Water Forum & Tech Roadmap

"The linkage between water, energy and food is key to the sustainable growth of Texas and security of all Texans."

- Dr. Jon Mogford
  Vice Chancellor for Research
  The Texas A&M University System
  Resource Nexus: Water Forum
  November 17, 2015

Resource Nexus: Water, Energy, Food

Water Forum & Technology Roadmap

TAMUS Resource Nexus Water Forum

San Antonio, TX
November 17-18, 2015

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Facilitator

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Foreword

Photo near San Antonio by Forum speaker J. Carl Ganter

The Texas A&M University System and Area 41 co-hosted with Texas A&M University-San Antonio the Resource Nexus: Water Forum. Centering on the WEF Nexus Initiative of Texas A&M University, the two-day event held November 17-18, 2015, in San Antonio, Texas, focused on expanding the scope of the Water, Energy, Food (WEF) Nexus dialogue. Topics included identifying and responding to local, state, national and global challenges and opportunities relative to water resources in research, education, outreach and policy implementation. Other topics included holistic solutions to water security in Texas, and engaging stakeholders at home and worldwide in dialogues that will lead to resolution and prevention of conflict over WEF Nexus-related resources. WEF Nexus Initiative partners include The Texas A&M University System, Texas A&M University, Area 41, Dwight Look College of Engineering, College of Agriculture and Life Sciences, College of Geosciences, George Bush School of Government and Public Service, Texas A&M Engineering Experiment Station, and Texas A&M AgriLife Research.

"Water, energy and food drive our San Antonio economy and are key education and research areas of the university."

- Dr. Cynthia Matson
President Texas A&M University San Antonio
Water Forum Tech Roadmap
November 18, 2015

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Summary

The Texas A&M University System (TAMUS) and Area 41 co-hosted with Texas A&M University-San Antonio the Resource Nexus: Water Forum, held November 17-18, 2015, in San Antonio, Texas.

The two-day event focused on expanding the scope of the Water, Energy, Food (WEF) Nexus dialogue. Water-related challenges in Texas are similar to those seen globally, such as climate variability that impacts multiple ecological zones, the complexity of water governance, multiple siloed utilities, water rights disputes, energy exploration, varied requirements for reporting water use, and historic use of water resources in agriculture and society.

Topics of the forum included identifying and responding to local, state, national and global challenges and opportunities relative to water resources in research, education, outreach and policy implementation. Other topics included holistic solutions to water security in Texas, and engaging stakeholders at home and worldwide in dialogues that will lead to resolution and prevention of conflict over WEF Nexus-related resources.

The forum was timely because Texas and the world at large face a 40 percent gap between the capacity to supply water and demand. Competition for water usage between food production, energy and domestic needs provides a compelling nexus globally. A striking example is found in San Antonio, Texas, where a three-way demand on water resources for agriculture, hydraulic fracturing in energy production, and general domestic use pulls at a supply limited by natural availability and need for environmental flows in the region's streams.

The forum drew from a broad range of stakeholders, representing all aspects of the nexus community. It also drew from a comprehensive spectrum of TAMUS talent currently working on aspects of the WEF Nexus. TAMUS already serves as a testbed for global efforts to bridge the gap between water availability and water demand, drawing on resources available at the Borlaug Institute, the Energy Institute, AgriLife Extension, Texas A&M University (TAMU)Engineering, the Bush School of Government and Public Service, a distinguished body of TAMU alumni working in all the relevant sectors, and partnerships with government, business, and industry.

The Water Forum Technology Roadmap charrette brought together invited thought leaders on nexus to define the most critical problems facing nexus and technology from the perspective of human, education, policy and legal dimensions. Participants held a common interest in accelerating an understanding of nexus and related technologies. The National Science Foundation-supported Texas Research Coordination Network, RCN-CE^{3}SAR served as an independent facilitator.

There was consensus among participants on consequences of failure to educate decision makers and the public about nexus, changes needed in education systems, barriers to action, and benefits if action is taken. There was general agreement on what is most important to fix first and what needs to be done to fix it.

The Texas A&M WEF Nexus Initiative has the following goals:

- Facilitate science-based policy.
- Raise awareness among academia, society, government, and industry for holistic approaches to address nexus-related challenges.
- Identify and respond to national and global opportunities in research, education, outreach, and policy implementation.
- Assist with the management of primary nexus-related resources by helping to provide a platform for quantification and assessment of tradeoffs as we learn to sustainably allocate those resources.

Recommendations

The key take-away message from the San Antonio meeting is clear: a global effort will be required to successfully bridge the gap between water availability and water demand. This effort must include work in policy, technology, consumer science, education and capacity building. Additionally, efforts must focus on building a global network of cooperation toward establishing a platform to share knowledge and data that will identify and help researchers and resource managers respond to WEF Nexus-related state, national, and global challenges and opportunities.

Strategic actions recommended from the Water Forum's Technology Roadmap charrette follow, with specific examples and actions contained in the full report:

- Education and outreach is needed to develop understanding and support by the public for work on the nexus.
- Basic principles of the nexus, as well as significance for future economic and environmental sustainability, need to be taught to students through formal and informal education means starting as early as possible and continuing through higher education.
- Technical and higher education must adapt their models for curricula development and research more quickly and place higher value on solution-based research and public-private-university partnerships to address nexus subject areas, related technologies, and workforce needs that accompany technology advancement. Participants believed that without such change, universities will become even less effective at meeting the needs for education of the real-life workforce and become even farther removed from the very technologies universities are helping create.
- Because water, energy and food program responsibility is spread across many different work groups, agencies, colleges, departments, and other institutional divisions in government, industry and universities, work must be initiated to foster communication among responsible parties and coordinate action in spite of fragmented responsibility.
- Because participants believe the State's current legal and regulatory framework fails to fully reflect basic science underlying the lifecycle of water and use by humans, they recommended education and outreach to create greater levels of awareness about the nexus, and for water in particular, to help pave the way for science-based policy change.
- Universities and private research organizations should play a role as independent brokers for demonstration of nexus-related technologies to accelerate commercialization and application.

Nexus - Introduction

"The WEF Nexus Initiative focuses on urgent needs for science, governments and society."

- Dr. Rabi H. Mohtar

TEES Endowed Professor

Department of Biological and Agricultural Engineering

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WEF Nexus Research Group [wefnexus.tamu.edu]

WEF Nexus Initiative [wefnexusinitiative.tamu.edu]

Texas A&M University, College Station

The Texas A&M WEF Nexus Initiative focuses on the urgent need for science-based policy making and heightened awareness among academe, society, government and industry about holistic approaches to addressing the grand challenges of Nexus-related resource management and allocation. This includes identifying and responding to local, state, national and global challenges and opportunities in research, education, outreach and policy implementation. This forum is expected to help expand scope of the Nexus dialogue and promote holistic solutions to water security in Texas, engaging stakeholders at home and worldwide in ongoing activities and future plans.

Session 1: The Water Challenge

Moderator: Carl Ganter

Panelists: Karin Krchnak, Edward Drusina, Kathleen Jackson, Robert Puente

The Water Challenge session raised relevant questions about preparedness to meet the impending demand for water. This included questioning the ability of municipalities and utilities to meet water demand. Presenters spoke about giving a voice to the disenfranchised and telling their story, and about efforts and successful implementation of sustainable development goals. They explained how to address issues within economically-distressed areas, and what constitutes technological success, including describing when technology helps or hinders success.

Water tops the World Economic Forum's list of global risks that create increased probability of conflict. For example, as groundwater is depleted, choke points are reached. Globally, infrastructure is aging and subject to increasing attacks from nature and humans. Traditional values need to be re-evaluated along with true costs. Sustainable accounting based on reliable and accessible data must become part of the formula. Stakeholders need to become part of the conversation, because public ignorance is a luxury too costly to be allowed to continue. We need to challenge conventional assumptions about water, nature, energy, supply, and 'rights' to each.

At the same time that we are addressing and seeking to change perceptions, we also need to close the loop that brings new technologies to bear. We must begin the rethinking of water for power and water to drink. There are systemic risks in water use that require more integrated approaches to water management and allocation. Technology developers and water producers need to think in terms of resilience, savings, and conservation. They need to rely upon new technologies, such as micro-sensors to address existing problems, such as leaks, cracks, etc., in aging infrastructure.

Leadership needs to take actions to amend traditional perceptions about water and to adapt to, as well as encourage development of, new technologies. This requires financing for water infrastructure, sanitation for public health and welfare, education, and equity in access. We must redefine the valuation of water, and in so doing, rethink policies that impact the way in which we act and communicate our actions. Siloed approaches are proving ineffective. Considering transboundary impacts, we no longer can afford the luxury of failing to integrate projects or cooperate in their development and operation. The role of government in this process is changing. Huge numbers of projects have failed due to lack of integration and sustainability of financing and support.

Setting appropriate, achievable goals and working together to achieve them is increasingly important. The sustainability of efforts is necessary for work in developing and developed countries. Water management and sanitation goals need to be integrated and energized through continued support and financing to ensure access and sustainability. Application across broad natural and economic landscapes is increasingly important.

Session 2: Multi-Stakeholder Landscape

Moderator: Richard Lawford

Panel Members: Rattan Lal, Monty Alger, Peter Saundry, Francisco Bernaola

The Multi-Stakeholder Landscape of the Water Challenge session addressed questions of the sustainability of future water programs and the readiness of leadership to address the challenges by using an inclusive, multi-stakeholder approach. Acknowledging the degree of interconnectivity and the need for sustainable action and outcomes, the panel addressed the WEF Nexus. They spoke of a sense of urgency for implementing an integrated systems approach to problems, and investigating strategies, such as using soil sustainability to improve overall sustainability of WEF Nexus resources.

Panelists addressed the question of how the government and academia can effectively engage the private sector to improve the sustainability of WEF Nexus resources. They acknowledged a need to properly identify both the challenges and potential solutions, and include potential contributions of the private sector. Although panelists felt the basic ideas will generally come from academia, there needs to be a shared language that increases communication understandable within academic circles, and also understood by the private sector. Government, in addition to formulating policy, must provide financial support and guidance to achieve policy objectives. Academia, the private sector, and government must work effectively together, both vertically and horizontally, to allow ideas to flow through open dialogue. Such a partnership will provide greater clarity in defining problems and implementing possible solutions.

A common forum or platform is needed to bring academia, the private sector, and government together to define common, attractive, meaningful and workable goals and shared objectives. Additionally, data and measurements are important. A common set of indices must be developed to ensure development, sharing, and distribution of effective technologies and data relevant to water quality and carbon footprints. Problems must be well defined and should be addressed by knowledgeable managers working together with academia and the private sector to define parameters and needs accurately.

While multi-stakeholder engagement requires a great deal of development and maintenance, the effort is worthwhile and critical to progress in a number of WEF Nexus areas. Such engagement maximizes

potential benefits by ensuring meaningful, inclusive involvement by stakeholders. It helps build and cement relationships throughout the value chain, engaging (not merely informing) stakeholders, and making them partners in the planning and goal-setting processes. Broad horizontal and vertical engagement ensures identification of a range of perspectives and clarification of priorities as well as identification of available resources. Engagement also helps align objectives and actions with sustainability goals, such as promoting renewable energy for clean water production and stimulating synergies in water treatment and reuse.

At the same time, bridges must be built between the academic community and industry. Such partnerships will help identify and work on the interests of stakeholders and promote interdisciplinary work groups. A mechanism to promote an interdisciplinary working environment is the creation of "learning spaces" or "playgrounds" for universities, industry, and other stakeholders. Financial contributions and other opportunities for support, recognition, and reward for time and commitment will further strengthen bridging partnerships.

Panelists also addressed funding. In the short term, funding is needed to develop low-cost technologies for WEF Nexus resource management. An example is sensors that would have the capacity to collect and assimilate large quantities of 'big' data and improve the understanding of complicated WEF Nexus systems. Some funding may come from national agencies such as the anticipated National Science Foundation Innovations at the Nexus of Food, Energy, and Water Systems program. But the stakeholders can assist with funding and "in-kind" resource contributions through coordinated activities, publications, programs and other organization activities such as a Community of Practice network to help stimulate the emergence of a WEF Nexus community.

It was noted that the new Texas A&M University Institute for Water Resources Science and Technology in San Antonio poses an outstanding opportunity for academia to contribute to solving real-world problems by establishing stronger links to industry through applied research and education that address local WEF Nexus-related industry needs. Orienting research institutes to address today's practical needs could help bring the WEF Nexus community together to solve current global issues, including improving access to and use of relevant and reliable information.

Breakout Sessions

Plenary sessions were followed by four breakout sessions, with participants able to choose which session to attend. Each allowed participants to engage in an intensive planning session (charrette) in which various "stakeholders" (including participants from academia, industry, government, and civil society) collaborated in creating a vision for action.

Four breakout sessions were conducted:

- Role of Water Technologies: water-energy-cost tradeoffs
- Capacity Building
- Nexus Public Opinion Survey
- Water Law/Policy

Each breakout group discussed the following questions:

- What are the problems that need to be addressed?
- What additional knowledge do we have and need to address these problems?
- What kind of public-private partnerships are necessary/ possible to address these problems?
- What actions can help build public-private partnerships?
- Way forward?

Summary - Role of Water Technologies

Water-Energy-Cost Tradeoffs

Desalination is considered still too expensive to be a useful technology in agriculture. It also lacks sufficient buy-in from farmers and ranchers in Texas. Nanotechnology could help with filtration of targeted contaminants, but there are barriers to customized treatment, including levels of quality, cost of energy, hydrate formation, and disposal. Additional concerns were raised regarding the impacts of desalination on water efficiency, soil moisture, reuse in irrigation, and water consumption.

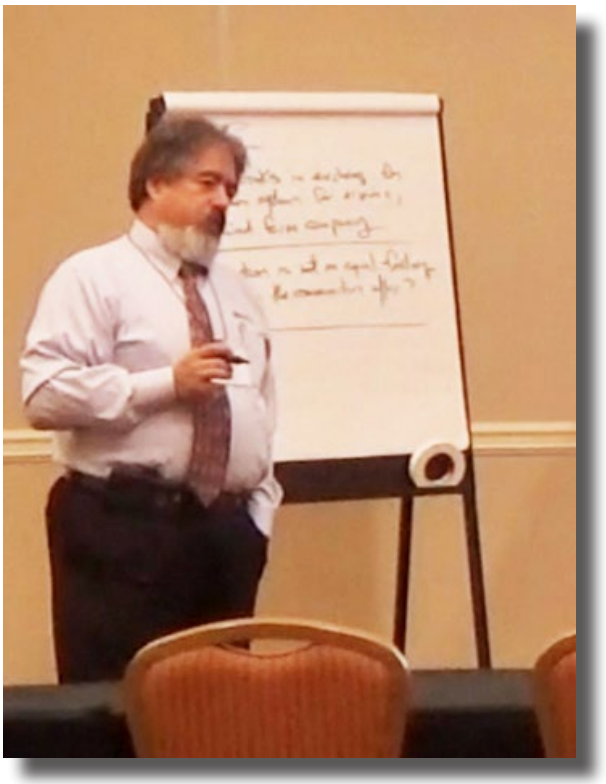
The suggestion was made to consider a Design-Build-Finance-Operate-Maintain-Transfer Public-Private Partnership (DBFOMT-PPP) model to address water consumption behavior. There is no real way to measure and monitor water markets, yet there are examples of aggregated resources management in other areas of the WEF Nexus. For example, the Electric Reliability Council of Texas manages the flow of electric power to 24 million Texas customers, or about 90 percent of the state's electric load. Establishing a DBFOMT-PPP within the water sector could help optimize consumption, assist with financing, identify appropriate technology solutions, and then suggest relevant policy changes. Though additional financing would still be needed, involvement of private sector investors and the potential for an efficiently-distributed water system holds great promise.

It was suggested that the way forward might include a formal public-private partnership team to develop an action plan focusing on consumption, reuse, and secondary use of water. Such a team would 'own' the activity, including identifying regional priorities, developing a Texas community of practice, and working in partnership with universities. This would also include involving graduate students who would serve a dual role as trainees and future stakeholders, and as citizens and workers in the industrial, private, and civil sectors.

Summary - Capacity Building

The discussants acknowledged that well-intended policies and regulations can have far reaching and sometimes unintended consequences. Much depends upon education of the public and the development of trust. Streamlining regulations and policies are clear initial steps toward capacity building, particularly at the local government level. At the same time, creation of new markets forces new investment. Economic development groups can provide information to enhance the way in which investments are objectively evaluated. The public-private partnership mechanism could be effective, both as a 'score keeper' and as a brokerage mechanism for potential investors and consumers. An example might include tax breaks for a wind farm company in exchange for a filtration system for arsenics.

The 'right' people need to be brought to the table, including those who understand or represent multiple stakeholders. Return on investment needs to be considered, and incentives should align with opportunities. Nevertheless, accountability must be expected for both action and lack of action. Public–private (community) partnerships must consider entrepreneurial and profitable ventures, healthcare, education, and business. It is also necessary to look at types of technologies, such as mobile verses stationary infrastructure, distributed verses focused water, and sanitation systems.



A key challenge is understanding the connectivity among systems (their interactions, interdependencies, and relationships), developing the baselines (inventory of resources and assets), and formulating plans of action that consider wants verses needs, timing, and costs (both financial and political).

Summary - Nexus Public Opinion Survey

Session participants sought to look comprehensively at risk. Using the example of climate change, they saw the issue embedded in a larger system of risks having geophysical, economic, human, and health factors in play. They also noted that how divisive concepts such as climate change are framed is crucial, because divisive terminology can impede progress on projects. Hence, discussion focused on the importance of recognizing trade-offs within the WEF Nexus system and articulating how nexus resources are related to each other.

Specific discussion questions were posed to this group and addressed. Here are the questions and answers:

What are the problems that need to be addressed, and how are policy makers informed and influenced?

It is necessary to create alternative future scenarios that portray possible outcomes. For example, a 'millennium ecosystem model' could offer a menu of different future outcomes as a means of influencing policy. It is also important to recognize that university reward structures are not in alignment with a localized focus, such as engaging local stakeholders.

What additional knowledge do we have, or is needed to address these problems?

It is necessary to identify the elites and the opinion leaders in the community and then to know how to engage these leaders.

What kinds of public-private partnerships are possible?

It is essential to involve stakeholders at all levels: industry, local governments, academic institutions, private and civil sectors. A localized focus may be the most meaningful, but the university reward structure is probably not aligned with local perspectives for engagement.

What actions can help build public-private partnerships?

Create common ground. Involve a champion/policy entrepreneur with the ability to see a common problem and get people to come to the table.

Summary - Water Law/Policy

The discussion focused around three specific topics: (1) strong state private property rights affecting quantity of water, (2) federal regulations regarding quality of water, and (3) the impact of eminent domain on property rights. The absence of comprehensive or consistent state laws on water quantity and/or clarity regarding who has the rights to water in transboundary river basins leads to conflicting laws and confusion between and among jurisdictions. Where traditional or historic rights are entrenched, attention needs to be paid to transferring those antiquated rights to new uses, especially where existing requirements provide no incentive for conservation or efficient use. An example are the many situations in Texas where there is little or no incentive to conserve groundwater. Generally, laws are not responsive to new technology, new information, changing social perceptions or norms, or to climate change. All aspects of water resources use and management need to be considered and incorporated into a revised water policy.

Water resource stakeholders are not required to communicate across jurisdictions. This can lead to confusion between political solutions and water basin limitations. Examples include 'bottom up' regional water plans that begin locally with little consideration of impacts basin wide or beyond. Often, these do not consider or protect the public interest. There is not a single agency in Texas charged with vetting information and addressing water priorities. A body charged with regional planning and education is needed to address definitions, policies, public awareness and other broad matters affecting water resource use and management. At one time, research and funding were linked to regulation. That coupling no longer exists. There is no organized body to develop the conversation and consider the landscape.

The legal system lags behind the science of water and water-related technologies. Laws have not kept pace with technology development. We have no clear science-based political resolution on simple matters, such as (1) what brackish water is and who owns it, (2) the connections between ground and surface water and how these resources should be regulated in concert, and (3) market-based issues and public good. There is huge disparity between the price of water and price of gasoline, but we fail to address the real 'value' and true 'cost' of water.

Specific discussion questions were posed to this group and addressed. Here are the questions and answers:

What additional knowledge do we have/need to address these problems?

Studies are needed that quantify resources, define property, and enable proper management and valuation. It is necessary to understand the science. For example, we should understand the reasons why some aquifers deplete and

others do not. We need studies that quantify the damage of willful harm or misuse of resources.

What types of public-private partnerships are necessary and possible to address these problems? Are they necessarily a positive thing?

Solutions may include incentivizing private corporations so that they benefit from mitigation of harm. For example, partnering with governments to restore or protect natural resources, which should lead to greater sustainability. Government is expected to establish the rules, while private corporations are expected to be a source of funding. We need to take action to promote sustainability and financial benefit. This is not necessarily always positive. Using celebrities and non-governmental organizations is fine, as long as participants are properly informed. Incentives (public and private alike) need to be inclusive of all stakeholders. Terms must be clearly defined. Policy should be based on science (knowledge) not law. However, soundly-based science must inform the law.

The public needs to become involved. Stakeholders should make investments to promote the overall sustainability of water resources. A statewide water resource education campaign—conducted by both private and public groups—will bring about a better understanding of the roles, rights, and responsibilities of individuals, corporations, and governments. The education and technology sector should inform the political sector. The private sector should be incentivized to streamline, yet profit, while becoming more involved in crafting new, science-based laws and policies allowing for greater cooperation between industry and universities.

Tech Roadmapping - Introduction

The main goal of Water Forum Technology Roadmapping was to gather information and solutions from experts leading to a pathway for nexus-related technology development and implementation.

The Water Forum Technology Roadmap was designed as a charrette bringing together invited thought leaders on Nexus from universities and organizations interested in accelerating an understanding of nexus and related technologies. The National Science Foundation-supported Texas Research Coordination Network, RCN-CE^{3}SAR served as an independent facilitator.

Participants focused on defining the most critical problems facing nexus and technology from the perspective of human, education, and policy and law dimensions.

Nexus experts focused on three dimensions in breakout groups:

- **The Human Dimension**
- **The Education Dimension**
- **The Policy, Law and Regulatory Environment Dimension**

Barriers and solutions were discussed. Participants also considered roles of the various sectors and opportunities for cooperation. From this, a pathway for promoting a better understanding of nexus and technology implementation was drawn—a roadmap for nexus tech.

Roadmaps

Setting the stage to define Nexus deliberations in the context of a technology roadmap is a previous roadmapping charrette: http://TexasWaterTech.org

Roadmaps are much like strategic plans. At the outset, roadmaps require clear vision of the goal and objectives obtained through stakeholder agreement.

The roadmap displays a continuum of steps to take to achieve stated outcomes. It outlines links among tasks and priorities for actions to be taken immediately and in the future. Stakeholders help create a consensus around performance targets, pathways, assets, priorities, market needs, obstacles, and time frames for research, development, demonstration, and deployment of technology and subsequent commercialization pathways.

Roadmaps are often used as a means to help display and simplify understanding of complex systems. The process itself engages and aligns stakeholders in a common course of action.

Building a roadmap is a dynamic process. Over time, the roadmap must evolve and be adapted, accommodating the successes and failures of implementing roadmap-guided actions, with stakeholders remaining engaged.

Water Forum Charrettes

Water Forum Technology Roadmapping was done through an intensive workshop involving people working together under compressed deadlines. It was facilitated using a charrette process.

Charrettes provide for an interactive pace in which a diverse group of stakeholders, representing pluridisciplinary perspectives (i.e., multi-, inter-, cross-, and trans-disciplinary) are brought together. Participants follow a rigorous, facilitated vision-driven process to achieve specified outcome-oriented goals and objectives. Charrettes are especially suited to encourage discussions that go beyond conventional thinking, and that stretch the envelope of the status quo into the realm of new possibilities.

Participants had opportunity to organize their thoughts in advance of the charrette by attending the Nexus Conference and Workshop the day preceding the charrette.

Upon arrival at Texas A&M University-San Antonio, participants received welcomes from the president of the university and organizers. Participants then received a briefing on the charrette process. After the briefing, participants were asked to attend one of three breakout discussions.

Breakout group discussions during the charrette offered participants an opportunity to contribute to discussions and learn from others. Discussion is an essential element of the process, because it begins the vitally-important process of developing a common understanding among stakeholders with different perspectives and knowledge levels regarding the various issues. While in subgroups, participants brought forward the most critical issues facing technology and the nexus from the human, education and policy/law dimensions. They focused on identifying barriers and the roles of the private sector, government, academia, and research institutes to address critical problems through technology innovation and market-driven solutions.

Moving from a generalized discussion to a more specific level, participants discussed solutions, near-term needs, and gaps. The groups discussed scenarios for collaboration, coordination, and alignment of opportunities on the nexus, such as new laws, collaborations, and more nimble public education systems. After subgroup breakout discussions, a closing session provided participants an opportunity to immediately hear highlights of discussions from each breakout session.

Breakout group facilitators from RCN-CE3SAR presented the summaries. A presentation by forum facilitator Dr. Jorge Vanegas during the final plenary session offered participants an opportunity to contribute to possible next steps.

This report provides participants a record of the process, results, conclusions, and next steps.

Results - The Human Dimension

This breakout session focused participant attention on water technologies from the point of view of human dimensions and in light of previous discussions about the nexus of water, energy and food. Discussions included, but were not limited to, public stakeholder processes and engagement, trust, empowerment, communities, cultural challenges, political realities, complacency, understanding, and partnerships.

Critical Problems

The most critical problems brought forward by the groups are listed with notes of explanation. These are not presented in any particular order.

Public understanding. Understanding sufficient for reasoned decision making by the public regarding technology is generally lacking in many areas. This includes understanding of the need for change and impacts on the future. Without understanding, the public may distrust change.

Choices versus directives. The public, especially consumers, like to be engaged in change with impacts explained, but the public often feels left out or inadequately involved before solutions are implemented. Stakeholders, even ratepayers, often don't understand the 'WHY' for change and how technology fits. They may feel unempowered, even as they see the rates they pay are used to finance the change or new technologies. Under such circumstances, even the best most useful technology can fail if stakeholders fail to understand or don't accept it.

Socio-economic mismatch. Technology may not be relevant or fit the needs of some segments of the public served, despite the universal need for adequate water, energy and food supplies. For example, use of many new technologies require having Internet and Wi-Fi access, but in many areas such access is unavailable or too expensive for many members of the public.

Priority Solutions and Technologies

Top priorities for solving problems identified are listed.

Understand stakeholder interests. As changes or new technologies come on line, it is important to understand relevant characteristics of the public that will be served. Use this insight to communicate openly and effectively with the public at the right levels culturally, economically, generationally, and at an appropriate level of understanding.

Recruit and grow advocates. Openly and constructively engage community leaders and members of community organizations to successfully implement change or employ new technology. Organizations of merit exist to support community social-welfare, educational, environmental, economic or religious needs. As an example, the Girl Scouts helped in San Antonio to implement water efficient toilets. There is a multiplier effect when these organizations are effectively engaged. An example

of an effective engagement action are 'ride-alongs' with utility workers that enable community leaders to better understand the utilities' operations. The public can be invited to project sites for events or as a matter of course through field trips or static exhibits. With education organizations or schools, expand internships with utilities to leverage the influence of education institutions, students and parents. In particular, engage water-energy-food oriented organizations, such as the Alliance for Water Efficiency (AWE) to build an extended sense of community.

Incentives. Stakeholders, and especially ratepayers, may see technology as costing them money without benefit. Provide incentives to stakeholders for adopting/accepting new technology. Concerns about financial impact may be reduced with effective incentives.

Education. Water-energy-food relationships need to be established through formal and informal education means as early as possible. As an example, participants mentioned the common knowledge about food-energy pyramids created in the past by inclusion of the principles of such pyramids in middle and high school curricula. Today, new examples are needed to ingrain principles of water conservation, energy and food throughout education. This can be cast as an annual event. An example is creation of a 'Water Day,' similar to Earth Day created in 1970 and still practiced annually.

Improve communications. Old means to communicate with the public may no longer be the most effective way to reach the public, such as through newspapers or radio. Communication now needs to include social media.

Inhibitors, Obstacles, Barriers

Participants listed a number of barriers. None appeared technically difficult. Instead all were tied to political resolve, personal will, or leadership competency. The following appeared to be the most significant. None are limitations on advancements in technology itself.

Complacency. Whenever an issue is contentious complacency may make progress or change difficult. Moving outside one's own comfort zone can be difficult. This can be particularly prevalent where there is a lack of personal accountability. The result is that consequences for complacency are passed on to the next generation.

Political will. There may be little political will to change or adopt technologies if there is resistance. It may matter little why the resistance exists. Even if it is due to lack of education, ineffective communication, or misinformation there may be little political will to implement technology if constituencies are perceived as unsupportive.

Exposure. Many people lack direct exposure to water issues. Despite droughts and water restrictions, many people simply are not directly affected and do not read or pay attention to educational media related to water problems. A perceived lack of relevancy can create complacency or obstructionism.

Cultural differences. Socio-economic matters may mean some groups perceive water, energy and food challenges differently than other groups. Such differences can make it difficult to reach some entire groups of stakeholders. Trust must be established first in some communities before information can effectively pass from one person to another. Hence, there may exist a wide divergence of opinion in some communities and/or among some groups of how to address water-energy-food challenges.

Moving Forward

Participants were optimistic that challenges can, and must, be overcome. They listed a number of immediate actions to take.

Planning. It's impossible to implement change or implement new technologies successfully if you don't know where you want to end up. Thus a first step to moving forward is to create a plan with a clear definition of what is possible. During planning, prioritize short term, long term, and most impactful actions. Develop a strategic plan for achieving public awareness. Plan an annual community water awareness day.

Funding. Funding is needed for to sustain communication and outreach efforts to engage stakeholders.

Partnerships. Establish local university-utility partnerships on water education, efficiency and technology development. Through such partnerships promote the water-energy-food nexus and community support for future sustainable management and advancement of technology and conservation measures. Create strategic alliances with local and statewide organizations that have strong ties to communities (e.g. Texas Water Foundation).

Engage and recruit. Meet and engage the public where they are, that means wherever – at a flea market, through on-line social media, going to community events and organization meetings, and so on. In these locations educate, assemble, and recruit supporters and advocates. Create forums that help blend stakeholders of various levels of understanding, strategic alliances, and engagement to enable cross education, broad support, and common understanding.

Results - The Education Dimension

This breakout session focused participant attention on education, the nexus and water technologies. Participants envisioned a goal of creating an educated public that cares about the water-energy-food nexus, and that takes actions in support of nexus sustainability.

Critical Problems

The most critical problems brought forward by the group are listed with notes of explanation, but are not presented in any particular order.

Awareness. The general public is not aware of the nexus. Perhaps most important to the discussion about education, there is a lack of clear perceived value in nexus-related new technologies to the public and lack of incentives to increase awareness at any level of traditional education.

K-12 education. Teaching about the water-energy-food nexus is mostly absent. Change will not be easy. There is general resistance to altering curricula in K-12. Even when changes do take place, they take place slowly and may involve political challenges.

Technical training. As new technologies emerge, there is a time lag between the need for trained operators and publicly or for profit available training. As a result, industry itself must often become the first line of training development simply due to the inability of extension services, community colleges, or workforce-savvy universities to respond to future need quickly. Public-training institutions are often unable to look beyond past market needs and into the future. They simply do not keep up with technology implementation, despite obvious trends, industry marketing, and massive amounts of information spread across today's electronic media.

Higher education. The separation between what industry needs as technology advances and what is being taught to students is even greater in higher education than at technical-training institutes. This results in a lack of alignment from what educators, and by consequence students, think needs to be learned versus what students actually need to know in order to meet workforce needs for new technology. The higher education "culture" has been slow to value solution-based research and development. There is little or no incentive for administrators and faculty to redefine the carrier path required for students to meet the demands of new technologies as those technologies appear in the nexus workspace. In practice, there may be disincentive for responsiveness, yet technology advances and workforce needs change.

Scalability. Current approaches are not scalable to the problem. The K-12 community, training community and higher education community are not working on their own, let alone cooperatively, to address the problem.

Inhibitors, Obstacles, Barriers

Participants listed a number of barriers, or underlying causes. The following appeared to be the most significant, but are not presented in any particular order.

K-12 education. Changes in K-12 education often require clearing political obstacles and structured demands on educators. It will take time to educate leaders of education reform and initiate a grassroots movement with sufficient influence to add nexus education to K-12 curricula.

Technical training. Extension services and technical training are often slow to change without strong direction or incentives from industry or markets.

Higher education. University research and educational models are not ones that bend easily to disruptive change. Thus higher education has created its own restrictive environment to adapt their models quickly enough to respond to new innovative technologies and the workforce needs that invariably accompany technology change. The current trend in our system of higher education is for universities to become as much alike as possible. At the present, few universities strive to develop graduates with practical operational training versus theoretical training. In addition, university curricula approval is tied to accreditation agencies. These agencies are slow to respond and regimented to a degree, making adaptation of curricula or adopting new curricula a difficult and drawn out process.

Scalability. Without the K-12 community, training community and higher education community working cooperatively to bring forward nexus-related education little will happen. At all levels of education, the funding that is available for workforce development, new curriculum development, and STEM (science, technology, engineering, and mathematics) education has accounting and re+porting requirements that are so burdensome that few educators or education administrators are willing to accept these funds and incorporate them into building new programs or curricula. Currently there is no distinct career path for students to follow at the various levels of education to meet workforce needs of new technology relative to the nexus.

Moving Forward

Participants listed a number of immediate actions to take.

Awareness. Learning is increasingly taking place in informal spaces, using videos, Internet, social media, and other new communication technologies. Such means should be used in general public education, in addition to making nexus information part of curricula used in formal public education. We also need to involve regulators early, engaging them in nexus discussions that lead to higher levels of understanding and better informed regulators. The objective of this education is to encourage regulations that are firmly based on science and reason.

K-12 education. In order to implement change in K-12 education, a leader must emerge. Some one or more individuals must recognize the importance of education about nexus and take on the politics of change, as well as advocate for new curricula among educators and administrators.

Higher education. Current incentives that are forcing universities to focus on theoretical training and become as much alike as possible must be reversed. Incentives should be made available to universities that choose to equip graduates with practical operational training on new technology. Administrative, leadership, and funding models need to change to enable such disruption of current practice. The very definition of career path through higher education may need to evolve to make it possible to address future workforce needs in a way that will meet new technology requirements of the nexus. Because university curricula are tied to accreditation agencies, these agencies will need to adapt to enable universities to quickly adapt to meet new technology-driven workforce demands. It remains questionable if higher education can adapt quickly enough to address the new innovative technologies and the workforce needs that invariably accompany technology change. The alternative to changes described by the group is that universities will simply become even less effective at meeting the educational needs of the real-life workforce and become still farther removed from the technology it is in the process of helping create.

Scalability. Nexus is not just a single subject area. It addresses matters of water, energy, and food. At most levels of government and in universities these areas are addressed in different work groups, agencies, colleges, departments, or other institutional divisions. This increases the challenge of making anything happen without leadership, political support and allowance for disruption. Such leadership will need to extend to creating an environment where the K-12, training, and higher education communities can work in concert to establish appropriate level curricula on nexus.

Public-private-university partnerships. Public-private partnerships can form a basis for new educational models. Higher education and technical training/extension can learn from industry models for training and education. Universities need to benchmark with private industry and figure out how to partner in a fashion that allows industry to use higher education in a smarter way than ever before. There is no need to reinvent what already exists. A new model for nimble delivery of education can be created that takes into account what industry needs and what higher education can best deliver. Finally, we need to add an education and outreach component to the agenda of meetings on nexus. Workshops and other meetings on nexus subjects should include education components to ensure education keeps pace. Such meetings should be held regularly, because when new technologies become available, the market quickly establishes need and use, immediately after which trained operators are needed. Anticipating and getting ahead of the cycle creates advantages for industry and education. Only this way will education institutions meet new demands for education and create recognition of the nexus and the evolving technologies it drives.

Results - The Policy Dimension

This breakout group focused participant expertise on the policy, law and regulatory environment dimension. Discussions included, but were not limited to statutes, regulation and public agency practices, and the legal regulatory environment within which all actions affecting the nexus exist.

Critical Problems

The most critical problems brought forward by the group are listed with notes of explanation. These are the policy, law, and regulatory issues and impediments affecting the water-energy-food nexus. The following are not presented in any particular order.

Legal and regulatory framework. The State's current legal and regulatory framework does not take into consideration the life-cycle of water, from extraction through distribution, use, treatment, recovery, reuse and ultimate disposal into the environment. Water rights are allotted based on historical factors such as prior appropriation, that may not meet current and future water security and sustainability needs. Water rights are beginning to be influenced by water management plans, but the plans are not consistent across regions. One group member reported that some energy companies are acquiring water rights and establishing virtual utilities, a situation that could create future conflict among users.

Fragmentation of authority. There is no authority—central or otherwise—that spans the three elements of the nexus: water, energy, and food. Furthermore, there is fragmentation with respect to regulations and decision making regarding water quality, water production and quantity, distribution and availability. Fragmentation results from mixed authorities of different agencies and different levels of responsibility at the federal, state, regional, and local levels. Intensifying the problem is a lack of communication, cooperation, and collaboration among the various parties, agencies, etc. Neither the Texas Water Development Board nor any other entity has implementation or enforcement authority for water. Competing needs, wants, demands, and rights for water often conflict. Priority of allocation and use affects energy, food, the environment, and other arenas of interest and concern. In addition, actions in one part of the nexus can produce unintended consequences in another. For example, no-till farming enhances crop production and reduces water consumption, but requires heavier use of herbicides. There is no integration of decision making and prioritization across the various needs and demands for water. This leads to inefficiencies and a more legalistic approach in dealing with conflicts.

Inconsistent use of science. The most basic and scientifically-indisputable interrelationships between surface water, groundwater, quantity of water, and quality of water may not be recognized by controlling stakeholders.

Inhibitors, Obstacles, Barriers

Participants listed a number of barriers, or underlying causes. Available technology was not a constraint to solution, but access to it was. The following appeared to be the most significant.

Misperceptions. Perceptions about the availability of water, energy, and food vary widely. The ready availability of cheap water has created a relatively wide-spread public perception that water is an essentially unlimited resource. In general, members of the public believe everyone has a simple and basic right to water and pay little attention to where it comes from or how it gets to them. Extending this lack of understanding and perception of right, there also is a general lack of understanding about how the production and availability of water, energy, and food interrelate. This is exacerbated by the profoundly-different valuations of these commodities: although water is essential to both energy and food availability, it is assigned the least value in the pricing structure. There is incomplete or inconsistent knowledge regarding water availability, particularly how overall supply is affected by the interrelationships among reducing, recycling, reusing, and repurposing of water.

Data needs. Availability and access to data and information in an understandable, usable, and actionable form is inadequate. Combined with generally poor results with education and engagement efforts to date, this drives what is perceived, believed, and acted on by all parties. Transfer and introduction of existing technologies are incomplete, inadequate, and insufficient to meet current needs. Technical staff at relevant agencies and resources such staff have to work with are insufficient, particularly in the smaller groundwater conservation districts. In particular, funding is inadequate to support studies at the groundwater conservation district level that would provide better understanding about resource availability, interactions among surface and groundwater, water quality, water demands, and more.

Political constraints. Political pressures, legal questions and challenges, and public opinion create risks for elected officials and other decision makers. These forces suppress willingness among elected officials to pursue new laws and regulations. Pressures

Photos near San Antonio by Forum speaker J. Carl Ganter

are driven by differing, and at times, competing value systems among stakeholders. Factors include public rights versus private property rights, a perception of greater good of society at large, impact on non-human species, the environment, etc. Factors including a lack of a common value system, absence of an appropriate valuation of water, and risks combine to cause a general lack of trust among the parties. For example, there is lack of trust between citizens with water rights and citizens without water rights, and among environmentalists, politicians, developers, agribusiness, water-project companies, utilities, and so on. Furthermore, it is difficult to introduce change, because there is considerable inertia driving the current system of laws, regulations, and practices. There are also preferential individual treatments associated with the status quo. Water, energy, and food are complex subjects individually, which makes achieving a consensus on the nexus all the more difficult.

Lack of incentives. There are inadequate incentives for users to conserve water. For most consumers, there is not even a system in place to recognize any water conservation efforts they may make.

Moving Forward

Participants provided suggestions on addressing challenges. They listed a number of immediate actions to take.

Studies (and funding). Studies should be conducted to quantify the water-energy-food nexus, with work to include validating the legitimacy of focus on the nexus by illustrating appropriate case studies. As examples of such works, consider an examination of the energy cost of water production, treatment, and distribution for food production. Adoption and adaptation of existing technologies should be demonstrated, particularly where uncertainties may be high. Proof-of-concept demonstrations should be undertaken for new technologies or for emerging or unproven concept technologies in areas critical to nexus. There is a role for universities and private nonprofit organizations to serve as independent brokers for the case studies and demonstrations. To enable such studies, however, there must be new cooperative and integrative funding mechanisms. One option is to establish a major federal program designed along the lines of the Advanced Research Projects Agency, either for water only or for the nexus. If it is necessary to work within existing agency constraints, then agencies responsible for funding research and development in the nexus arena at the federal, state, and local levels should be identified and the leaders in these agencies and relevant legislative branch committees contacted with information about nexus. Among options to consider are direct appropriations and user fees or assessments, for funding at the state or federal levels. For such funding, and especially for user fees or related assessments safeguards to assure the funding is actually used as intended should be added to authorizing legislation and/or regulatory authority.

Planning. High-value conservation projects should be designed and incorporated into the Texas State Water Plan. Current funding in the plan designates a percentage of loan funding to be used on conservation projects; a consensus on high-priority projects would provide a basis for allocation of loan funds.

Coordination. Increased interactions and cooperation among appropriate State agencies should be encouraged. Agencies at issue include the Texas Commission on Environmental Quality, Texas Water Development Board, and Texas Parks and Wildlife Department. A university or group of universities could help promote such coordination through forums or workshops. Even though it may be politically volatile, these same universities could initiate an effort to evaluate the need for and potential role of a single State-level agency responsible for the water throughout its lifecycle, including production, distribution, conservation, reuse, and discharge into the environment.

Roadmap - Closing Session & Conclusions

Participants reconvened in a closing session following completion of breakout group discussions. They heard summaries of results of those discussions. Facilitator, Dr. Jorge Vanegas, identified themes that cut across breakout sessions. Dr. Vanegas asked several questions of the entire group to probe areas of consensus and in anticipation of future courses of action. Participants from all sessions described similar problems and priority solutions. There was a similar consensus among participants on consequences of failure to act, barriers to action, and benefits if action is taken. There seemed to be general agreement on what is most important to fix, and what needs to be done to fix it.

Outreach Education

Charrette participants focused on a general goal of using education and outreach as a means to develop understanding and support among the public for work on the nexus. However it was not clear who would pay for such education and outreach. Water, energy and food program responsibility is spread across many different work groups, agencies, universities, departments, and other institutional divisions in government, industry and universities. This gives some responsibility to all, but final accountability to none.

Because the general public is not aware of the nexus, there is a lack of clear perceived value of nexus-related work or of associated new technologies. Using water as an example, despite droughts and water restrictions many people simply are not directly affected and do not read or pay attention to educational media related to problems.

To achieve education and outreach several actions were recommended.

Participants suggested using case studies as real-life examples of why everyone should care about the nexus.

To address generational challenges to information delivery, they recommend that education and outreach extend to informal education spaces by using videos, Internet, social media, and other new communication technologies. This prompted the suggestion to generate outreach and education opportunities using virtual, immersive visualization options that create interesting engagement environments. This could include game play to get people engaged. It could also include the water equivalent of a doomsday clock to allow people to visualize the nature of sustainable resource use. Another example was creation of a "Water Day," similar to Earth Day first recognized in 1970 and still practiced annually as a means to promote education about the environment.

Participants also stated that education must extend to all members of the public, regardless or whether or not nexus technologies are now perceived relevant to or fit the needs of some segments of the public.

To forward change, participants recommended offering choices versus directives. They believe the impacts of nexus-driven change or technology must be explained, and that stakeholders should be empowered

with an understanding of "why," even as they may see rates they pay increase to finance new technologies for nexus-related goods or services.

In an effort to recruit and grow advocates for nexus, participants suggested openly and constructively engaging community leaders and members of community organizations in efforts to implement change and employ new technology. They believe there is a multiplier effect when community organization members are effectively engaged.

Where socio-economic or cultural conditions may create misconceptions about the water, energy and food nexus, education efforts may require first establishing a high level of trust. Participants suggested meeting and engaging the public wherever they are through community events and community organization meetings, ride alongs with utility workers, public invitations to project sites for events, field trips, exhibits, and school events and internships to leverage the influence of education institutions. They also suggest creating educational outreach forums that help blend stakeholders of various levels of understanding, strategic alliances, and engagement to enable cross education, broad support, and common understanding.

Education Reform and Role of Universities

Charrette participants stated that the basic principles of the water-energy-food nexus, as well as significance for future economic and environmental sustainability, need to be taught to students through formal and informal educational means starting as early as possible and continuing through higher education. Attention turned to the need for education reform to enable faster response by education at all levels to enable incorporation of relevant new technology in curricula, research and workforce training .

Public educational curricula development and delivery models are not ones that bend easily to disruptive change. Participants questioned if education will be able to address the new nexus subject areas, related technologies, and workforce needs that invariably accompany technology advancement.

> Without change, universities will become even less effective at meeting the education needs of the real-life workforce and farther removed from the very technologies universities are helping create.

K-12. With subject matter about the nexus mostly absent in K-12 curricula, the first priority for educating students about nexus is to develop and add nexus-related subject matter to appropriate K-12 curricula. Because changes in K-12 education often require clearing political obstacles and structured demands on educators, work should start immediately at the political level and with teachers and administrators. Participants recommend this start with educational efforts directed at (1) elected officials in education policy leadership positions, and (2) grassroots education of STEM educators throughout Texas. One place this can be implemented is through university continuing education programs for teachers and as K-12 education students take university coursework for their degree. In order to implement change in K-12 education, participants believed a leader must emerge. Some one or more individuals must recognize the importance of education about nexus and take on the politics of change, as well as advocate new curricula among educators and administrators.

Technical training. As new technologies emerge, the time lag must be reduced between the need for trained operators and publicly available training at technical training institutes. Technical training

institutes must keep up with technology implementation by following industry marketing and deployment trends. This can be done through attendance at industry conferences and by following industry-related media.

Higher education. The challenge of change is magnified by the separation between what industry needs as technology advances and what is being taught to students. This is greater in higher education than at technical training institutes. The higher education "culture" that fails to place high value on solution-based research and development must be changed to engage with changing technologies. Current disincentives must be changed to incentives for administrators and faculty to redefine the carrier path required for students to meet the demands of new technologies. University research and educational models are not ones that bend easily to disruptive change, creating a restrictive environment for adapting quickly to respond to new innovative technologies and the workforce needs that invariably accompany technology change. To support change in higher education, curricula accreditation agencies must also adapt their models and processing times to enable universities to quickly respond to meet new technology-driven workforce demands.

Scalability. Education about nexus needs to scale to meet the needs of the K-12, training and higher education communities. This will require all three communities working cooperatively to bring forward nexus-related education. Funding should be made available to promote new curriculum and workforce development. To enable ready use of funds, the excessive accounting and reporting requirements that impede use of such funds should be lessened or removed entirely.

Public-private-university partnerships. Partnerships should be used to form the basis for new, faster evolving educational models. Based on industrial education requirements for applying nexus technologies, universities must benchmark with private industry and partner in a fashion that allows universities to tap into industry resources, and industry to use higher education in a smarter way than ever before. Understanding there is no need to reinvent what already exists, a new model for nimble delivery of education can be created that takes into account what industry needs and what higher education can best deliver.

In furtherance of more rapid evolution of education, meetings should be held regularly between university faculty, regulatory agency staff, and industry leaders on emerging topics where nexus-related technology is entering the market and application. Anticipating and staying ahead of the technology implementation cycle creates advantages for industry, researchers and educators. Only this way will education institutions remain engaged with relevant research, meet new demands for education, and create recognition of the nexus and the evolving technologies it drives.

Public Policies

Participants stated the State's current legal and regulatory framework fails to reflect the basic and indisputable science underlying the lifecycle of water and use by humans, from extraction through distribution, treatment, recovery, reuse, disposal into the environment, and ultimate recycling as groundwater, surface water or atmospheric water. Water rights are distributed based on historical factors, such as prior appropriation, that may not meet future water security and sustainability needs. Participants expressed understanding of the political, social, technical, and economic constraints to rapid change in policies, laws, rules, and public opinion.

Unifying leadership. Water rights are beginning to be influenced by water management planning and adopted plans, but the plans are not consistent across regions. Progress in this area should continue, but fragmentation of authority

over regulations and decision making regarding water quality, production, quantity, distribution, and availability make any decision about water difficult. Challenges expand as focus turns to the nexus which encompasses many additional subject areas. Policy changes affecting water or the nexus may require coordination among numerous work groups, agencies, universities, governmental departments, or other institutional divisions that are responsible for policy at the local, regional, state and federal levels of government. As such, there needs to be increased reliance on science and better coordination across the various levels of government and working groups responsible for nexus matters. As with education, political and grassroots leadership in advocacy of disruptive change will be needed to counter the political and bureaucratic constraints to integration of nexus science into the policy-making process.

Use of science. Education and outreach will be required to create greater levels of awareness about the nexus, and for water in particular, about the indisputable interrelationships between surface water, groundwater, quantity of water, and quality of water. Such education will help pave the way for reasoned policy change based on recognition of factual information.

Planning. High-value conservation projects should be designed and incorporated into the Texas State Water Plan. Direct funding for high priority conservation work should be added to the plan.

Coordination. Increased interactions and cooperation among universities and state agencies with responsibility for nexus-related policy should be encouraged and implemented. A university or group of universities could help promote such coordination through an ongoing series of forums or workshops.

Research and Data

Universities and private research organizations can play a role as independent brokers for demonstration of nexus-related technologies to accelerate commercialization and application. Proof-of-concept demonstrations for emerging or unproven concepts should be undertaken in areas critical to nexus.

There is need to increase access to data and information, making it available to industry, researchers, and policy makers in an understandable, usable, and actionable form. This includes an inventory and transfer of information on existing technologies. Making use of this information, studies should be conducted to better quantify the water-energy-food nexus, with work to include widely disseminating results through development and distribution of appropriate case studies.

Funding will be required for new work, with normal routes for funding water, energy and food related research suggested as first steps for inquiry. One option suggested was to seek establishment of a new federal program designed along the lines of the Advanced Research Project Agency, either for water only or for the nexus. This would include direct appropriations at the state or federal levels.

Planning. It's impossible to implement work or test new technologies if you don't know where you want to end up. A key step forward will be creation of a plan, with clear short- and long-term actions, including actions to achieve public awareness.

Appendices

Photo near San Antonio by Forum speaker J. Carl Ganter

Appendix I — Participants

James Abbey – The Texas A&M University System

Monty Alger – The Pennsylvania State University

Francisco Javier Bernaola – Abengoa

John Blake – Texas A&M University

Regina Buono – Baker Institute for Public Policy

David Burnett – Texas A&M University-Global Petroleum Research Institute

Angel Bustamante – El Paso Water Utilities

JoAnn Canales – Texas A&M University-Corpus Christi

Luis Cifuentes – Texas A&M University-Corpus Christi

Richard Coffin – Texas A&M University-Corpus Christi

Robert Cunningham – Texas Water Future

Edward Drusina – International Boundary and Water Commission

Marianne Dwight

Gabriel Eckstein – Texas A&M University

Allison Elder – San Antonio River Authority

David Ellis – Texas A&M Transportation Institute

Ali Fares – Texas A&M University-Prairie View

James Fischer – Texas A&M Engineering Extension Service

James Fletcher – Texas Water Future

Joe Fox – Texas A&M University-Corpus Christi

Carl Ganter – Circle of Blue

Juan Gomez – University of Texas San Antonio-TSERI

Heather Griffith Peterson – The Texas A&M University System

Mario Guel – Texas A&M University-Galveston

Karen Guz – San Antonio Water System

Ashley Hunter – HMM Risk Group

Kathleen Jackson – Texas Water Development Board

Jose Gutierrez – Texas A&M University

Karin Krchnak – World Wildlife Fund (WWF)

Rattan Lal – The Ohio State University

Martha Landwehr – Texas Chemical Council

Richard Lawford – Future Earth/Morgan State University

Ying Li – Texas A&M University

Jerry Lin – Lamar University

Tom Linton – Texas A&M University-Galveston

Jingbo Liu – Texas A&M University-Kingsville

Cindy Loeffler – Texas Parks and Wildlife Department

Cynthia Lyle – Texas A&M University-Corpus Christi

Erika Mancha – Texas Water Development Board

Missy Mandell – Mandell & Associates

Howard Marquise – Northwest Vista College

Terry McDevitt – The Texas A&M University System

Peyton McGee – Institute for Science, Technology, and Public Policy

Trey Mebane – National Oilwell Varco

Jon Mogford – The Texas A&M University System

Rabi Mohtar – WEF Nexus Initiative

Lyda Creus Molanphy – Connections Consulting

Dorina Muglet

Oscar Munoz – Texas A&M University

Wesley Patrick – Southwest Research Institute

Charles Porter – St. Edward's University

Kent Portney – Bush School of Government and Public Service, Texas A&M University

Robert R Puente – San Antonio Water System

Steven Raabe – San Antonio River Authority

Sarah Richards – Cynthia & George Mitchell Foundation

Rudolph Rosen – Texas A&M University-San Antonio

Peter Saundry – National Council for Science and the Environment

Stephen Searcy – Texas A&M University

Josephine Sosa-Fey – Texas A&M University-San Antonio

Brian Stipe – Texas A&M Engineering Extension Service

Bill Stockton – Texas A&M Transportation Institute

Susan Stuver – Texas A&M AgriLife Research

Aarin Teague – San Antonio River Authority

Kenneth Tobin – Texas A&M International University

Rudolfo Valdez – Texas A&M University-San Antonio

Jasper van Heesch – OmniEarth Data and Analytics

Jorge Vanegas – College of Architecture Texas A&M University

Arnold Vedlitz – Bush School of Government and Public Service, Texas A&M University

Jennifer Walker – Sierra Club, Lone Star Chapter

Cindy Wall – Texas A&M Engineering Experiment Station

Jim Wall – Texas A&M Engineering Experiment Station

Gina Warren – Texas A&M School of Law

Steven Whisenant – Texas A&M AgriLife Research

Katherine Zodrow – Rice University

Appendix II — Organizers

Resource Nexus

Forum Host

Dr. Jon Mogford – Vice Chancellor for Research, The Texas A&M University System

Organizer and Facilitator

Dr. Rabi Mohtar – TEES Professor, Departments of Civil and of Biological and Agricultural Engineering, WEF Nexus Initiative, Texas A&M University, College Station

Master of Ceremonies

Dr. Rudolph Rosen – Director, Institute for Water Resources Science and Technology, Texas A&M University-San Antonio

Plenary Session: The Water Challenge Panel Discussion

Moderator

Mr. Carl Ganter – Co-Founder, Circle of Blue

Panelists

Mr. Robert Puente – President, San Antonio Water System

Ms. Kathleen Jackson – Chair, Texas Water Development Board

Mr. Edward Drusina – Commissioner, International Boundary Water Commission

Ms. Karin Krchnak – Director, Freshwater Program, World Wildlife Fund

Plenary Session: Multi-Stakeholders Landscape of the Water Challenge

Moderator

Dr. Richard Lawford – Future Earth

Panelists

Dr. Rattan Lal – Professor, The Ohio State University

Dr. Richard Lawford – Future Earth

Dr. Monty Alger – Director, Institute for Natural Gas Research

Dr. Peter Saundry – Chief Scientist, National Council for Science and the Environment

Breakout facilitators

Role of Water Technologies: Water-Energy-Cost Tradeoffs

Dr. Bill Stockton – Texas A&M Transportation Institute

Dr. David Ellis – Texas A&M Transportation Institute

Dr. Rabi Mohtar – Texas A&M Nexus Initiative

Capacity Building

Dr. Jorge Vanegas – Texas A&M University College of Architecture

Nexus Public Opinion Survey

Dr. Arnie Vedlitz – Texas A&M University Bush School of Government and Public Service

Dr. Kent Portney – Texas A&M University Bush School of Government and Public Service

Water Law/Policy

Dr. Gabriel Eckstein, Texas A&M School of Law

Water Forum and Technology Roadmap

Forum Host

Dr. Cynthia Matson – President, Texas A&M University-San Antonio

Organizer

Dr. Rudolph Rosen – Director, Institute for Water Resources Science and Technology, Texas A&M University - San Antonio

Master of Ceremonies and Workshop Facilitator

Dr. Jorge Vanegas – Dean, College of Architecture, Texas A&M University-College Station and Professor, Texas A&M Engineering Experiment Station

Workshop Facilitators

Dr. Luis A. Cifuentes – Vice President, Division of Research, Commercialization and Outreach, Texas A&M University–Corpus Christi

Dr. Wesley Patrick – Vice President, Geosciences and Engineering Division, Southwest Research Institute, San Antonio

Ms. Cindy Wall – Assistant Agency Director for Regional Divisions, Texas A&M Engineering Experiment Station, College Station

Dr. James Wall – Executive Director, Texas Center for Applied Technology, Texas A&M Engineering Experiment Station, College Station

Contributors

Ms. Claudia Pollard and Ms. Mallory Stocker – The Texas A&M University System, College Station

Ms. Nuala Martinez – Texas A&M University-San Antonio

Ms. Mary Schweitzer – Texas A&M University, College Station

Report Editors

Dr. Rabi Mohtar – TEES Professor, Departments of Civil and of Biological and Agricultural Engineering, WEF Nexus Initiative, Texas A&M University, College Station

Dr. Rudolph Rosen – Director, Institute for Water Resources Science and Technology, Texas A&M University-San Antonio

Appendix III — Agenda

The Texas A&M University System - Resource Nexus: Water Forum
Marriott Riverwalk Hotel and Texas A&M University-San Antonio
San Antonio, Texas
November 17-18, 2015

AGENDA

Tuesday, November 17

8:30 – 8:55 a.m. **Registration and Light Breakfast Fare**

Master of Ceremonies – Rudolph Rosen, Texas A&M University San Antonio

9:00 – 9:10 a.m. **Welcome** – Jon Mogford, Vice Chancellor for Research, The Texas A&M University System

9:10 – 9:15 a.m. **Introduction to Forum Objectives** – Rabi Mohtar, Texas A&M Nexus Initiative

9:15 a.m. – 10:30 a.m. ***The Water Challenge*** **Panel Discussion** –
Moderator - Carl Ganter, Co-Founder, Circle of Blue

- City Perspective – Robert R. Puente, San Antonio Water Systems (SAWS)
- State Perspective – Kathleen Jackson, Texas Water Development Board (TWDB)
- National Perspective – Commissioner Edward Drusina, International Boundary Water Commission (IBWC)
- Global Perspective - Karin Krchnak, World Wildlife Fund (WWF) – via WebEx

10:45 a.m. – 12:00 p.m. ***Multi Stakeholders Landscape of the Water Challenge*** **Panel Discussion**
Moderator – Richard Lawford, Future Earth

- Rattan Lal, The Ohio State University, UNFLORES – Video presentation
- Monty Alger, The Pennsylvania State University
- Peter Saundry, National Council for Science and the Environment– via WebEx
- Francisco Bernaola, Abengoa Water

12:00 – 1:00 p.m. **Networking Lunch**

1:15 – 3:00 p.m. **Breakout Discussions Group 1:** ***Role of Water Technologies: water – energy – cost tradeoffs***
– Facilitators – Bill Stockton, Texas A&M Transportation Institute; David Ellis, Texas A&M Transportation Institute; and Rabi Mohtar, Texas A&M Nexus Initiative

Breakout Discussions Group 2: ***Capacity Building***
– Facilitator – Jorge Vanegas, Texas A&M University College of Architecture

Breakout Discussions Group 3: ***Nexus Public Opinion Survey***
- Facilitators **–** Arnie Vedlitz and Kent Portney, Texas A&M University Bush School of Government and Public Service

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Breakout Discussions Group 4: *Water Law/Policy*
– Facilitator – Gabriel Eckstein, Texas A&M School of Law

3:00 –3:15 p.m. **Break**

3:15 – 5:00 p.m. **Forum Reconvenes for Discussion Group Summaries and Way forward**
Moderator – Rabi Mohtar, Texas A&M Nexus Initiative
Bridging the Texas Water Gap: Technological, Policy, and Societal Perspectives

Adjourn

5:30 – 7:00 p.m. **Networking Reception**

Wednesday, November 18

7:30 a.m. Buses depart Marriott Riverwalk Hotel to the campus of Texas A&M University–San Antonio (TAMU-SA)

8:00 – 8:30 a.m. **Networking Continental Breakfast**
Vista Room, 402 Central Academic Building

8:30 a.m. **Introduction of the President, Texas A&M University-San Antonio**
Rudy Rosen

8:30 – 8:40 a.m. **Welcome and Introduction to Texas A&M University-San Antonio**
President Cynthia Matson

Master of Ceremonies – Jorge Vanegas

8:40 – 9:10 a.m. **Session 1: *Establishing the Point of Departure* for the Charrette Process**
Welcome and Introduction to objectives and logistics
Rudolph Rosen. Texas A&M University-San Antonio

Description of the *Texas Water Technology Roadmap: process, results, and historical significance*

Presentation of the charrette process, scope, and *Rules of Engagement*

Facilitated plenary discussion on, and formal documentation of, *roles*, *drivers*, and *expectations* of participants

9:15 – 9:25 a.m. **Session 2: Breakout Group Discussions: *Water Tech Development Acceleration***
Jim Wall, Texas Center for Applied Technology

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Facilitated Breakout Group Discussions on three key dimensions surrounding water technologies, which extend the focus of prior work in this topic: from a source point of view, from a transportation and delivery point of view, from a use point of view, and from an enabling technologies point of view. These dicsussions will also build and extend the discussions from Day 1. Participants select their first choice of discussion topics.

9:30 – 11:10 a.m. **Breakout Group No. 1: *The Human Dimension* –** 204 Madla Building
Cindy Wall, Texas Engineering Experiment Station, Regional Divisions

This breakout group will focus on a discussion of water technologies from human and social dimension points of view, from individuals and families, through communities, to organizations in the public and private sectors.

Breakout Group No. 2: *The Education Dimension* – 207 Madla Building
Luis Cifuentes, Texas A&M University-Corpus Christi

This breakout group will focus on a discussion of water technologies from an education dimension points of view, from K–12 education, through community college education, to higher education at undergraduate, masters, doctoral, and post-doctoral levels.

Breakout Group No. 3: *The Policy, Law, & Regulatory Environment Dimension* – 209 Madla Building
Wes Patrick, Southwest Research Institute

This breakout group will focus on a discussion of water technologies from a policy, law, and regulatory environment dimension points of view, from local county and municipality government, through state government, to federal government levels.

11:20 a.m.–12:00 p.m. **Session 3: *Plenary Presentations on Breakout Group Discussions* –** Vista Room, 402 Central Academic Building
Jorge Vanegas

Each Breakout Group will present the highlights of their discussions in Round 1 to all participants. All participants to participate in discussion.

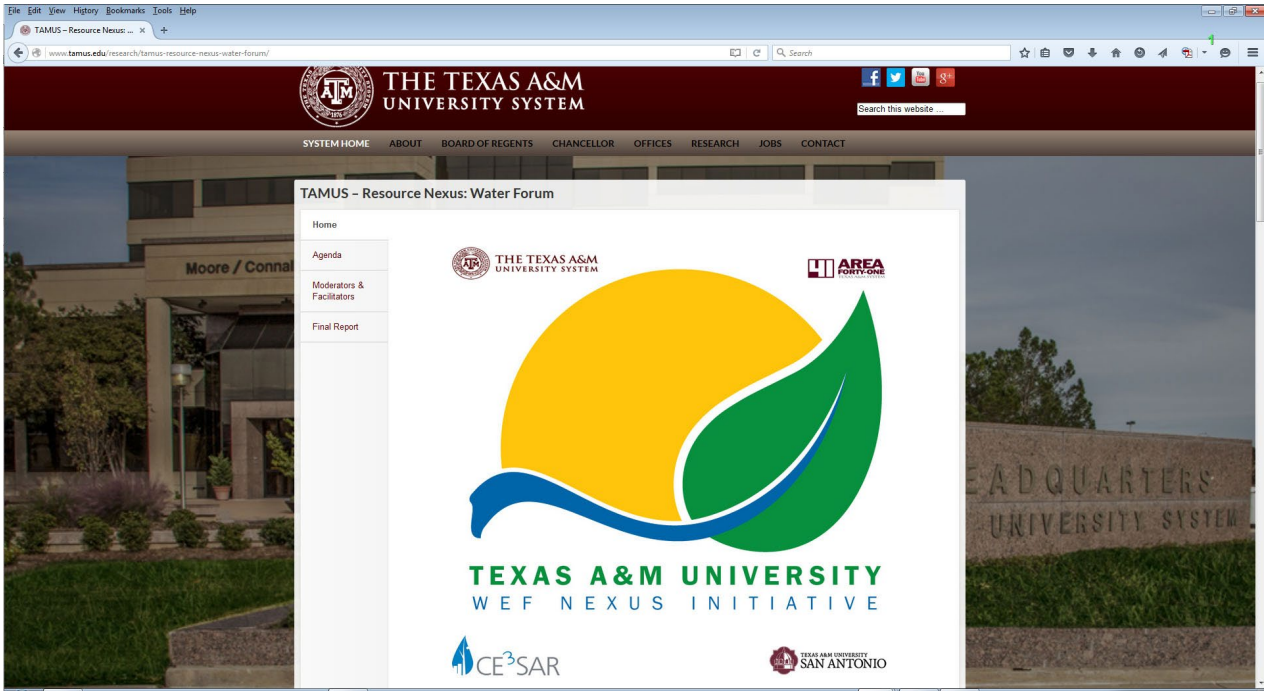
12:00 p.m. **Lunch and Concluding Session –** Vista Room, 402 Central Academic Building
Session 4: *The Pathway Ahead*
Jorge Vanegas

Facilitated plenary discussion on, and formal documentation of a preliminary consensus among participants on the content of the presentations done in Session 3.

1:00 p.m. **Adjourn and board buses to Marriott Riverwalk Hotel**

Appendix IV — Forum Website

The forum was supported through a website. This site can be accessed at http://www.tamus.edu/research/tamus-resource-nexus-water-forum/



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Copies may be obtained at http://www.tamus.edu/research/tamus-resource-nexus-water-forum/ and at The Texas A&M University System, 301 Tarrow Street, College Station, TX 77840.