Reflections from some FEWS Fellows:

Michael Evans, School of Chemistry and Biochemistry, ***Sustainability-centered Laboratory Experiments for General Chemistry Labs***

Chemistry and sustainability have always had an awkward relationship. In my role as the laboratory coordinator for First-year Chemistry at Georgia Tech, I have to be sensitive to the fact that students' perceptions of chemistry are a mixed bag. On the one hand, chemistry helps us understand and control the world at the molecular level. For example, we now understand the molecular-level effects driving such diverse phenomena as anthropogenic global warming, the degradation of coral reefs, and antibiotic resistance. On the other hand, the chemical industry has been an extremely relevant player in many of the environmental problems we face today. It's unclear at this point whether our understanding of chemistry will lead to improvement in the relationship of humanity to nature.

As a participant in the Food-Energy-Water Systems (FEWS) Program, my hope was that I could help students in the First-year Chemistry laboratories appreciate the positive role that chemistry plays in helping us understand the environment. Analytical data represents an important starting point for conversations about the state of the environment and what to do about it. To get students thinking along these lines, I developed experiments for the Chemical Principles II laboratory at Georgia Tech in which students analyzed local food and water samples. Conversations with other FEWS Fellows were a valuable part of this process, particularly as I began to think about how to move beyond traditional lab reports for these experiments. For analytical data to start a conversation, it has to get into the right hands and be comprehensible by the right audience; a traditional technical report is almost certainly not the right vehicle to do this. My work in developing innovative laboratory assignments to communicate data and results to traditionally underserved audiences is ongoing, but without the FEWS Program, I would have had no idea where to start!

The response of students to these new experiments was quite positive, which was an important motivator in keeping up the work. In the water analysis experiment, students collected their own samples and generated a map with their location and analytical data. Seeing the spatial distributions of chloride and dissolved oxygen concentrations in environmental and municipal water was a big source of excitement for students. Moving forward, I hope to continue developing analytical experiments that help students "see" their local environment at the molecular level and generate data that could be useful to local populations.

Jessica Fisch, School of City and Regional Planning, ***Examining Equity and Access in Green Urban Projects***

My experience as a Serve-Learn Sustain Food-Energy-Water Systems Fellow exposed me to a variety of sustainability-focused groups and projects around the Atlanta area and was a wonderful opportunity to see what different groups are doing in the areas of food, energy, and water systems. From the work of Friends of Refugees surrounding food systems in Clarkston, Georgia, to the WaterHub at Emory University, there are so many opportunities to learn about sustainable systems from people who are hard at work in these areas all around us. I really appreciated the opportunity to connect with these groups and get an up-close perspective of their efforts, and to connect with scholars across Georgia Tech with interests in these issues.

My work with FEWS has also allowed me to hone my research interests for my dissertation project proposal, which focuses on issues of equity and access in green urban projects. Throughout the semester, it was great to have access to the Serve-Learn-Sustain team to discuss my project and get new input. I will be focusing on large, green, urban projects, such as the Atlanta Beltline, which have the potential to bring environmental, economic, and social benefits to cities and neighborhood residents, from recreation opportunities and improved public health outcomes to filtering of stormwater, increasing urban tree canopy, and local economic development opportunities. These benefits are often of particular importance in low-income, high-poverty neighborhoods. However, research has proposed that equity concerns, such as access for low-income and marginalized groups, affordability, and displacement, are often not addressed with wealthier residents moving into areas surrounding green projects. Low-income residents and people of color often cannot afford to stay in the neighborhoods, or may not be able to easily access the new amenities due to socio-spatial or economic factors.

My research will involve surveys of trail users and non-users in two Atlanta neighborhoods and will examine socioeconomic, socio-spatial, and cognitive factors involved in trail utilization and access. I hope to provide insight into the accessibility of green projects to low-income and marginalized groups who may stand to gain the most from access with regard to transportation options and economic wellbeing, physical and mental health benefits, social capital, and environmental quality. I will be further developing this research that began during my time with the FEWS program over the coming semester.

Overall, the Serve-Learn-Sustain FEWS program was a wonderful introduction to sustainability in the Atlanta area and also gave me the opportunity to connect with scholars at Georgia Tech and people working in sustainability throughout the city. I look forward to continuing to develop these connections and to furthering the conversation surrounding sustainability in food, energy, and water systems throughout my time at Georgia Tech and into my career as a planner and educator.

Sabrina Grossman, CEISMC; Cassandra Telenko, School of Mechanical Engineering; Malte Weiland, Campus Services, *Sustainable Systems Mapping/Modeling*

Working with Cassandra Telenko and Malte Weiland, the focus of our SLS project is to plan and implement an analysis of the existing waste and recycling systems at Georgia Tech. Through Dr. Telenko's spring graduate course, students will examine the inputs into Georgia Tech and then map their output with what materials are recycled, reused, composted, and/or brought to a landfill. Malte Weiland, the sustainability project manager for campus services, will facilitate the project and organize meetings for the students with various stakeholders throughout campus. As Georgia Tech has only participated in building level audits of their waste system, but never as a whole campus, this work is extremely important in understanding the interconnected web of waste management and how each sector affects the other. The expected outcomes will greatly benefit Georgia Tech's understanding of these systems and allow for information for decision-making on improvements to them.

Through my role at CEISMC as a program director in science education, I have the opportunity to run a sustainability science camp for high school students every summer. The theme of the camp changes every year, but we try to focus on specific themes of research across the Georgia Tech campus. I will be connecting the work from Dr. Telenko's course to our camp themes this year and will hopefully have a student from the course work with our students to expose them to systems mapping and modeling. In addition to focusing just on waste and just on Georgia Tech's campus, we will take a broader view and look at specific inputs and outputs in the students' community (school, home, neighborhood) related to food, energy , water, and materials. Students will spend two weeks on campus looking at how to reduce our footprint and focus on the reuse and recycling of our resources. Dr. Telenko's students will provide an example of basic system mapping which will be able to show students how data can inform decisions. Malte Weiland will connect the students to campus resources that can demonstrate how these systems can change to reduce waste. Students will attend field trips to the Waterhub at Emory (inspired by the FEWS Fellowship), The Robert C. Williams Museum of Papermaking, and the Center for Hard to Recycle Materials, just to name a few. By the end of the camp, students complete a basic system map of their assigned resource in their community and use the data from that investigation to develop a campaign to change behaviors on how we use and dispose of our resources. There is still a lot of planning to be done, but hopefully with the partnership formed from the FEWS Fellowship, we can expose high school students to systems thinking as they become more sustainable citizens. **(Sabrina Grossman)**

As part of my work in FEWS and the CTL Teaching Fellows program and my own research, I will be examining "systems thinking" of students enrolled in the cross-college course "Sustainable Systems Design". Multiple assessments throughout the course will be used to examine development of systems thinking by the students from the Colleges of Engineering and Design while participating in a campus community project with campus services to map out the food waste and material waste systems on campus. Learning objectives for the activity are to: (1) identify agents and other variables within a food, energy, and water (FEW) system; (2) map relationships between variables (e.g. socio-technical); (3) synthesize stakeholder needs; (4) hypothesize and critique opportunities for meaningful change within the FEW system. Malte Weiland will act as a client and partner within the project, and final deliverables will be a video presentation of the findings as well as a graphic and data-driven report outlining the findings. The final deliverables will be utilized to share the findings of the project as a model for other communities and to solicit future community partnerships. The results and lessons from this project can then be revised to be used for K-12 outreach programs with Sabrina Grossman, and perhaps students from my class can work as counselors or help with the program in other ways. **(Cassandra Telenko)**

Our SLS project involved the planning and eventual implementation of an analysis of the existing waste and recycling systems at Georgia Tech. There are multiple stakeholders and processes in the current system that will benefit from a detailed review and mapping exercise. The expected outcomes will greatly benefit Georgia Tech's understanding of these systems, allow for information decision making on improvements to them, and help meet the learning outcomes of related to Lifecycle Assessments (LCAs) and Circular Economies.

As a Sustainability Project Manager for Campus Services, this topic was of direct interest to me, as all the departments for which I develop sustainability initiatives are stakeholders in this process. The outcomes generated from this partnership will provide real impact and benefits to these stakeholders. The SLS FEWS Fellowship allowed me to meet Georgia Tech Faculty and Staff that were in a position to help with this work and greatly shaped the direction in which my fellowship went. They provided access to resources that I otherwise would not have been able to utilize in my current position. I was very pleased to work with the other participants in the program and look forward to continuing the project next semester. **(Malte Weiland)**

Emanuele Massetti, School of Public Policy, *Sustainability, Technology, and Policy*

Fall 2016 has been a sustainability-centered semester for me: I taught "Sustainability, Technology and Policy" – a class affiliated with the SLS program – and I have been a fellow of the Food, Energy and Water (FEW) program of SLS.

Food, Energy, and Water are more and more connected as the traditional boundaries between energy and bio-systems are changing, under the pressure of using renewable energy. Water is a key input in both energy and food systems, and is at increasing risk of being mismanaged. Unfortunately, we are poorly managing food, energy and water systems in a way that leads us to an unsustainable future.

My students and I have spent many hours discussing how inadequate policies in agriculture, energy and water system are compromising sustainable development. Many current policies encourage the overuse of natural resources rather than preserving them for future generations. Polluters do not pay. Actually, many times polluting or resource depleting activities are subsidized.

Agricultural subsidies lead to overproduction, with excessive exploitation of soil, and overuse of fertilizers and pesticides. Rather than promoting sustainable agricultural practices, subsidies distort the agricultural market for the advantage of few. My students were surprised to learn that relatively few large farms and wealthy investors in the agribusiness collect a disproportionate chunk of subsidies.

Water use is typically poorly managed. Most surface water is adjudicated by farmers on the basis of a complex water rights system. Many times water rights have been assigned decades, if not centuries ago, in a world that was not facing the challenges of the present. These anachronistic rules tend to generate water waste. For example, farmers may lose water rights if they do not use each year the amount of water to which they have access. This leads to waste of water because farmers use it with the sole scope of preserving water rights for the future. Underground water use has possibly even worse management, as there are few constraints to pumping water out of deep aquifers. The excessive use of underground water reservoirs is leading to a progressive depletion of immense fossil underground aquifers along the Central Plains of the United States, an area much in need of water reserves.

Recently, biofuel mandates have exacerbated the existing problems in the use of soil, water and chemical inputs by creating the incentive to greatly increase production of corn for ethanol. Future policies to reduce CO_2 emissions may further increase the pressure on natural resources, as biomass is increasingly seen as a key component of any deep climate mitigation strategy. If we do not fix how resources are used in the agricultural sector, the ecosystem will be greatly damaged and resource extraction will become unsustainable due to the increasing demand of agricultural commodities for food and energy needs.

As an economist, I have been trained to think that if people are faced with the right policy incentives they will change behavior in a way that the private and the public good are aligned. It is time to stop subsidizing the use of natural resources and to promote sound regulation that increases an efficient use of land, energy and water. I have taught my students that technological innovation has a huge potential to bridge us towards a sustainable future. But we need policies that trigger the right kind of technological innovation. To put it simply, we should start paying the full cost – including all environmental costs – of our actions on the present generation and on future generations. Sorry, but no more free lunches.

Raghu Pucha, School of Mechanical Engineering, *Project-based SLS Activities in Design Courses*

Today, we are what our education has made of us. Tomorrow, we shall be what our education will make of us. The “Gurukul” concept of ancient Indian culture, for example, facilitated the transfer of knowledge, social skills and humanitarian values by a single “Guru” to his students. The “Guru” in those days, not only used to teach the vocational skills needed to help the society, but also pay attention to inculcate social and ethical values in his disciples. With continuous increase in human needs, desire for knowledge and systematic compartmentalization of knowledge, the concept of teaching / learning process has continuously evolved over generations. However, the fundamental role and responsibility of Guru / Teacher / Instructor is very much the same over the years.

In recognition of the importance of a university education for sustainable and responsible development the United Nations General Assembly declared 2005-2014 the “UN Decade of Education for Sustainable Development”. Universities are microcosms of culture and of the society that supports them. An instructor should also play an important role in assisting students to view social and ethical choices as a vital part of their future lives, both as professionals and in their daily living. In addition to addressing great global challenges, there is an increasing need for engineers to reach out to publics and communities by building alliances between academia, industry and civil society to create the conditions for a sustainable future. For engineering technologies to provide answers continued depletion of natural resources and resource management, global energy demand, and rising inequality; it is essential for engineers to engage not just with the technologies but “with how people live their lives”.

Project-based SLS (Serve-Learn-Sustain) activities are currently being implemented in one of the sections of ME 1770 (Introduction to Engineering Graphics and Product Visualization). The instructor also plans to implement these activities in the ME 4041 (Computer Aided Design) course.

Individual projects: Product design with external representations promoting sustainable resource-use need to motivate people to make decisions that sustain resources, and persist with this behavior. Georgia Tech made several public commitments – through various organizations, master plans and guidelines -– to address the sustainability needs of the Georgia Tech campus. Some of near and long-term strategic planning includes initiatives to: (i) Reduce energy use by 15 percent by 2020 (ii) Expand renewable energy use to 10 percent of energy consumed on campus by 2040 (iii) Reduce energy use to 50 percent below 2007 levels by 2040

Students are asked to take the lead on designing creative and unique appliances that promote sustainable use of natural resources for Home & office use of the Georgia Tech community. Designs with external representations promoting sustainability also lower the cognitive load involved in sustainability decisions. In addition to other design constraints, in individual projects the focus includes designing products that (i) increase opportunities and resources (ii) reducing risks and harms and (iii) enhance human capabilities.

Team projects: The Proctor Creek community in Atlanta, GA has been the focus of environmental justice and community revitalization efforts for over fifteen years. The flooding hazard is high for much of Proctor Creek, and the Proctor Creek watershed overall is approximately 33% impervious. The topography, prevalence of impervious surfaces in the watershed, and a strained combined sewer system have contributed to pervasive flooding in the Proctor Creek community and created environmental, public health, economic, and redevelopment issues. Neighborhoods within the watershed, many of which are primarily minority low-income populations, experience overlapping environmental and public health issues: Urban Health Disparities (which include West Nile Virus cases, asthma, lack of access to healthy foods, and diabetes), a significant number of abandoned and derelict properties and blighted sites (brownfields), illegal tire dumping, lack of access to greenspace and pervasive flooding. The occurrence of prolonged heat events and extreme weather events under a changing climate will likely continue to adversely affect the cost of energy as well as air and water quality alongside human comfort and health. Therefore, the communities of Proctor Creek watershed may be more vulnerable to many of the health concerns related to extreme heat events and flood events. In Fall 2016 students worked on low-cost dehumidifiers that have been suggested by local community leaders as a potential solution for reducing public health risks associated with mold and mildew in the Proctor Creek watershed, Atlanta.

Yuanzhi Tang, School of Earth and Atmospheric Sciences, *Resource Recovery from Waste Streams*

The Food Energy Water System (FEWS) Fellow Program that I participated in, in Fall 2016, was an exciting and humbling experience. Although my research interests are related to resource recovery from waste streams, it was throughout the semester that I gradually learned how complex any FEW system can be. In fact, it is quite interesting to learn how these three different elements (food, energy, and water) are interconnected and intimately affect each other. We toured three different facilities, Emory Water Hub, Atlanta Food Bank, and Southface Energy Institute, each with different focuses (water, food, and energy, respectively). To me the most striking impression is how much wastes we are producing and how many resources are needed to treat them, yet how much embedded resources can be potentially utilized (or are currently discarded).

For example, wastewater treatment plants process huge amounts of sewage sludges, which contain large amounts of nitrogen and phosphorus, both being critical nutrients for plant growth. Sludges and other solid biowastes, such as food wastes, also contain large amounts of biomass, which is essentially carbon (potential nutrient and energy). Of course, all these wastes first need to be treated or properly disposed of, but there are many challenges associated with their treatments. Take sewage sludges as an example. The most common practice for sludge treatment and disposal in the US is composting and land spreading. However, a wide range of contaminants (e.g. heavy metals, organic contaminants, pathogens) remain in the composts and can transport to and accumulate in soils and water bodies, posing significant environmental and human health threats. Consequently, stricter environmental regulations are gradually limiting or prohibiting the direct land spreading of sludge products. While landfill is a relatively safer disposal option, the increasing issues associated with transport and land space costs, leachate contamination and remediation, and stricter regulations are also making it a less favorable option. The safest way seems to be incineration or addition to cement products, yet the dewatering and drying processes necessary for converting sludge into fuel or cement products are neither energy nor cost-efficient.

On the other hand, globally increasing concerns for the depletion of phosphorus resources also calls for phosphorus recycling from waste streams such as sewage sludge, manure, and crop residues. Phosphorus is an essential nutrient for plant growth and its source is heavily dependent on geological mining of phosphorite rocks. Yet the distribution of phosphorite is not widespread worldwide, and its geological storage is limited. With the increasing growth of human population, phosphorus availability will essentially become a bottleneck for food security if we continue with current trend of inorganic phosphorus fertilizers and do not recover/recycle them. Since a significant portion of human-consumed phosphorus is ultimately converged into wastewater treatment plants and removed by microorganisms, phosphorus in sewage sludge is an important source for phosphorus recycling and reclamation. Sludges also contain large amounts of nitrogen, which is also a critical nutrient although its source availability (i.e. nitrogen gas) is not limited.

How can we properly address all the challenges associated with sludge treatment (or other solid biowastes), while taking advantage of their high nutrient contents, and recover resources from these waste streams? To me this is a question that requires thorough analysis and integration of geoscience, environmental science, engineering design, cost benefit and environmental analysis. The choice of different treatment methods (at government, organization, or community level) and the choice of farmers on different fertilizers (at organization, community, or personal level) are also interesting topics for social, economic, and business model analyses. The FEWS (and SLS) program has served as a catalyst for these discussions among the fellows, and will continue to provide inspiration and connections for interested minds.

William Winder, School of History and Sociology, *The Political Economy of the Global Meat Industry*

As a sociologist, most of my research has examined the political and economic contexts of agriculture and food. For example, I have a new book out, titled Grains, which examines how the geopolitics of food grains and feed grains influence a number of issues, including international trade, world hunger, and biotechnology. Building on that research, I have recently begun a project exploring the global meat industry (GMI) and its social, environmental, and economic effects.

The GMI has grown dramatically over the past 25 years. Global meat production stood at 164 million metric tons (MMT) in 1995, but had risen to 257 MMT by 2015, an increase of more than 50 percent. Perhaps even more telling is the number of animals slaughtered to be consumed as food. In 1995, 259 million cows and 100 billion pigs were slaughtered, but the totals increased to 298 million cows and 1.4 billion pigs in 2015. During the same period, the number of chickens slaughtered increased from 34 billion to 61 billion. Understanding such a large and growing industry is important because of the potential implications on a variety of social issues already seen as problematic: climate change, clean water supplies, food insecurity and world hunger, consumers, health, workers' rights and well-being, and the treatment of animals.

My immediate focus is to examine the political economy of the GMI, especially regarding international trade. Just tracing the geography of the international meat trade has been interesting. For example, India was the second leading exporter of beef in 2015, accounting for 19 percent of the world's beef exports and second only to Australia. Over the past 25 years, meat consumption has increased most in countries like South Korea, Brazil, China, and Mexico.

The FEWS Fellows Program is supporting this work in two ways. First, the program is helping to support a scholarly workshop that I am hosting in the spring on the global meat industry. This workshop will bring together a small group of scholars who each study various aspects of the global meat industry. My own contribution to this workshop will focus on geographic concentration and economic power in international trade for meat from cows, pigs, and chickens. Other scholars will discuss specific dimensions of the GMI, including the pork industry in China, the influence of three of the biggest meat processing companies, sustainable cattle ranching in Ecuador, and the role of the GMI in contributing to greenhouse gas emissions. The goal will be to put together a more comprehensive picture of the GMI, which is expansive in both its reach and its effects.

Second, the FEWS Fellows Program created a context in which I could connect with other scholars on campus who are interested in food and agriculture, including the meat industry. I expect to continue conversations with other FEWS Fellows about how our research fits together and how we can collaborate to better understand different dimensions and implications of the food system.

Fumin Zhang, School of Electrical and Computer Engineering, *Intelligent Physical System for Fish Habitat Survey*

An intelligent physical system (IPS) features integration of a software and hardware and possesses a high degree of independence when interacting with its physical environment. An IPS can recognize problems in its environment and formulate new goals that remove problems. An integration of control theory with a cognitive architecture is necessary to enable an IPS.

In the future, IPS can play a significant role in real-world application of autonomously mapping and tracking marine life, which represents a myriad of challenges. The ability to accurately map and track the movement of fish and interpret their variability has long been a challenge in sustainability science. The ultimate goal of identifying "ecological hotspots" and understanding their connectivity is difficult to achieve without integration of collected data with knowledge of the ecosystem and the species within. Our vision is to employ underwater gliders and other marine robots to form mobile sensor networks for localizing and tracking acoustically tagged fish while simultaneously surveying the conditions of the fish habitat. The complexity of this vision motivates the developments of heterogeneous IPS that are cognizant, taskable, reflective, and knowledge-rich. Underwater gliders will be used to survey the fish habitat to construct a map of the physical conditions, acoustic properties, and fish detections for the habitat. Marine robots will be deployed to concentrate their sensing power in areas with high fish density, to localize and track high-value fish species. The acoustic data and oceanographic measurements collected by the system will be integrated into maps that serve two purposes: (1) to provide predictions of fish movements and ocean conditions that guide the operation of gliders and robotic fish; and (2) to provide versatile views of the acoustic, environmental, and ecosystem data for different users including artificial intelligence (AI) practitioners, oceanographers, marine biologists, policy makers, and the general public for situation awareness and decision/policy-making.

We are planning to work in a 10km by 10km coastal ocean area in the Gray's Reef National Marine Sanctuary (GRNMS), together with stationary sensor arrays and ship-based surveys. This work will offer significant insight in developing a reliable fish tracking system that provides support for environmental and sustainability research relevant to the impact of human activities on marine species. In particular, we will track acoustically tagged black sea bass while detecting other species such as snapper, gag, and scamp grouper; all species are of high recreational and economical value.

Fish tracking is a unique problem that involves: multi-modal sensing; environmental survey and target tracking; path planning against environmental disturbances; and a significant demand for background knowledge. Since these components are representative of larger challenges in autonomy that exist in a broad range of smart systems applications, the methods developed in this project will be generalizable to other IPS applications.