

**Solutions at the Nexus of Food, Energy and Water (FEW) Systems  
Findings from the 2017 FEW Nexus Workshop and Multi-Stakeholder Dialogue  
on Integrated Science, Engineering, and Policy**

College Station, Texas | January 26-27, 2017

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**Highlights of Final Report**



**June 29, 2017**

**Texas A&M University**

**College Station, TX**



## FEW Nexus Workshop on Integrated Science, Engineering, and Policy: A Multi Stakeholder Dialogue

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### 1.0 Executive Summary

Our national and global communities face huge challenges in securing access to the primary resources of water, energy, and food. These insecurities are fueled by changing climate, population, and demographics. The resources are highly interlinked at multiple scales, such that managing and integrating our responses to the interactions and interdependencies of food, water and energy (FEW) systems is increasingly part of the public consciousness. The long term sustainability of these systems requires holistic, systems level solutions that integrate across scales and disciplines, and that provide a platform for combining deeper knowledge of this complex system of systems with appropriate technological, policy, and human behavioral perceptions. The Food–Energy–Water (FEW) Nexus offers such platform. The platform is progressing rapidly to design and offer solutions that rely upon the integration of science, engineering and policy and that incorporate knowledge-towards-action, new technologies, planning, policy, behavioral adaptation, and finance pathways.

Urban growth, migration, resource constraints, changing climate, and multiple additional factors bring these challenges to the fore. Yet, the science, engineering and policy communities must grapple with challenging questions regarding what can be or should be done; how rapidly; in what order. Just how to mold FEW nexus policy in order to help achieve sustainability and resilience goals was the focus of a high level meeting in which leading experts working in FEW fields, their policy and governance, and the data collection and modeling of these, were assembled. The assembly addressed **new research and data collection approaches for enhancing research that is capable of modeling and monitoring the processes associated with resilience, vulnerability, climate change, and risk reduction. Among its primary outcomes will be development of a conceptual framework to address these issues effectively.**

The NSF *FEW Nexus Workshop on Integrated Science, Engineering, and Policy: a Multi Stakeholder Dialogue Symposium*, took place January 26-27, 2017 in College Station, Texas. A local organizing committee worked with representatives of the larger scientific committee (see appendices III and IV for a complete list). In all, the workshop included 125 scientists and professionals from the private and industrial sectors, government agencies, civil society, national laboratories, and more than 30 research and educational institutions. Portions of the meeting were live broadcast, to include participation globally. Each of two days began with plenary sessions and panel discussions that were followed by break outs focused on specific relevant topics. Following the sessions, participants reunited for a closing plenary each day and an evening reception and two lunches offered informal networking opportunities. (See the detailed program, Appendix I.)

The workshop identified interdisciplinary research agendas for engineering, agriculture, geosciences, social, behavioral and economic sciences. It also called for new approaches to innovative research and data collection to enhance research that is capable of modeling and monitoring the processes associated with changes in climate, resiliency, vulnerability, risk perception and overall enhancement of sustainable management practices for primary resources. Specific discussions were organized around **10 BIG IDEAS** identified in advance and prepared as white papers to provide a springboard for addressing specific research themes in the context of the FEW Nexus interrelations and the need for transdisciplinary collaboration to address their integrated management. These white papers became the foundation of a special issue that will be published by Springer, making it available broadly to the global scientific, policy and stakeholder communities who must address nexus issues (See Appendix V for a list of white paper scopes and authors.) Follow up is planned to explore ways to encourage a community of science and practice to more effectively understand and address the FEW Nexus challenges.

The discussions focused on ways to address the many challenges posed by the interdependent FEW systems and their integrated governance and management. Also explored were the core challenges, data gaps, and potential transformative solutions associated with the FEW nexus. The essence of the current state and the gaps we face are summarized in these proceedings. [The papers will appear under the online first tab, "articles not yet assigned to an issue," at the link <https://link.springer.com/journal/volumesAndIssues/40518> until transferred to Issue 3 (on September 1, 2017)]. A synopsis of the special issue papers follows.

## Appendix I. Program

**January 25:** Check in at Hilton Hotel

### **Day 1: January 26 (Ideas Day)**

*Masters of Ceremonies:* **Peter Saundry**, Senior Fellow, National Council for Science and the Environment & Adjunct Professor of Energy, John Hopkins University, and **J. Carl Ganter** Circle of Blue

8:00 Registration and coffee

9:00 Welcome Notes

**Glen A. Laine**, VPR, Texas A&M University

**Dimitris Lagoudas**, Sr. Assoc. Dean for Research, College of Engineering, Assoc. Vice Chancellor for Engineering, Texas A&M Engineering

**Craig Nessler**, Director, Texas A&M AgriLife Research, College of Agriculture

9:15 Workshop Objectives **Rabi Mohtar**, Texas A&M WEF Nexus Initiative

9:30 Opportunities and Challenges in the FEW Nexus - **JoAnn Lighty**, NSF-CBET

10:15 Burst Session of 10 BIG IDEAS

(Questions posted on portal to be discussed in breakout session)

1. Data and modeling **Bernie Engel**, Purdue
2. Governance, policy, and financing **Kent Portney**, Bush School, Texas A&M
3. Governing resources in future cities **Josh Sperling**, NREL
4. Tradeoffs and decision support tools **Suzanne Pierce**, UT Austin
5. Energy for water **Enid J. Sullivan-Graham**, NM State
6. Water for food **Elsa Murano**, Borlaug Institute, Texas A&M
7. Water for energy production **Ashlyn Stillwell**, U IL
8. Food processing and waste **Stephen Searcy**, Texas A&M
9. Soil – Food – Climate Nexus **Rattan Lal**, Ohio State
10. Engagement and outreach: Community Building **Jon Padgham**, futureearth

12:00 Networking Lunch

1:00 Breakout session #1: **Exploring the FEW System**

1. FEW Research Facilitator, **Noël Bakhtian**, former Senior Policy Advisor, White House Office of Science & Technology Policy
2. FEW Education Facilitator, **Adel Shirmohammadi**, U Maryland
3. FEW Practice: applied research, industry, policy; Facilitator, **Jamal Yagoobi**, Worcester Poly
4. FEW Community Building Facilitator, **Molly Jahn**, UWI

#### **Questions:**

1. Define target FEW system(s)
2. What are the key challenges
3. What are the solutions (immediate possibilities to leverage opportunities)
4. What are the key potential impacts (social, environmental, economic)
5. What resources are needed for implementation

3:00 Summary Panel from moderators of breakouts and Q/A

4:00 Goals for tomorrow and Closing (**Rabi Mohtar**)

**Evening Networking Reception immediately following**, hosted by Texas A&M WEF Nexus Initiative.

Welcome: **Martin Scholtz**, Executive Associate VPR, Texas A&M

**Day 2: January 27 (Action Day)**

*Masters of Ceremonies Jack Baldauf, Geosciences, Texas A&M and J. Carl Ganter, Circle of Blue*

9:00 Hotspot – Nexus Live – **J. Carl Ganter**, *Circle of Blue*

9:30 Science and Policy Panel with Q/A

Moderator, **J. Carl Ganter**. Panelists: **Rattan Lal**, *Ohio State*, **John Tracy**, *TX Water Resource Inst.*, **Vanessa Casado Peres**, *TAMU Law*, **Astrid Hillers**, *Global Environmental Facility*

**Kickoff Questions:**

1. How do you characterize the state of FEW science and policy interaction nationally?
2. What steps should be taken to improve the science base decisions related to FEW resources?
3. What policy changes can improve the science and science – policy coherence in FEW resources?

10:30 Industry and Technology Panel with Q/A

Moderator: **Michel Boufadel**, *NJIT*. Panelists: **Walid Saad**, *VA Tech*, **Andrea Putman**, *SoAR*, **Gerrit Hoogenboom**, *UFL*

**Kickoff Questions:**

1. Do we have the right incentives for innovations in the FEW system
2. What unique technological challenges / opportunities that FEW system exhibits?
3. What are the infrastructure and human capacity needed for fostering innovations in the FEW system.

11:30 – 12:00 Breakout assignments

12:00 Networking lunch

1:00 **Breakout session #2 Moving Forward: the Road map**

- a. Building on the white papers **Ali Fares**, *PVAM*
- b. Community of Science: RCN & e-portal **Katrina Bennett**, *LANL*
- c. INFEWS **Lucy M Camacho**, *Texas A&M-Kingsville*
- d. Belmont Forum **Rick Lawford**, *Futurearth*

**Sessions Deliverables:**

1. Establish targets and priorities for the theme
2. Develop action plan including activities, timeline, teams and role for achieving the target.
3. Identify resources needed for implementation
4. Are there other targets that should be included?

3:00 Panel summaries and discussions

4:00 Conclusions and recommendations

**Brandi Schottel** and **Jim Jones**, *NSF INFEWS*. **Rabi Mohtar**, *TAMU WEF Nexus Initiative*

4:00 Adjournment

### **Appendix III. Scientific Committee**

**Monty Alger**, Pennsylvania State University

**Anik Bhaduri**, Water Future Program

**Manochar Dorraj**, Texas Christian University

**Amr Elnashai**, Pennsylvania State University

**Bernard Engel**, Purdue University

**J. Carl Ganter**, Circle of Blue

**Karin Krchnak**, World Wildlife Fund

**Rattan Lal**, Ohio State University

**Upmanu Lall**, Columbia University

**Richard Lawford**, Morgan State University

**Claudia Ringler**, International Food Policy Research Institute (IFPRI)

**Peter Saundry**, Nat'l Council for Science & Environment and John Hopkins University

**Kurt Schwabe**, University of California, Riverside

**Shashi Shekhar**, University of Minnesota

**Joshua B. Sperling**, National Renewable Energy Lab

**Enid J. Sullivan Graham**, University of New Mexico

### **Appendix IV. Organizing committee Texas A&M University**

**Jack Baldauf**, Professor, Executive Assoc. Dean, Assoc. Dean for Research, College of Geosciences

**Phil Berke**, Professor, Director, Inst. of Sustainable Coastal Communities, College of Architecture

**David Burnett**, Director of Technology, Global Petroleum Research Institute

**Shankar Chellam**, Professor, Zachry Department of Civil Engineering

**Ali Fares**, Assoc. Director for Research, Prairie View A&M University

**Bruce McCarl**, Distinguished Professor of Agricultural Economics

**Ari Michelsen**, Professor, Resident Director, Texas AgriLife Research & Extension Center, El Paso

**Rabi Mohtar**, TEES Professor, Texas A&M WEF Nexus Initiative, Zachry Dept. of Civil Engineering,  
Dept. of Biological and Agricultural Engineering

**Efstratios Pistikopoulos**, TEES Distinguished Research Professor, Director, Texas A&M Energy Inst.

**Kent Portney**, Professor, Director, Inst. for Science, Technology and Public Policy, Bush School

**Rudy Rosen**, Professor, Director, Inst. for Water Resources Science and Technology, TAMU-San  
Antonio

**David Smith**, Extension Program Specialist, Department of Biological & Agricultural Engineering

**John Tracy**, Director, Texas Water Resources Institute, Professor of Civil Engineering

**Kevin Wagner**, Deputy Director Texas Water Resources Institute, Professor of Soil and Crop Sciences

## Appendix V. White Paper Authors and Scope

The essence of the current state and the gaps we face are summarized in this document. The white papers (\*denotes corresponding author) are published in a Special Issue by Springer Link. This issue is accessible: <https://link.springer.com/journal/40518/4/3/page/1>.

### 1. Energy for Water and Desalination

**Authors:** *Enid Jeri Sullivan Graham\**, *Noël Bakhtian*, *Lucy Mar Camacho*, *Shankar Chellam*, *Ahmed Mroue*, *Joshua B. Sperling*, *Kevin Topolski*, *Pei Xu*.

**Scope:** Improved efficiency; interactions in the energy, water, and industrial systems; increased availability and delivery of water for agriculture. It productively leverages connections between natural and engineered water systems.

### 2. Water for Energy: Systems Integration and Analysis to Address Resource Challenges

**Authors:** *Ashlynn S. Stillwell\**, *Joshua D. Rhodes*, *Margaret A. Cook*, *Joshua B. Sperling*, *Tyler Hussey*, *Ahmed M. Mroue*, *David Burnett*, *Michael E. Webber*.

**Scope:** Highlights the water requirements of the energy sector, and summarizes interdisciplinary research opportunities for sustainable and efficient management of water for energy.

### 3. State of the Art of Water for Food within the Nexus Framework

**Authors:** *Sonja Loy*, *Jeffry Tahtouh*, *Clyde Munster\**, *Kevin Wagner*, *Ali Fares*, *Srinivasulu Ale*, *Richard Vierling*, *Fouad Jaber*, *Anish Jantrainia*.

**Scope:** Reviews the state of knowledge regarding water for food within the WEF nexus framework and considering improved plant genetics; irrigation technology and practices and urban agriculture.

### 4. Governance of the Water-Energy-Food Nexus: The Conceptual and Methodological Foundations for the San Antonio Region Case Study

**Authors:** *Kent E. Portney\**, *Arnold Vedlitz*, *Garett Sansom*, *Philip Berke*, *Bassel T. Daher*.

**Scope:** Focuses on providing an outline of the “governance” group’s approach to conducting research on nexus issues in this case study.

### 5. Food Processing and Waste within the Nexus Framework

**Authors:** *Jeffry Tahtouh*, *Elena Castell-Perez\**, *Carmen Gomes*, *Rosana Moreira*, *Eric S. McLamore*, *Hal S. Knowles, III*

**Scope:** Presents challenges and potential solutions regarding the food manufacturing industry and waste production within the WEF nexus framework. Also considers prevention and recovery solutions to alleviate waste from food production (farm), industrial/retail (processing), and consumption.

### 6. Soil as a Basic Nexus Tool: Soils at the center of the Food Energy Water Nexus

**Authors:** *Rattan Lal\**, *Rabi Mohtar*, *Amjad Assi*, *Ram Ray*, *Haimanote Baybil*, *Molly Jahn*

**Scope:** Presents a conceptual model and discusses the role of soil as a naturally organized medium to protect global food, water, energy securities. Elaborates on the use of soil as a basic nexus tool and proposes a paradigm shift that integrates soil, creating the FEWS Nexus.

### 7. Building a WEF Nexus Community of Practice (NCoP)

**Authors:** *David W. Smith*, *Matthew Welch*, *Katrina E. Bennett*, *John Padgham*, *Rabi H. Mohtar\**

**Scope:** Examines the literature for common threads and attributes inherent to scientific-based communities of practice, and identifies challenges and potential solutions for building a community of scientists to address the water-energy-food nexus.

### 8. Model Use in FEW Nexus Analysis: A Review of Issues

**Authors:** *Bruce A. McCar\**, *Yingqian Yang*, *Kurt Schwabe*, *Bernard A. Engel*, *Alam Hossain Mondal*, *Claudia Ringler*, *Efstratios N. Pistikopoulos*

**Scope:** Highlights that modeling and analysis are a necessity as the Nexus approach is about widening perspectives to unexplored levels. Describes the challenges of representing an appropriate geographic region while encompassing relevant FEW activities. Includes discussion of an integrated modelling framework for Nexus analysis in an example setting.

9. **Trade-offs and Decision Support Tools for nexus-oriented management**

**Authors:** *Bassel Daher, Walid Saad\**, Suzanne A. Pierce, Stephan Hulsmann, Rabi H. Mohtar

**Scope:** Explores integrated assessment approaches for FEW systems trade-off analyses and evaluation; how to identify and design a set of strategies that are robust under various future conditions.

10. **Data for FEW System Analysis: A Review of Issues**

**Authors:** *Bruce A. McCarl\**, Yingqian Yang, Raghavan Srinivasan, Efstratios N. Pistikopoulos, Rabi H. Mohtar

**Scope:** Highlights that disciplinary data has been gathered for years but cross disciplinary data is not frequently integrated and correlated. Emphasizes Nexus data systems must integrate across spatial, temporal, and thematic dimensions, and outline challenges in Nexus data acquisition and ways to address this research gap.

11. **Urban Nexus Science for Future Cities: Focus on the Energy-Water-Food Nexus**

**Authors:** *Joshua B. Sperling\**, Philip R. Berke

**Scope:** Presents an analytical systems framework for data integration and analyses on the theme of 'urban nexus science-towards solutions with respect to accelerated planning and decision-making at the WEF, nexus. Overall, a summary of the core challenges, data gaps, and potential transformative solutions associated with the WEF nexus are explored.