recycling, repairing and upgrading infrastructure, and incentivizing conservation among the agricultural and public sectors) need to be the first priority of government water policies, followed by support for innovation that may lead to new sources of water.

- California's lengthy and restrictive permitting process needs to be modified so as to safeguard the environment without stifling innovation. Policymakers need to create a framework that enables controlled and monitored experiments of innovative technologies that could lead to more water being available for both human and environmental needs (e.g., desalination, aquaculture operations, expanding the State Water Project).

- State and federal governments need to develop, fund and implement a transitional plan for California's water infrastructure that helps the system evolve from its current design to a design that can handle more people, less water and new sources of water.

- A tiered water pricing system would improve water conservation, but is challenging to implement. Concerns to be addressed include guaranteeing the human right to water, and current California law discouraging tiered pricing.

- Senior water rights must be part of long-term planning discussions. Incentives need to be created for the agricultural sector to use less water and to protect existing water supplies.

- To promote water conservation, awareness of water issues must be raised among the general public through educational/informational campaigns, price incentives and policing of excess water usage.

Current realities
In California, severe drought conditions, minimal water recycling, an unbalanced system of water rights, and outdated infrastructure are jeopardizing water supplies in regions throughout the state.

California's agricultural sector accounts for approximately 2% of the state's economy and about 80% of the water utilized in the state. Thanks to holding senior water rights, the agricultural sector pays very little for water and so has little incentive to conserve or change wasteful practices. In urban usage, significant amounts of water go to landscaping and pools.

Southern California produces significant quantities of wastewater every day, but captures very little of it for re-use. Although a few recycled water systems are operating in the state, it was noted that these systems currently process and salvage only a fraction of the available wastewater. Public support of recycled water programs is believed to have dissipated due to labels such as "toilet to tap."

Despite the state's historical susceptibility to drought, it was charged that California legislators have done little to improve long-term access to water. Infrastructure investments (which are primarily the responsibility of the federal and state government) have been based on short-term needs rather than long-term planning for water shortage. There is an acute lack of storage capacity to take advantage of periodic rainfall.

Tiered pricing was highlighted as a way to encourage water conservation by making heavier users pay more. However, it was noted that tiered water pricing is problematic in California. For example, the tiered pricing structure created by the city of San Juan Capistrano to encourage conservation recently was struck down by the courts as violating a state law preventing government agencies from charging more for a service than it costs to deliver it.

A long, expensive and non-transparent governmental permitting process was decried for slowing down innovation that could lead to future water conservation. For example, it was stated that if the water desalination plant now being built near Carlsbad, CA, were being built in Israel, it would cost only one-third as much to build, due in part to the extra costs imposed by California's permitting process. While it was recognized that the process protects important environmental standards, it was argued there is an immediate need to address the water supply, and controlled experiments should be allowed to encourage innovation.

The Carlsbad plant was held up as a good example of a controlled experiment. In response to concerns about the plant increasing the salinity of the ocean and killing sea life, it was argued that desalination plants in Japan, Israel and Australia have successfully addressed these problems, and that the environmental impact of the plant is expected to be very small.

Concerns also were raised about the health of California's aquifers. Historically seen as the water of last resort, aquifers now are being over-pumped (more water taken out than is recharged). For the first time, even "old aquifers," which cannot be recharged, also are being

pumped. It was stated that the public often doesn't realize that aquifers are being over-pumped. For example, Long Beach, CA, gets about 40% of its water from groundwater, leading residents to feel less vulnerable to water shortages than cities relying primarily on the Delta and Colorado River. But a 75% cut in Long Beach's recharge allocation from the Metropolitan Water District means that the city has had to significantly reduce the amount of water that is put back into its aquifer, imperiling that source.

There have been numerous educational programs and public awareness campaigns about water conservation, but they do not seem to have had much impact on public behavior, especially when it comes to landscaping.

Scientific opportunities and challenges

Although California is rich in universities, venture capitalists and innovators, it has not taken full advantage of the opportunities presented by the water shortage.

Due to the expanding population of California and the rapidly depleting water supply, the current system of delivering water is inadequate for future needs. An opportunity exists to develop transitional strategies that balance immediate infrastructure needs with innovation so that a new system can evolve that will better fulfill future water demands. Suggested infrastructure improvements include expanding the delivery capacity of the State Water Project (while accounting for environmental concerns), and repairing water utilities. Due to California's unique delivery system that includes public and private water utilities, a challenge to repairing and upgrading infrastructure will be determining who bears the costs of repairs.

Before investing in technology such as water desalination, it was emphasized that the first steps to improve the water supply must be conservation and efficiency in both the agricultural and public sectors.

In agriculture, several scientific opportunities were identified, including improving water-conserving irrigation technology and developing low-water-use crops and sources of protein that require less water than beef (e.g., aquaculture operations off the coast of California). A challenge is getting the agricultural sector to invest in new technology and ideas, as low agricultural water prices do not encourage conservation.

In the public sector, conservation opportunities can be found in creating new methods to capture and store rainwater and run-off; and in finding efficient ways to expand the recycling of wastewater, including scaling up the usage of gray water.

Ocean desalination plants were the subject of much debate. While there was general agreement that ocean desalination plants provide viable opportunities to increase water supplies, significant discussion centered on the challenges of the project. Concerns include disruption of marine ecosystems from intake pipes, high energy costs, and destruction of marine life from brine discharge. It was argued that a variety of workable options already exist to offset these risks (e.g., burying intake pipes, diluting salty brine discharge) and that the risk of negative environmental impacts is very small.

A big science communication challenge has been to raise public concern about water conservation. Despite a plethora of programs, it has been difficult to get a cross section of society to care about the issue. A number of opportunities were highlighted, such as finding ways to point out the connection between water, jobs and a better economic future. It was proposed that the mainstream media can be helped to play a more significant role in communicating compelling, accurate and relevant information about water issues.

Just as the public needs to learn about conservation, the private sector needs to learn from other countries' experiences in water innovation and then apply and refine that knowledge in California, so that the state can move to the forefront of addressing global water shortage problems.

Policy issues

In drafting water policy, three themes were emphasized throughout the debates:

(i) Conserving and re-using the water we have now should be the first policy priority, followed by strategies to create more water, such as desalination.

(ii) The agricultural sector's water usage and senior water rights must be part of the policy discussion.

(iii) Long term and transitional planning is needed.

Significant discussion centered on the importance of improving infrastructure. It was agreed that federal and state funding is necessary to complete infrastructure improvements and repair leaks in both public and private utilities. Priority was placed on repairing infrastructures in older cities most at risk for water loss via pipe leaks. It was proposed that the State Water Project be restructured and the impacts of the project on the Delta re-evaluated to create a more reliable delivery system in California.

It was generally agreed that the private sector does a better job at innovation than government, but that government's role includes setting standards to which the private sector must conform. California's permitting process and its impact on innovation in the area of water conservation was much discussed. While it was acknowledged that environmental standards must be upheld, it was stated that the permitting process should not be allowed to suppress innovative experimentation. Environmental regulations, it was argued, may be stymying the very innovation needed to increase supply for the water-stressed environment. One proposed solution is to allow controlled experimentation with new technologies, and issue permits that require ongoing monitoring so that environmental impacts can be assessed as the project progresses.

On the other side of the problem, concern was raised about the ease with which permits are issued to developments in areas with limited water flow and supply. It was argued that, before new housing development is permitted in water-stressed regions, questions of water supply, delivery management and storage capacity need to be addressed.

While the implementation of a tiered water pricing system (i.e., higher users pay higher rates) was favored by many as a way to encourage conservation and efficiency, it was acknowledged that significant challenges exist to changing the pricing structure. At the top of the list is the concern that a tiered pricing system may violate the human right of access to water. Tiered systems must address the concerns of those with low incomes and access to water must be guaranteed. Another significant challenge is the legality of implementing a tiered pricing system under current California law. While there was uncertainty as to whether the existing laws should be restructured to incorporate tiered pricing, there was a general agreement that tiered water pricing would save water. At the least, water should be priced at its true value, it was noted.

Policy makers need to consider how outdated senior water rights are encouraging water wastage in the agricultural sector and take the hard steps necessary to restructure the rights so water has more economic value to food producers. It was argued that senior water rights can be modified without compromising the integrity of the state's agricultural economy.

An informed and aware public is essential both for conservation efforts and for enacting effective long-term water policies. A combination of consciousness-raising strategies should be employed, including improved public education, higher prices and "water cops." It was noted that sometimes education takes a long time to make a difference.

Policy makers were urged to realize that short-term improvements in rainfall do not mean the drought is over and planning is not needed. It was stated that it would take more than a decade of good rainfall to get the state back to where it was before the drought started, which is why long-range plans are essential.

When Subsidies Work and When They Don't: Food vs. Power**

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Summary
California's system of water rights implicitly subsidizes agricultural production by pricing water for farms at far below market levels. State policies directly subsidize solar electricity consumption by providing rebates and other forms of support for solar cells installation. While both food and electricity are household staples, these two subsidies are completely different in terms of the cost-benefit analysis because water is a truly limited resource, while solar energy is not.

Current realities
Water is provided for agricultural use at such a low price, it may as well be free. Farmers, however, are unable to sell their supplies under normal circumstances. This perverse incentive means that water has no implicit value to them outside of growing crops. Water subsidies have limited incentives for more water-efficient irrigation systems and less water-intensive crop choices. The resulting overuse of this scarce resource has harmed the environment, intensified the effects of the drought, and left urban water users with massive emergency cuts that will ultimately cost billions in lost consumption.

In California, water is largely allocated on the basis of riparian water rights, where water is assigned to parcels of land on the basis of a historical claim. Water-rights holders can use their allocation, but cannot sell it to other users. Consequently, there are no transactional "opportunity costs" attached to using the water, beyond those of actually moving it to where it is needed. Most of these rights were allocated when the state was largely agrarian. Agricultural interests still control and use 80% of the state's developed water, even though their operations make up less than 2% of the state's economy. Water prices are extremely low for areas with heavy agricultural output — basically only pump costs that as less than $50 per acre-foot, compared to over $1,000 an acre-foot for water agencies in the Los Angeles area. Even in times of scarcity, such as now, prices run well below $150 per acre-foot.

In theory, California agricultural subsidies help keep the price of food low and help "feed the nation." Subsidies also may encourage crop diversity. But the costs of water subsidies are also clear: in response to receiving "cheap" water, the California agricultural sector has grown very water-intensive crops (e.g., alfalfa and hay) in highly arid areas. Data from the agricultural census shows the value of alfalfa is $250 per acre-foot of water consumed. Compare this to the $200,000 of economic output per acre-foot of water used in urban areas. Farmers use roughly 4.5 acre-feet of water per acre of the crop. Much of the alfalfa California farmers produce is not even used to feed the nation; rather it is shipped to China to feed dairy cows. By comparison, lettuce, much of which is used for local food, uses just 1.5 acre-feet of water per acre and has a value of over $4,500 per acre-foot of water consumed.

There has been little incentive to invest in water-saving irrigation techniques. The agricultural sector's consistently higher-than-necessary water consumption has had environmental impacts. By using such large amounts of water, the agricultural sector has substantially raised costs for urban and industrial users that today represent the vast majority of the state's economy. These higher costs come from the restricted supply that reduces consumption below an optimal level and forces some urban areas to invest in expensive technologies (e.g., desalination or dual systems for gray water). California's agricultural water subsidies make it harder to fill reservoirs

in times of plenty, leading to excessive groundwater consumption in times of shortages and triggering various "emergency" efforts to sharply reduce short-run consumption that could have been avoided with better conservation in good times.
Solar energy subsidies offer an interesting contrast to water subsidies. Solar energy consumers receive an explicit subsidy to invest in solar cells. Yet most studies today show that solar is far more expensive than other forms of energy production, even if the current cost of greenhouse gases are included. As such, subsidies are implicitly shifting consumption to a high-cost economic source. There are reasons to support solar subsidies, however. By increasing production in the short run, we push the technology much faster down the learning curve, making it more likely solar power can become truly cheaper than other forms of energy. Subsidizing solar cell purchases incentivizes companies to produce ever better cells at cheaper prices in a competitive environment. It also shifts the system from a centralized to a noncentralized model, which has the additional benefit of reduced system capacity.

Scientific opportunities and challenges
Changing California's current water policy provides both an opportunity and a challenge. As the California climate changes such that conservation becomes increasingly important, state leaders have an opportunity to reform outdated contracts entitling farms to senior water rights and to ensure that water pricing is more fair and promotes efficient use. State leaders also have an opportunity to open water markets that will encourage the sale of water from agricultural sources where water is cheap to consumers in areas where water is comparatively expensive. This will discourage wasteful consumption, such as farming low-value, high-water-use crops, while at the same time reducing the risk of water shortages in some parts of the state. This, in turn, would help to stabilize agricultural output levels and, in the long run, could be better for farmers, by encouraging production of crops that have more consistent yields each year.

The politics behind water use in California make policy changes difficult. There is little motivation to change the status quo, apart from dry spells that lead to mandated conservation measures. The process of setting up a robust water market is a steep challenge. It certainly will be difficult to initially allocate water to those who currently do not have set supplies, as well as to public agencies, local or nonlocal. These types of issues are partly to blame for slowing the development of water markets in California. The benefits of water markets, however, are substantial. Not only would they help to provide a more stable supply of water for many urban and agricultural water agencies, they could also be expanded to environmental agencies. For instance, rather than trying to balance competing interests for water from the Bay Delta in Northern California through top-down rules, these interests would have a clear market price to pay for the supply of water. The State of California could maintain a fixed level of water for streams in the Delta through payments to Delta or Central Valley farmers or urban water agencies. Farmers seeking extra water from Delta streams might pay a tiered price to do so. Prices motivate incentives for urban, agricultural, or environmental agencies alike.

On the power side, investment in solar energy provides an increasingly greater opportunity to provide cheap, clean energy that will require fewer subsidies over time. One of the biggest hindrances in transitioning to solar power is its unaffordability relative to sources such as natural gas. Solar subsidies have helped to narrow the gap in price significantly, but if natural gas remains cheaper than solar, there will be much less of an incentive to switch. Yet, subsidies to consumers who buy solar panels or producers who invest in solar energy development reduce solar energy costs by increasing returns to scale. Lower production costs decrease prices, leading to greater demand, which boosts production further. As production grows and efficiencies reduce production cost over time, the per-unit price drops, bringing the price of solar energy closer to the price of other energy sources. Local solar energy subsidies produce benefits well beyond local borders. In less-affluent countries, low-cost solar energy can

generate power without large centralized energy systems. Photovoltaic panels would be sufficient in themselves to power homes and businesses. More attention is being given to solar because it is clean and abundant. Solar power subsidies can help hasten the transition from natural gas or coal toward solar.

However, energy storage remains a challenge to increasing solar energy production. The efficiency of solar panels has improved substantially in a short time, but much of the energy produced by the panels is lost in the storage process. When solar production is weaker — in evening hours, for instance —the "base load" of energy still has to come from more traditional sources such as natural gas, coal or nuclear power. Fortunately, as solar energy has become more popular, research and development into energy storage has increased significantly, helping energy storage to (slowly) catch up to improvements in solar energy production.

Policy issues

- California's water policies are long outdated and need to be substantially cut back. They serve as implicit subsidies for the state's agricultural sector but do not support lower food prices in the way that more direct subsidies, like tax incentives or wage rebates, would. Low water prices encourage production of low-value, high-water-use crops like alfalfa and lead to waste of a scare resource.

- The development of water markets should be encouraged and facilitated. "Use it or lose it" water contracts encourage wasteful consumption, while water markets would allow transfers from agriculture to urban agencies. Water prices for urban users are higher because outdated water contracts for agriculture misallocate a scarce resource. These contracts also force more efficient water users (i.e., urban consumers) to make steep cutbacks when water levels are low. Alternatively, demand for water in urban areas is inelastic, so if water prices were more equitable between urban and agricultural water agencies, such that the price of water decreased for urban consumers, the demand for water in urban areas would not increase that much. Lower water prices for urban consumers would not lead to a shortage.

- Solar power should continue to be explicitly subsidized through state and federal policy. These solar subsidies generate very positive outcomes and should be encouraged or even expanded by the State of California. Solar subsidies such as tax credits for large-scale solar producers or credits for residential or commercial solar panels encourage new production, which leads to increasing returns to scale. As investment in and production of solar technology has grown, efficiency has increased, such that solar power is getting closer to meeting the cost, *without subsidies*, of other energy sources like coal or natural gas. Unlike subsidized water, subsidized solar power generates mostly positive externalities. Subsidizing the purchase of solar cells may work better than directly subsidizing primary solar research at universities, as the profit model encourages multiple paths to efficient outcomes in a rapid environment. But constant monitoring is needed to make sure such efforts pay off.

- The State of California needs to reduce pollution through clean energy production. Solar energy production is capable of supplying much of California's energy demand. In addition, solar subsidies spur investment in solar infrastructure, which generates output, jobs, and spending. Subsidies also support California's economic growth. Some of the largest builders of solar energy systems, such as SolarCity, Rosendin Electric, and Sungevity, are headquartered in California.

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*** A policy position paper prepared for presentation at the conference on Sustainability Challenges: Coping with Less Water and Energy, convened by the Institute on Science for Global Policy (ISGP), on June 5, 2015, in Whittier, California, U.S.*

Debate Summary

The following summary is based on notes recorded by the ISGP staff during the 90-minute not-for-attribution debate of the policy position paper prepared by Dr. Christopher Thornberg (see above). Dr. Thornberg initiated the debate with a 5-minute statement of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Dr. Thornberg. Given the not-for-attribution format of the debate, the views comprising this summary do not necessarily represent the views of Dr. Thornberg, as evidenced by his policy position paper. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- Because subsidies for agricultural water usage tend to incentivize water waste, water policy needs to be changed to reflect the value of water as a scarce resource and allocate that resource to its highest-value use. Water markets need to be created to ensure that the existing water supply is used in a sustainable manner and is available for agricultural and industrial uses, urban consumers, and the environment.

- To increase investment in the solar energy industry, direct consumer subsidies for solar technology need to remain in place and policies that support the improvement and integration of solar technology into existing infrastructure need to be created.

- While reforming water subsidies in the agricultural sector may raise the cost of food production, policies that seek to address food insecurity must be targeted to the root of the problem (e.g., direct poverty-reduction programs for families) rather than at agricultural water pricing.

- To regulate oversight of local and regional water markets, policy makers need to create a central water agency charged with overseeing the movement of water among existing and new markets.

- Since it is vital that pollution mitigation continue to be a priority for the state of California, government subsidies for solar energy need to incentivize the consumption of clean

energy. Additionally, internalizing the costs of run-off pollution into local water markets will encourage pollution mitigation.

Current realities

Economically speaking, California has not been suffering from a drought, but rather from a water shortage. A drought was defined as a water shortage that produces significant economic consequences. California is not facing intense economic hardship as a direct consequence of water shortage (e.g., the unemployment rate is falling as job growth increases). Abundant fresh water is indeed available in the state of California and there are several storage techniques. The various water authorities throughout the state invest in the use of man-made reservoirs to collect rainwater and store it for use when water is scarce. The water shortage could become a drought, however, if resources are not allocated properly.

Today's system of water allocation does not uphold the premise that water is a scarce resource that must be allocated in responsible ways to its highest value usages. The agricultural industry uses 80% of available water. It was argued that there is a critical misconception among the public is that there is a 1-to-1 linkage between water consumption and agricultural output in California. It was argued that, in fact, the agricultural industry could maintain its current levels of production and simultaneously decrease water consumption.

California's system of water rights discourages water conservation. Farmers with senior water rights have access to water at a significantly lower price than urban consumers, but are prohibited from selling any surplus water. A positive impact of water subsidies is that they lower the cost of food production. However, there is no incentive for farmers to reduce water usage because the surplus has no alternate value (e.g., as a commodity to sell to urban areas or for water storage). This lack of incentive results in wasteful irrigation techniques, and in farmers choosing to grow water-intensive, low-economic-value crops such as alfalfa, which often is exported for cattle feed. It was noted, however, that alfalfa has agricultural value as part of a crop rotation to maintain soil health.

It was generally agreed that water subsidies to the agricultural industry divert supply from other users, such as urban communities, the environment, and reservoirs. The agricultural industry in Imperial County, California, uses large amounts of water growing alfalfa crops that produce very low economic returns. Meanwhile, San Diego has invested in a desalination plant that will produce water costing at least $1,800 per acre-foot. Water is excessively consumed in Imperial County for small returns per acre-foot, while a large amount of money is invested in San Diego to produce fresh water.

The Mojave Water Basin is an example of one of the few open water markets in the state of California. Former alfalfa growers are financially benefiting and simultaneously reducing water waste by selling or leasing their water rights to the local water agencies in the high desert. Implementing this change in policy took a great deal of effort, it was noted.

In the area of solar energy subsidies, the United States has seen explosive growth in solar energy investment since 2005, resulting in solar technology's increased efficiency, capability, and integration into existing infrastructure. In California, consumer subsidies are in place through various tax rebates and incentive programs. Although subsidizing solar energy can result in excessive electricity consumption, such subsidies also encourage a move towards cleaner sources of electrical energy. Subsidizing consumers' investment in the solar industry is allowing the industry to grow, become more effective, and further its technological innovations, helping it to become more competitive with traditional energy sources such as coal.

Scientific opportunities and challenges

There is significant opportunity for improved allocation of water resources through the opening of water markets in California. Rather than imposing different prices for urban, industrial, and agricultural usages, an open water market would allow prices to rise and fall according to demand. It was stated that water demand in urban areas is very inelastic and price-insensitive. If water prices rise, urban consumption will not decrease significantly; if prices fall, urban consumption will not increase rapidly, particularly if conservation efforts are in place to encourage efficient water consumption. If a market for water resources is implemented, it was argued that the price of water would quickly decrease to the price farmers currently pay through subsidies. However, water is expensive to move relative to its value, which means different kinds of submarkets, carrying different market prices, must be developed.

With an open market, when California suffers from a water shortage, the price of water will rise. Consumers who will be most affected by such price changes will be those using water for low-value uses, such as growers of alfalfa and other low-return, water-intensive crops. It was emphasized that the purpose of implementing an open market with fluctuating prices is not to block out certain water users (e.g., eliminating alfalfa farmers) but to reallocate resources towards more efficient uses. California alfalfa crops still will exist if there is a demand for them, but the difference is that under an open market the water consumed to produce alfalfa would be at the appropriate market price.

The opportunities presented by an open water market in the state of California are not without challenges. The state water supply would no longer be diverted to reserve a subsidized portion for the agricultural industry. Prices may fluctuate, leading to increases in the price of food, a change that would hit the poorest people the hardest. It was argued, however, that increased prices may not necessarily be detrimental to food security because food production does not equal food consumption. In other words, not every calorie produced in the United States is consumed by human beings; 40% of food goes to waste. This waste is incurred because food is underpriced and therefore undervalued. Increased food prices present both opportunities to address food waste as well as challenges to address food insecurity in more direct ways than through water subsidies (e.g., through poverty-reduction programs).

There are several opportunities to expand the efficiencies of solar energy. A goal of solar energy research is to store the energy generated during peak hours (around noon each day) for use during peak consumption periods (morning and evening), and it has been found that solar cell capacity is significantly increased when the cells are integrated with batteries. Batteries have their own set of "externalities," or harmful environmental impacts, that must be considered in the cost. Incentives need to promote the integration of not only efficient batteries but also cleaner batteries into solar industry. As the solar industry grows, efforts need to be made to increase the efficiency of solar cell production, expand the distribution of solar technologies, and integrate solar technologies into the existing energy infrastructure.

It was suggested that opportunities also lie in the strategic combination of traditional electricity generation, storage batteries, and solar power. In this manner, a consumer may be able to charge batteries using electricity generated by traditional sources that can be used at the peak consumption periods of the day instead of relying exclusively on solar energy. Although this strategy would provide an alternative to the challenges of storing solar energy, traditional sources of power (e.g., coal) tend to produce heavy externalities.

Policy issues

It was strongly agreed that policies need to focus on amending California's system of water rights. The allocation of the water supply can be increased for urban and environmental

consumption if the supply reserved for agriculture is opened. Policies need to support the implementation of various small water markets to equilibrate the sustainable market price for water and supply water it to its most efficient net uses. Policy development can be informed by what has been done with water markets in the Mojave Water Basin.

During water shortages, California tends to relax restrictions on water markets. It was observed that policies concerning such markets seem to be re-written each time there is a water shortage, and that there is a need for a consistent policy concerning the implementation of such markets.

Water conservation policies should not focus on capping agricultural water usage directly. Instead, riparian water rights should be reformed. Instead of investing in desalination plants, policy needs to move towards opening up markets for the water that is currently available yet is being wasted.

The current production of alfalfa is successful in California because the agriculture industry directly benefits from water subsidies. Much of the alfalfa grown in California is exported to China as feed for its meat industry. If trade transactions are mutually beneficial then it is economically advantageous to continue such trade and instead develop policies that focus on properly pricing the water for efficient allocation. If alfalfa farmers were to purchase water at an adjusted market price, it may not be economically worthwhile to export to China because profits would evaporate. Trade restrictions are not an effective tool for water allocation.

Water markets need to be regulated, however. It was proposed that policy support a central oversight process of water markets by creating a global water agency. This agency would oversee the creation of local and regional water markets that allow for exchange. Additionally, in order to have functional markets, it was recommended that policies allow for the free movement of water through existing and new infrastructure. Regarding ground water, new policy must solve the obscurity of rights to common underground aquifers. Ground water needs to be integrated into the water markets system and regulated. Furthermore, local water markets need to account for water pollution mitigation and conservation in urban settings (e.g., if San Diego citizens over-water their lawns and create run-off, policy should be implemented to charge extra fees for mitigation efforts).

There was a general consensus that the issue of poverty and the ability to afford water in a free market must be addressed. Restricting an open water market to address poverty, however, causes secondary negative consequences that affect the whole of the economy. Policy instead needs to address poverty at the root through programs directed at families in poverty (e.g., housing subsidies, reductions in water bills) rather than by enacting restrictions in water policy. The basic human right to water was emphasized.

In terms of solar energy, policy makers need to continue subsidizing consumer investment in the industry. Currently, the only options for storage capacity are batteries. Consumers may choose not to purchase solar technologies in combination with storage batteries because cheaper forms of energy exist. However, if the price for these cheaper forms of energy is adjusted to account for externalities, then solar energy may already be cheaper. Solar energy has promise for the future, and policy needs support this promise through subsidies that encourage investment in the industry. Additionally, incentives need continue to be utilized to encourage integration of clean batteries into solar technology. The externalities of dirty batteries need to be accounted for in their pricing to encourage consumption of and investment in the integration of clean batteries for solar technology.

It was proposed that efforts to sufficiently incentivize and encourage the production of clean batteries will lead to the integration of clean batteries into the solar energy industry.

Water and energy policies may be improved by focusing on public education. The public needs to have the knowledge to interpret media reports and to separate current realities from misinformation.

Balancing Efficient Use With Sustainable Generation

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Summary
We need to develop a wide range of new technology to support a more sustainable future. In the United States, this means developing a system-wide optimization for the infrastructure, understanding the connections between water, energy, food, and other built systems. In the developing world, it means pushing the most efficient clean energy-generation technology as soon as possible, to defer/avoid the deployment of fossil energy. In all cases, California can lead the world in development and implementation if we are willing to invest in the long term.

Current realities
Climate change mitigation policy is piecemeal throughout the U.S. and around the world. California is among the most aggressive areas in pursuing a clean energy and carbon mitigation agenda, and is starting to address an antiquated and unsustainable system for water distribution in the face of the current severe drought.

The state's current and proposed energy and water strategies rely heavily on efficiency: measures to reduce per capita consumption, in addition to developing new, sustainable (often local) generation of these resources. This has been a part of the leadership approach that California has taken since the 1970s. Often called the "Rosenfeld effect" (thanks to pioneering Energy Commissioner and scientist Art Rosenfeld from University of California Berkeley), California's per capita electricity use has been essentially flat (roughly 7,000 KHW/yr/person) since the early 1970s, while energy use nationwide has nearly doubled over that same time. Based on data from the early 2000s, increased electricity consumption is strongly linked with increased economic prosperity and increased quality of life, but there are diminishing returns above roughly 4,000 KHW/year/person. Although the correlations are weaker, a similar general trend is seen in water use. Based on these data, policies that focus primarily on efficiency are not healthy for many parts of the developing world. In fact, drastic increases in per capita energy and water use are likely needed to improve health and lifestyle for the approximately 9 billion to 12 billion people expected on the planet between 2050 and 2100. In the U.S. and Europe, however, we can focus on reducing consumption (or keeping it flat), while replacing existing fossil fuel power plants with renewable energy in a way that minimizes disruption. It is also worth noting that increases in efficiency driven by technological innovation tend to lead to HIGHER consumption rather than lower, but that efficiency driven by increased costs leads to LOWER consumption. This has been observed in several sectors in the past (the "Jevon's Paradox").

Scientific opportunities and challenges
The underlying desire is to reduce carbon emissions from energy sources, and reduce reliance on unsustainable generation of energy (i.e., electricity) or water. The science and technology opportunities can be split into two main areas: (i) technology to enhance the distribution/supply infrastructure, and (ii) technologies for generation, storage, and end use.

For California, as well as the rest of the U.S. and developed countries, the largest challenge currently is the distribution/supply infrastructure. Our existing infrastructure was not developed to allow renewable energy or other new energy technologies to be incorporated. There is a need to build a new system-wide control and optimization scheme that allows as much "plug and play" adoption of new technologies as possible without destabilizing the system or the electricity market.

Developing countries will need a distribution system. They can adopt newer systems more easily than in the U.S. and developed countries, but need as much energy as possible to improve quality of life. These areas can also directly adopt the newer and more energy efficient technologies (such as LEDs instead of incandescent bulbs), and build systems from scratch that can incorporate these technologies.

In California, the biggest challenge/opportunity is to reach a holistic, system wide view of the electricity/fuel/transportation/water/food infrastructure. Again, this infrastructure is very developed, and so currently consists of trillions of dollars in long-term capital investments. Fundamental and applied research in multiscale optimization (from individual devices to coordination across the entire region/state) is required. Although we have a goal to get to 50% renewables by 2030, the biggest barrier to achieving that goal is not developing a better/cheaper solar panel; it is figuring out how to incorporate those panels into the grid in a way that doesn't destabilize the system. Furthermore, the drive to reduce CO_2 emissions from vehicles by developing electric vehicles (EVs) will significantly INCREASE electricity use. Demand response, in which customers choose to delay or defer certain energy use because of an emergent issue (or in the future, because of a price or market signal), has the potential to smooth variation and help match supply and demand, but also to destabilize the grid as a whole if pricing and control schemes are not developed and implemented carefully. Utilities and third-party service providers need to measure carefully, share data appropriately, and use that data to build the best models and the best optimization algorithms possible. We also need to develop new power electronics technologies to support this new system. As more forms of energy storage become cost effective, they can also serve to stabilize the system for renewables, but must be approached in the same way: as a part of the larger system optimization challenge.

Regardless of global location, eventually more efficient solar and wind clean energy technologies will become the major barriers to higher adoption of renewables. Fundamental and applied research is needed now to make sure that technology is being developed and can be deployed as rapidly as makes economic sense. Current photovoltaic (PV) technology on the market is pushing 20% efficiency, but thermodynamics tells us that we should be able to capture 50%–60% realistically (more than 80% theoretically). In the developing world, the sooner we can increase these technologies' efficiency (or lower their cost), the sooner we can raise production and make development of new fossil energy in those areas unnecessary. In the U.S., the infrastructure upgrades are more likely to drive increased solar and wind adoption for the short term, as these technologies are already (or nearly) cost effective for individuals.

In addition to solar storage and distribution infrastructure, similar efficiency thinking can be applied to natural gas/fuel development (whether this is conventionally developed, "fracked," or developed from a renewable source), and to water treatment and distribution. We need to understand how to effectively convert between electricity and gas and build an infrastructure that allows such conversion, and also develop systems for doing this as efficiently as possible. Fuel cell technology is promising, as the efficiency is high, but research is needed to improve cell costs and lifetimes. Reversible fuel cells can be developed that convert fuel into electricity and also can convert electricity back into fuel, to make the system as resilient as possible by providing energy storage. In addition, membrane technology and other process improvements to make water treatment as efficient (in terms of water wasted and energy used) will require significant new research, even as current systems can now be deployed.

Policy issues

The above state-of-the-art and new technology development needs are driven by support from the federal and state governments, largely through research grants and tax breaks. Direct subsidies for solar power are being phased out at the federal and state levels. California lawmakers have recently laid out a package of new bills for consideration to increase renewable energy use and decrease carbon emissions between now and 2030. These measures are a good start, but we need to emphasize a bigger vision, highlighted below.

It is worth noting that both energy and water are areas where cost-effectiveness is considered essential for new technology to be deployed, but where that concept is often hard to define or quantify. As the end goal is to provide broad societal benefit, a different, still somewhat undefined, accounting may be required to understand cost-effectiveness, and this must be supported by the policies enacted. For instance, taking into account societal costs for business as usual in a quantitative way can help define a baseline cost.

Focus on the long term:

- Support the development of new technologies that can really change the game over the next 30–50 years. These technologies include new, renewable, high efficiency energy generation as well as those that support the control of a complex, dynamical system, creating an overall efficient system. It is essential that funding from the U.S. Department of Energy, the California Energy Commission, and other federal, state and local agencies should be invested in basic research, not just demonstration projects.

- Support development of a system that is as adaptable to these technologies as possible, and create as much certainty in that support as possible for effective planning.

- Sustained support at every point along the research and development pipeline is required. Currently, the state is too focused on pilot and demonstration projects. Also, almost all funding currently available for energy research from the state is funded through ratepayer surcharges, and must show benefit to the ratepayers in somewhat strict terms.

Focus on the big picture:

- Support for the system has been limited, and generally pieced together from smaller programs. In California this has been a major problem, as there are numerous proceedings at the Public Utilities Commission that all relate to one another, but they are taken in isolation.

- Smart communications systems are enabling for all of the infrastructure challenges, but we need to understand how to share data effectively across the electricity system.

Focus on the right incentives:

- Drop the false dichotomy between sustainability and jobs. We can support the development of new technologies here and create jobs as we invent, design, test, scale and deploy them around the region and the world.

- Remember Jevon's paradox. We care more about the system efficiency than about any one person's/organization's use. Focus on policy to support the most efficient system possible.

- Support end-use efficiency appropriately, with support for those at the low end, but with rates/taxes/penalties that really encourage careful use rather than additional

consumption. Note this is especially true in water where we need to reduce real consumption considerably, and have not been pushed to do so before.

*** A policy position paper prepared for presentation at the conference on Sustainability Challenges: Coping with Less Water and Energy, convened by the Institute on Science for Global Policy (ISGP), on June 5, 2015, in Whittier, California, U.S.*

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Debate conclusions

- Since priority needs to be given to long-term solutions over short-term fixes, infrastructure investments designed to enhance the ability of systems to deliver energy and water from diverse sources (e.g., traditional, renewable, and recycled sources, and unknown new technologies) are critical.

- To improve efficiency, smart technologies that allow systems to report on their usage need to be more widely utilized and gradually incorporated into existing infrastructures. The data generated by this technology need to be widely shared among all stakeholders (e.g., consumers, private providers, utilities) in a manner that protects individual privacy, maximizes system efficiency, opens up opportunities for innovation, and makes energy systems and markets more transparent and less vulnerable to manipulation.

- Since it is unlikely that any single technology will be sufficient to address all energy needs of all cities, a combination of technologies needs to be utilized (e.g., solar power during the day, battery power in the evening, and traditional electric sources at night). Developing and integrating alternative technologies on a small scale need to be encouraged to reduce strain on existing infrastructures without cutting service.

- Given that human behavior can thwart the best-intentioned conservation policy and while education campaigns are important, they have had little effect on conservation behavior thus far, peoples' behavior needs to be positively influenced by effective and innovative incentives, such as access to the energy market.

- To meet the innovation challenges of the future, funds need to be allocated for research that explores cutting-edge energy and water technology without the requirement of providing an immediate benefit.

Current realities

At present, more than 50% of the world's population lives in urban areas and that percentage is steadily increasing. This massive urbanization trend will require energy and water infrastructure. The challenges of meeting these infrastructure needs are different in affluent and less-affluent countries. Less-affluent countries often have limited infrastructures, making it easier to overhaul the entire system with innovative technologies that are more advanced than those being used in the complex and well-established infrastructures of more affluent nations. The infrastructures of affluent nations tend to be less amenable to technological innovation.

In the United States, and in particular in California, water and energy distribution systems were built on the premise that these resources were unlimited. Rather than striving for efficiency and sustainability, infrastructures were designed for reliability and safety. It was emphasized that these infrastructures, and the markets for their commodities, were not built to handle innovative and multiple sources of water and power (e.g., recycled water, solar, wind, batteries). For example, the current system of electric power transmission lines are not able to integrate with a multisource "smart grid" that can deliver traditional electric, solar, batteries, and a responsiveness to demand and price.

Despite these challenges, California was considered a leader in the switch to renewable sources of water and energy. Germany, which has invested heavily in national solar infrastructure, and Spain, which has developed wind power, also were considered leaders in utilizing renewable sources. These two countries have fundamentally changed the way they view energy resources and treat renewable energy as a stable long-term strategy, relegating fossil fuel as a risky strategy.

Although it was once imagined that future energy infrastructures would include giant wind and solar "farms the reality in the United States has been smaller commercial solar and wind projects and house-to-house adoption. The problem of storing power from solar and wind generation was raised, although steady improvements are being made in storage capacity. New batteries being developed by Tesla, and flow batteries that greatly improve storage capacity, are promising. Storage development has been spurred by California's recent energy-storage mandate that requires the three major utilities to buy 1325 megawatts of power storage capacity by 2020.

Several different innovative technologies are in development that incorporate both efficiency and sustainable generation. However, it was generally agreed that no single technology is able to address consumer needs by itself, and that solutions must balance a variety of technologies, such as traditional electric, solar, and battery power. Emerging technologies such as geothermal and wave energy, and atmospheric water generation (pulling water from the air) need to be part of a menu of resources.

Smart technology that monitors usage and regulates resource delivery was considered a model for improving efficiency. Sometimes call "the Internet of things," connected devices such as refrigerators and air conditioners are able to send messages about their usage and be remotely regulated to maximize efficiency. It was argued, however, that this data currently is not well utilized. Information is shared between private providers and consumers, but not with those who oversee the whole infrastructure. Privacy concerns were cited as one reason why consumers are reluctant to share this data, although corporations already are collecting masses of information about consumers.

Advances in technology that improve efficiency do not necessarily encourage behavioral choices that reduce energy use. Efficiency improvements can actually increase consumers' energy usage. Financial constraints (e.g., higher rates, or a cap-and trade system) have been shown to reduce usage. While a lot of money has been spent on public education campaigns to encourage energy and water conservation, consumers don't seem to be paying attention to these messages.

There are not enough incentives to experiment with innovative solutions, especially those on the risky cutting edge of research. For example, a small surcharge on Californians' electric bills is earmarked for research demonstrations, pilot projects, and deployment of new technologies, but the Public Utilities Commission mandates that this money be spent on projects that have immediate usefulness to ratepayers, limiting the scope of innovation. California's rigorous, expensive, and lengthy permitting process was decried as an obstacle to innovation in renewable energy development. California tends to take a "patchwork" approach to infrastructure development and has difficulty turning mandates into actions.

Scientific opportunities and challenges

It was generally agreed that the United States has not effectively invested in its infrastructure, even for upgrades. However, when maintenance and upgrades of the power and water infrastructures do occur, opportunities exist to discern whether to replace the technology with something similar, or to upgrade to a next-generation technology that is more adaptable to integration with multiple distribution systems (solar, recycled water, etc.).

The telecommunication system was cited as a classic example of infrastructure that is robust and adaptable to new technologies. Telephone, cable, and Internet began as separate industries but changed their operations (due in part to deregulation), enabling integration to the point that one can now watch TV, make phone calls, and use the Internet all on one device. It was acknowledged that telecommunications delivery systems are easier to construct than power and water systems, but emphasized that the goal should be similar, and could mimic the "layering" strategy employed by telecommunications companies.

The biggest scientific opportunities lie in creating a system that is as smart as possible in what it can report about its current state. Rather than overhauling entire infrastructures, scientific opportunities for innovation will come faster through individual solutions that address discreet problems. Data sharing among different providers was cited as a key to innovation and integration. For example, if the power company knows how much solar is

being generated, it can moderate production, or if solar companies know the carrying capacity of different circuits, they can create incentives for people in the appropriate places to get solar.

Research suggests that relatively small fields of photovoltaic cells on every continent would provide enough energy to significantly contribute to the grid. Current commercial solar panels typically are about 15%–20% efficient, but panels in development have efficiency rates as high as 40%. In developing photovoltaic cells that provide higher efficiency at affordable prices, science has an opportunity not only to produce cleaner energy, but to reduce infrastructure needs. This is especially important in expanding urban areas where space is constrained. It was noted, however, that solar power expansion is tied to the development of battery storage capacity. Numerous challenges exist in advancing battery technology, including difficulties in scaling up such as have been encountered with the promising "flow battery," which has the potential to provide a significant source of grid storage capacity. Other battery challenges include expense, the need for rare materials, and negative environmental externalities.

Significant opportunities for innovation in renewable and adaptable technology can be found in less-affluent nations, where simple infrastructures may be upgraded by "leapfrogging" over several generations of technological advances and sometimes by building from scratch. Scientists and international policy makers must support the best technology being incorporated into these projects. In more-affluent countries, however, change usually is not suddenly transformational but evolves over time, with generational shifts in priorities as technology changes. Although it was agreed that there are opportunities to encourage the prioritization of renewable and sustainable resources by improving science communication and education, it also was widely acknowledged that it's a challenge to get people to pay attention to such messages and to change their behaviors. The "human element" must be part of scientific thinking about technology innovation, and it was observed that the challenge is to find a way to build in greater efficiency without requiring people to change their habits.

Researchers need a place where they can fail, (i.e., where they can try things out and learn from the results, without necessarily showing immediate benefit to ratepayers or utility services).

Policy issues

In considering the future of water and energy delivery systems, there was agreement that long-term policy solutions are more important than short-term and patchwork solutions. Policies need to be based on the premise that technology is ever changing, and must prioritize adaptable systems that easily integrate with both traditional and renewable resources. Energy and water project goals need to include reducing unwanted emissions, integrating a diversity of resources (traditional, renewable, recycled), and being adaptable to unknown future technologies.

Obtaining energy from a diversity of sources is an important element in a reliable and resilient utility system, and additionally may help to mitigate the expected initial rate increases associated with increased usage of renewable technologies.

It was generally agreed that funding of technological solutions needs to be increased. Building adaptability into infrastructures can happen gradually in California and other more-affluent areas. It was proposed that a slight increase in the amount of money spent in the U.S. to replace worn-out parts in the power infrastructure could fund the incorporation of smart components over time, slowly and steadily increasing system responsiveness and flexibility. The telecommunications industry's experience provides good examples of overarching goals and practical strategies for the integration of different technologies. Germany's aggressive policies for encouraging solar energy development also were praised as models for other countries seeking sustainable and renewable energy. California's permitting processes and regulations need to be examined to evaluate whether they are creating barriers to innovation in sustainable resources. However, caution was raised that integrated systems are vulnerable to unintended consequences, and policy makers need to understand any downstream effects when approving these systems.

To make the energy system as a whole work better, data needs to be more widely shared among all stakeholders (utilities, the private sector and consumers). In response to privacy and security concerns, data can be shared anonymously. When data is not widely shared, it concentrates in the hands of private providers who can legally use it to manipulate markets. The example was raised of the rolling blackouts that occurred in California in 2011 because Enron had more information about the availability and price of energy than any other entity.

Educating people about available renewable energy subsidies has not been effective at expanding usage. It might be more effective to somehow change the market structure so people can engage at different levels in the energy market depending on their awareness and level of interest.

Consumer behavior plays a significant role in the effectiveness of conservation policies, and there was a call for policy and system-driven incentives to get ratepayers to consider reducing their energy and water consumption. As the youngest generation in California grows up with drought as a normal part of their lives, their perspective is naturally going to include concerns about conservation and sustainability. To move forward effectively, individual thinking may need to change from "how can I improve my life?" to "how will this affect the rest of the world?"

Concern was raised that mandating renewable energy might make California less competitive by raising already-high electricity rates. It was countered that research in other states has shown that implementing sustainable energy sources slows the increase in electricity rates, especially when a diversity of energy sources is used.

Although it was widely agreed that policy should support cutting-edge research that runs a risk of failure, it was acknowledged that it is unlikely that much funding will be allocated to this purpose. However, to create innovative and adaptable infrastructures, developers need to have the freedom to try out solutions that do not necessarily show immediate benefit.

Acknowledgments

Numerous individuals and organizations have made important contributions to the Institute on Science for Global Policy (ISGP) Climate Change Arctic Program (ICCAP) *Sustainability Challenges: Coping with Less Water and Energy* conference. Some of these contributions directly supported the efforts needed to organize the invitation-only conference, convened in partnership with the Whittier Working Group at PIH Health Hospital on June 5, 2015. Other contributions aided the ISGP in preparing the material presented in this report, including the three invited policy position papers, the not-for-attribution debate summaries, and a record of the results, without attribution, of the views presented in the discussions and caucuses that ensued.

Of special significance were the efforts of the three distinguished experts invited by the ISGP to present their views in each of the three concise policy position papers that were debated. The biographies of these three authors are provided in this ISGP report. The ISGP also greatly appreciates the willingness of those in the scientific and policy communities who agreed to be interviewed by the ISGP staff as potential conference presenters.

The success of every ISGP conference critically depends on the active engagement of all invited participants in the often-intense debates and caucuses. The exchange of strongly held views, innovative proposals, and critiques generated from questions and debates fosters an unusual, and even unique, environment focused on clarifying understanding for the nonspecialist. These debates and caucuses address specific questions related to both formulating and implementing effective public and private sector policies. The ISGP is greatly indebted to the wide range of policy makers, scientists, and community members who engaged in the vigorous debates and caucuses that compose all ISGP conferences.

The members of the ISGP Board of Directors also deserve recognition for their time and efforts in helping to create a vital, increasingly relevant not-for-profit organization focused on addressing many of the most important societal questions of our time. Their brief biographical backgrounds are presented at the end of this report.

The Whittier Working Group merits special acknowledgment for their efforts to help organize and convene this ICCAP conference. Their contributions in planning the conference and assembling the diverse and knowledgeable debaters seated around the table are greatly appreciated. Their brief biographical backgrounds are provided in this report.

The energetic, highly professional interviewing, organizing, and writing skills of the ISGP staff were essential to not only structuring the ICCAP conference itself, but also to recording the often-diverse views and perspectives expressed in the critical debates, accurately capturing the areas of consensus and actionable next steps from the caucuses, and persevering through the extensive editing process needed to assure the accuracy of the material published here. Their biographies are provided in this report.

Also deserving acknowledgment are the volunteers from Rincon, Sunnyside, and Palo Verde high schools, Pima College, the University of Arizona, and graduate students studying Soil, Water and Environmental Science at the UA. Center. A list of these individuals is included in this report.

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Dr. George H. Atkinson
Founder and Executive Director
Institute on Science for Global Policy
July 1, 2015

ISGP books from ISGP conferences listed below are available to the public and can be downloaded from the ISGP Web site: www.scienceforglobalpolicy.org. Hardcopies of these books are available by contacting info@scienceforglobalpolicy.org.

ISGP conferences on, or related to, Emerging and Persistent Infectious Diseases (EPID):

- *EPID: Focus on Antimicrobial Resistance,* convened March 19–22, 2013, in Houston, Texas, U.S., in partnership with the Baylor College of Medicine.
- *21st Century Borders/Synthetic Biology: Focus on Responsibility and Governance*, convened December 4–7, 2012, in Tucson, Arizona, U.S., in partnership with the University of Arizona.
- *EPID: Focus on Societal and Economic Context*, convened July 8–11, 2012, in Fairfax, Virginia, U.S., in partnership with George Mason University.
- *EPID: Focus on Mitigation*, convened October 23–26, 2011, in Edinburgh, Scotland, U.K., in partnership with the University of Edinburgh.
- *EPID: Focus on Prevention*, convened June 5–8, 2011, in San Diego, California, U.S.
- *EPID: Focus on Surveillance*, convened October 17–20, 2010, in Warrenton, Virginia, U.S.
- *EPID: Global Perspectives*, convened December 6–9, 2009, in Tucson, Arizona, U.S., in partnership with the University of Arizona.

ISGP conferences on Food Safety, Security, and Defense (FSSD):

- *FSSD: Food Security and Diet-linked Public Health Challenges*, to be convened September 20–23, 2015 in Fargo, North Dakota, in partnership with North Dakota State University.
- *FSSD: Focus on Food and the Environment*, convened October 5–8, 2014, in Ithaca, New York, in partnership with Cornell University.
- *FSSD: Focus on Food and Water,* convened October 14–18, 2013, in Lincoln, Nebraska, U.S., in partnership with the University of Nebraska–Lincoln.
- *FSSD: Focus on Innovations and Technologies,* convened April 14–17, 2013, in Verona, Italy.
- *FSSD: Global Perspectives,* convened October 24, 2012, in Arlington, Virginia, U.S., in partnership with George Mason University.

ISGP Academic Partnership (IAP) conferences

- *Food Security: Production and Sustainability*, convened April 24–25, 2015, in St. Petersburg, Florida, in partnership with Sigma Xi, The Scientific Research Society, and Eckerd College.
- *FSSD: Safeguarding the American Food* Supply, convened April 10–11, 2015, in Collegeville, Pennsylvania, in partnership with Sigma Xi, The Scientific Research Society, and Ursinus College.
- *EPID: Focus on Pandemic Preparedness,* convened April 11–12, 2014, in Collegeville, Pennsylvania, U.S., in partnership with Ursinus College.

ISGP conferences on Science and Governance (SG):

- *The Genomic Revolution,* convened September 6, 2014, in cooperation with the Parliamentary Office on Science and Technology of the British Parliament within the House of Lords. London, United Kingdom.

ISGP reports from ISGP conferences on Global Challenges are available to the public and can be downloaded from the ISGP Web site: www.scienceforglobalpolicy.org:

- ISGP Climate Change Arctic Program (ICCAP): *Sustainability Challenges: Coping with Less Water and Energy,* convened June 5, 2015, in Whittier, California, in cooperation with the Whittier Working Group
- ICCAP: *Living with Less Water*, convened February 20–21, 2015, in Tucson Arizona, in cooperation with the Tucson Working Group.

Appendix

Biographical information of scientific presenters

Neil Fromer
Dr. Fromer is Executive Director of the Resnick Sustainability Institute at Caltech, Pasadena, which works across the campus to develop new ideas and research technologies related to a sustainable future, and to translate those technologies quickly from the lab to the marketplace. He is currently focused on energy storage, clean fuel generation and use, smarter energy distribution systems, and energy efficiency in urban environments.

Jerry R. Schubel
Dr. Schubel is President/ CEO of the Aquarium of the Pacific, Long Beach, CA, which is dedicated to conservation efforts such as sustainable seafood, watershed education, and ocean literacy. He created the Aquatic Forum to bring together scientists, policymakers and stakeholders to explore alternative ways of dealing with important, complex, and often controversial environmental issues facing southern California and the nation.

Christopher Thornberg
A founding partner of Beacon Economics, LLC, Dr. Thornberg has particular expertise in economic forecasting, regional economics, labor markets, economic policy, and real estate analysis. He is a consultant to cities, Chambers of Commerce, regional and state agencies, as well as national and international groups concerning economic outlooks and trading activities.

Biographical information of the Whittier Working Group

Raymond Schmidt, Chair, is Senior Fellow with the Institute on Science for Global Policy. A physical chemist and chemical engineer, Ray was a professor, then spent 23 years in research and development in the petroleum industry until retirement. He has a strong interest in organizational effectiveness and community health care outcomes.

John Beynon is President at United Nations Association-USA, Whittier Area Chapter and has a special interest in architecture & planning.

Roger L Burtner is Consulting Geologist/Geochemist with R. L. Burtner & Associates and has served on several church, community and educational boards in his community.

Cinzia Fissore is Assistant Professor of Biology and Environmental Science at Whittier College.

Robert S (Bob) Grove retired as a Senior Scientist and Oceanographer for Southern California Edison, a division of Edison International, and now teaches courses in Ocean Science at the Art Center College of Design in Pasadena.

Gary Lynch is Vice President of Water Quality with Park Water Company, an investor-owned water utility operating in California and Montana.

Tami Pearson is Superintendent for the La Puente Valley Regional Occupational Program, and former Executive Director of High Schools for the Hacienda La Puente Unified School District.

Mark St. Julien is Administrative Facilities Director for PIH Health hospitals in Whittier and Downey.

List of conference debaters

Dan Arrighi
Water Resources Manager
San Gabriel Valley Water Company

Richard Atwater
Southern California Water Committee
Executive director

James Becerra
Professor, College of Environmental Design
Department of Landscape Architecture
California State Polytechnic Univ.-Pomona

John Beynon
Educational facilities architect and
education system planner
UNESCO, retired

Thomas Boles
Minister
Former corporate president and financial
advisor to Indonesia; semi-retired.

Roger Burtner
Exploration research geologist, minerals
exploration consultant, retired

Tessa Farmer
Assistant professor of Anthropology
Whittier College

Everett Ferguson
Hydrogeologist, Water Replenishment
District of Southern California

Cinzia Fissore
Assistant professor, Biology and
Environmental Science
Whittier College

Robert Grove
Senior scientist & oceanographer
Southern California Edison, retired

Leslie Howard
Emeritus Professor of Sociology
Whittier College

Lauma Jurkevics
Senior Environmental Scientist, California
Department of Water Resources, Southern
Region Office

Arthur Krugler
ChE/ME; Consultant/researcher
energy, environment & medical

Gary Lynch
Water utility executive
Park Water Company

Frances Mathews
Professor Emeritus, Biochemistry and
Organic Chemistry
California State University, Fullerton

John McCandless
Project manager & management integration,
Aerospace industry, retired

Alex McKenzie
Biology teacher
California High School

Veronica Morales
Biology and Environmental Science teacher
Whittier Union High School District

Owen Newcomer
Whittier City Council
Political science professor, retired

Adan Ortega
Water and natural resources consultant

Pereda Joel
Building analyst
Enso² Building Solutions

Margo Reeg
Acting president, League of Women Voters
of Whittier; former LWV SoCal
Environmental Action Committee chair

Charles Ritz
Professor of mechanical engineering, research scientist ,and petroleum engineer, retired

Thaddeus H (Thad) Sandford
Vice President for Engineering
Boeing Integrated Defense Systems, retired

John Shipman
Realtor, home performance contractor, Energy efficiency & green trainer

Theresa Slifko
Scientist, water quality
Metropolitan Water District

Drew Sones
Public Works Sanitation executive
City of Los Angeles, retired

Eliseo Tenorio
Human resources executive, retired
Community organizer

Don Winterstein
Research geophysicist,
Chevron, retired

Biographical information of ISGP Board of Directors

George Atkinson, Chairman
Dr. George Atkinson founded the Institute on Science for Global Policy (ISGP) and is an Emeritus Professor of Chemistry, Biochemistry, and Optical Science at the University of Arizona. A past president of Sigma Xi, The Scientific Research Society, he also is former head of the Department of Chemistry at the University of Arizona, the founder of a laser sensor company serving the semiconductor industry, and Science and Technology Adviser (STAS) to U.S. Secretaries of State Colin Powell and Condoleezza Rice. He launched the ISGP in 2008 as a new type of international forum in which credible experts provide governmental and societal leaders with understanding of the science and technology that can be reasonably anticipated to help shape the increasingly global societies of the 21st century. Dr. Atkinson has received National Science Foundation and National Institutes of Health graduate fellowships, a National Academy of Sciences Post Doctoral Fellowship, a Senior Fulbright Award, the SERC Award (U.K.), the Senior Alexander von Humboldt Award (Germany), a Lady Davis Professorship (Israel), the first American Institute of Physics' Scientist Diplomat Award, a Titular Director of the International Union of Pure and Applied Chemistry, the Distinguished Service Award (Indiana University), an Honorary Doctorate (Eckerd College), the Distinguished Achievement Award (University of California, Irvine), and was selected by students as the Outstanding Teacher at the University of Arizona.

Ben Tuchi, Secretary/Treasurer
Dr. Ben Tuchi is chairman of the board of directors of the Arizona Research Park Authority. He received his B.S. and M.S. degrees in Business Administration from the Pennsylvania State University and his PhD in Finance from St Louis University. His full-time teaching career began in 1961 at St. Francis College and continued until 1976 at West Virginia University. From 1976 through 1996 he served in cabinet levels at West Virginia University, The University of Arizona, The University of North Carolina at Chapel Hill, and finally as Sr. Vice Chancellor for Business and Finance of the University of Pittsburgh. During those assignments he was simultaneously a tenured professor of finance. He retired from the last executive post in 1996 and returned to a full-time teaching position as Professor of Finance at the University of Pittsburgh, until his retirement in 1999. For the two years prior to his retirement he was the Director of Graduate Programs in Business in Central Europe, at Comenius University, making his home in Bratislava, The Slovak Republic.

Janet Bingham, Member
Dr. Janet Bingham is President and CEO of the George Mason University (GMU) Foundation and GMU's Vice President for Advancement. Previously, she was President and CEO of the Huntsman Cancer Foundation (HCF) in Salt Lake City, Utah. The foundation is a charitable organization that provides financial support to the Huntsman Cancer Institute, the only cancer specialty research center and hospital in the Intermountain West. Dr. Bingham also managed Huntsman Cancer Biotechnology Inc. In addition, she served as Executive Vice President and Chief Operating Officer with the Huntsman Foundation, the private charitable foundation established by Jon M. Huntsman Sr. to support education, cancer interests, programs for abused women and children, and programs for the homeless. Before joining Huntsman, Dr. Bingham was the Vice President for External Relations and Advancement at the University of Arizona. Prior to her seven years in that capacity, she served as Assistant Vice President for Health Sciences at the University of Arizona Health Sciences Center. Dr. Bingham was recognized as one of the Ten Most Powerful Women in Arizona.

Henry Koffler, Member
Dr. Henry Koffler is President Emeritus of the University of Arizona (UA). He served as President of the UA from 1982-1991. From 1982 he also held professorships in the Departments of Biochemistry, Molecular and Cellular Biology, and Microbiology and Immunology, positions from which he retired in 1997 as Professor Emeritus of Biochemistry. His personal research during these years concentrated on the physiology and molecular biology of microorganisms. He was Vice President for Academic Affairs, University of Minnesota, and Chancellor, University of Massachusetts/Amherst, before coming to the UA. He taught at Purdue University, where he was a Hovde Distinguished Professor, and the School of Medicine at Western Reserve University (now Case Western Reserve University). Dr. Koffler served as a founding Governor and founding Vice-Chairman of the American Academy of Microbiology, and as a member of the governing boards of Fermi National Accelerator Laboratory, the Argonne National Laboratory, and the Superconducting Super Collider Laboratory. He was also a board member of the Association of American Colleges and Universities, a member and Chairman of the Council of Presidents and a member of the executive committee of the National Association of Land Grant Colleges and Universities. He was also Founder, President and board member of the Arizona Senior Academy, the driving force in the development of the Academy Village, an innovative living and learning community. Among the honors that Dr. Koffler has received are a Guggenheim Fellowship and the Eli Lilly Award in Bacteriology and Immunology.

Jim Kolbe, Member
For 22 years, Mr. Jim Kolbe served in the United States House of Representatives, elected in Arizona for 11 consecutive terms, from 1985 to 2007. Mr. Kolbe is currently serving as a Senior Transatlantic Fellow at the German Marshall Fund of the United States, and as a Senior Adviser to McLarty Associates, a strategic consulting firm. He advises on trade matters as well as issues of effectiveness of U.S. assistance to foreign countries, on U.S.-European Union relationships, and on migration and its relationship to development. He is also Co-Chair of the Transatlantic Taskforce on Development with Gunilla Carlsson, the Swedish Minister for International Development Cooperation. He also is an adjunct Professor in the College of Business at the University of Arizona. While in Congress, he served for 20 years on the Appropriations Committee of the House of Representatives, was chairman of the Treasury, Post Office and Related Agencies subcommittee for four years, and for his final six years in Congress, he chaired the Foreign Operations, Export Financing and Related Agencies subcommittee. He graduated from Northwestern University with a B.A. degree in Political Science and then from Stanford University with an M.B.A. and a concentration in economics.

Charles Parmenter, Member
Dr. Charles Parmenter is a Distinguished Professor Emeritus of Chemistry at Indiana University. He also served as Professor and Assistant and Associate Professor at Indiana University in a career there that spanned nearly half a century (1964-2010). He earned his bachelor's degree from the University of Pennsylvania and served as a Lieutenant in the U.S. Air Force from 1955-57. He worked at DuPont after serving in the military and received his Ph.D. from the University of Rochester and was a Postdoctoral Fellow at Harvard University. He has been elected a Member of the National Academy of Sciences and the American Academy of Arts and Sciences, and a Fellow of the American Physical Society and the American Association for the Advancement of Science. He was a Guggenheim Fellow, a Fulbright Senior Scholar, and received the Senior Alexander von Humboldt Award in 1984.

Thomas Pickering, Member
Mr. Thomas Pickering is Vice Chairman of Hills & Co, international consultants, and Strategic Adviser to NGP Energy Capital Management. He co-chaired a State-Department-sponsored

panel investigating the September 2012 attack on the U.S. diplomatic mission in Benghazi. He served as U.S. ambassador to the United Nations in New York, the Russian Federation, India, Israel, El Salvador, Nigeria, and the Hashemite Kingdom of Jordan. Mr. Pickering also served on assignments in Zanzibar and Dar es Salaam, Tanzania. He was U.S. Under Secretary of State for Political Affairs, president of the Eurasia Foundation, Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs, and Boeing Senior Vice President for International Relations. He also co-chaired an international task force on Afghanistan, organized by the Century Foundation. He received the Distinguished Presidential Award in 1983 and again in 1986 and was awarded the Department of State's highest award, the Distinguished Service Award in 1996. He holds the personal rank of Career Ambassador, the highest in the U.S. Foreign Service. He graduated from Bowdoin College and received a master's degree from the Fletcher School of Law and Diplomacy at Tufts University.

Eugene Sander, Member

Dr. Eugene G. Sander served as the 20th president of the University of Arizona (UA), stepping down in 2012. He formerly was vice provost and dean of the UA's College of Agriculture and Life Sciences, overseeing 11 academic departments and two schools, with research stations and offices throughout Arizona. He also served as UA Executive Vice President and Provost, Vice President for University Outreach and Director of the Agricultural Experiment Station and Acting Director of Cooperative Extension Service. Prior to his move to Arizona, Dr. Sander served as the Deputy Chancellor for biotechnology development, Director of the Institute of Biosciences and Technology, and head of the Department of Biochemistry and Biophysics for the Texas A&M University system. He was Chairman of the Department of Biochemistry at West Virginia University Medical Center and Associate Chairman of the Department of Biochemistry and Molecular Biology at the College of Medicine, University of Florida. As an officer in the United States Air Force, he was the assistant chief of the biospecialties section at the Aerospace Medical Research Laboratory. He graduated with a bachelor's degree from the University of Minnesota, received his master's degree and Ph.D. from Cornell University and completed postdoctoral study at Brandeis University. As a biochemist, Dr. Sander worked in the field of mechanisms by which enzymes catalyze reactions.

Richard Armitage, Special Adviser

Mr. Richard L. Armitage is the President at Armitage International, where he assists companies in developing strategic business opportunities. He served as Deputy Secretary of State from March 2001 to February 2005. Mr. Armitage, with the personal rank of Ambassador, directed U.S. assistance to the new independent states (NIS) of the former Soviet Union. He filled key diplomatic positions as Presidential Special Negotiator for the Philippines Military Bases Agreement and Special Mediator for Water in the Middle East. President Bush sent him as a Special Emissary to Jordan's King Hussein during the 1991 Gulf War. Mr. Armitage also was Deputy Assistant Secretary of Defense for East Asia and Pacific Affairs in the Office of the Secretary of Defense. He graduated from the U.S. Naval Academy. He has received numerous U.S. military decorations as well as decorations from the governments of Thailand, Republic of Korea, Bahrain, and Pakistan. Most recently, he was appointed an Honorary Companion of The New Zealand Order of Merit. He serves on the Board of Directors of ConocoPhillips, ManTech International Corporation, and Transcu Ltd., is a member of The American Academy of Diplomacy as well as a member of the Board of Trustees of the Center for Strategic and International Studies.

Biographical information of ISGP staff and volunteers

ISGP staff

Jennifer Boice, ISGP Program Coordinator
Ms. Boice worked for 25 years in the newspaper industry at the Tucson Citizen and USA Today, and was the Editor of the Tucson Citizen when it was closed in 2009. She received her M.B.A. from the University of Arizona and graduated from Pomona College in California with a degree in economics.

Sweta Chakraborty, ISGP Associate Director
Dr. Chakraborty received her doctorate in Risk Management from King's College London, and has more than 20 published articles, has contributed to three books, and is author of the forthcoming book "Pharmaceutical Safety: A Study in Public and Private Regulation." She is currently an adjunct assistant professor at Columbia University and a program associate at Oxford University's Centre for Socio-Legal Studies.

Katie Crosley, Ph.D., received her doctorate in Environmental Science and Policy from the University of Miami, focusing on mixed-method evaluation of complex socio-ecological issues. She specializes in applied field ecology and human dimensions of natural resource management. She will be applying these areas of expertise to help evaluate the ISGP climate conferences in Whittier and around the U.S.

Christina Medvescek, ISGP Program Administrator
Ms. Medvescek is an internationally published journalist and editor specializing in health, human development and conflict resolution. She also serves as an EEO mediator for the U.S. Postal Service, and as a volunteer mediator, facilitator and instructor at the Center for Community Dialogue, Tucson, AZ.

Ramiro Soto, ISGP Fellow
Mr. Soto graduated in May 2015 from University of Arizona College of Science with a degree in General Applied Mathematics and a minor in Hebrew Studies. He plans to enter a doctoral program to further his studies in mathematics.

Andrea Vazquez, ISGP Fellow
Ms. Vazquez is a student at Arizona State University pursuing her bachelor's degree in social work. She also serves as a college prep assistant at a Tucson, Arizona, high school. Her goal as a social worker is to advocate for people who are vulnerable and oppressed, especially youth.

ISGP volunteers

Jennifer Chang is a biomedical engineering student in the Pratt School of Engineering at Duke University. A competitive badminton player, she is interested in pursuing a career in medicine.

Eli Medvescek is a biomedical engineering student in the Pratt School of Engineering at Duke University. An avid rock climber, he is interested in pursuing a career in medicine.

Sally Schmidt, an active Whittier volunteer, recently conducted programs on the history of dolls for the Whittier Historical Society Museum and the Whittier Public Library. A steadfast ISGP supporter, she has been extremely helpful to the Whittier Working Group in organizing the Sustainability Challenges conference and related events.