URBAN FOOD SYSTEMS

Workshop report on the potential for growth and innovation in commercial scale urban agriculture at the nexus of food, energy, water, and transportation systems.

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Abstract

Commercial scale urban agriculture is an intriguing concept that could fulfill the demand for fresh, affordable food that is produced, processed, and distributed through more sustainable and resilient supply chains. While rural areas have the advantage of land supply, urban areas benefit from intensely developed energy, water, and transportation infrastructure, as well as the availability of diverse labor markets and an “ecology of synergistic industries” with which to collaborate. However, to date, there are few examples of commercial scale urban agriculture ventures that have been able to leverage successfully these advantages. With support from the National Science Foundation (NSF), researchers at Georgia Tech hosted two workshops that explore the challenges and barriers that need to be overcome in order for commercialized urban agriculture to compete directly with traditional rural agriculture. Repeatedly, a holistic discussion emphasized scale will derive from integration of urban agriculture into the regional food system. This report summarizes the workshops and presents a series of prospective research topics that emerged from the workshop. With all of these major concerns and talking points in mind - Where do we go from here? NSF can begin to form research programs to invest and fund type of research needed in order for commercial scale urban agriculture to become remarkable in 20-25 years.
Introduction

Urbanization, population growth, globalization, poverty, obesity, food insecurity, and climate change are just some of the forces that are challenging producers, suppliers, consumers, regulators, and many others to think more deeply about the interactions, interdependencies, sustainability, resilience, and performance of traditional food, energy, and water systems. It is also leading some to take action to try to develop alternative approaches that they believe will provide superior positive benefits with lower negative costs and impacts. This report summarizes the thoughts and opinions of a group of researchers, entrepreneurs, local government officials, and representatives from businesses, utilities, and non-profits regarding one such alternative: commercial scale urban and peri-urban agriculture.

There is more to urban agriculture than simply growing food within city limits. Rather it can be distinctly characterized as "an industry located within (intra-urban) or on the fringe (peri-urban) of a town, a city or a metropolitan region, which grows and raises, processes and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area".\(^1\) As such, urban agriculture could be an important facet at the local and regional level, with broader socio-economic implications, including contributions to food security, nutrition and income generation, recreational or educational functions, and preservation of green spaces in a city. The city context also highlights the important role of technology innovation, economic and market alternatives, infrastructure, logistics, and consumer behavior as being unique drivers that are shaping future urban agriculture growth, especially at the commercial scale.

A city with a well-designed and inclusive urban agriculture market is likely to see improved availability and access to fresh produce; local production and reduction of transport and storage; development of related micro-enterprises for input provision, processing and marketing of produce; increased recycling of nutrients (turning urban organic waste and wastewater into a productive resource); improved social inclusion of disadvantaged groups and community development; and urban greening and community involvement in maintenance of green spaces. Of course, urban agriculture is not a perfect panacea. It is possible that it may also have negative effects if precautionary measures or certain risks are not addressed or considered. These might include crop or water contamination, pollution,
improperly treated wastewater, pathogenic organisms, and disease transmission from domestic animals to people, among others. As such, a balance of policies that include support to grow the marketplace as well as regulations to ensure quality and safety must be present.

In a workshop held in Atlanta, GA on 8 December 2015, a diverse group of participants were asked to share their vision for the future of commercial scale urban agriculture, and the barriers that might exist for moving from the present state to the future state. In a second workshop held in Washington, D.C. on 11 February 2016, an expanded group was further asked to shape these challenges into research questions and programs of research that NSF could channel and direct funds. Both workshops focused on urban agriculture in Atlanta, Georgia. This was a strategic decision that was intended to challenge researchers and practitioners alike. It prompted participants to examine their beliefs and practices from the perspectives of those that are working in the same location – but perhaps in different media (i.e. food, water, energy, or transportation) or for different purposes (e.g. maximizing profit, ensuring equity, or minimizing environmental impacts).

This place-based approach encouraged different actors to find common ground and come to a shared vision in a collaborative manner, as they defined problems, and allocated resources in order to find solutions. This type of insight is critically important for informing NSF as it plans further investment in its “Innovations at the Nexus of Food, Energy and Water Systems” (INFEWS) initiative. For the workshop itself, the format of convening-around-place provided an environment for participants to quickly move beyond superficial connections and to focus on the deeper interactions and interdependencies in complex systems.
Atlanta Workshop Summary

Approach and Facilitation

The first workshop employed the Three Horizons framework, prompting the group to think creatively as they collaborated to explore and identify shared opportunities, challenges, obstacles, and pathways for future change and innovation across the region. After receiving an overview of the workshop focus and tool framework, the group ideated dimensions of the present (Horizon 1), ideal future (Horizon 3), and the transition pathways (Horizon 2) that might take us from the present state to the ideal future state. The Three Horizons Model provides a mechanism for understanding the significance of short, medium, and long-term futures. Attention to the three horizons always exists in the present moment, and evidence about the future is rooted in how people (including ourselves) are behaving now. A key difference between the Three Horizons framework and other strategic foresight methods is that it allows the selection of futures to be aspirational — instead of focused up front on strategy or intentionally broad. It tunes our awareness toward the signals of change that align with our aspirations, without the pressure of correctness or accuracy. The purpose of the tool is not to reach agreement on possible futures, rather to gather a large set of insights on current, near-term, and far-term states from the participants. Initially we use the framework to identify future dilemmas and emerging interactions to populate a system map for further study.

Figure 1. Three Horizons Map. Source: GTRI & GKI, Atlanta Conference on Science and Innovation Policy, 2015.

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2 The Three Horizons framework is a facilitation model for transformative innovation developed by the International Futures Forum (http://www.internationalfuturesforum.com/three-horizons).

Workshop Outcomes

The group ideation provided insight and understanding of pathways to growing commercial scale urban agriculture in Atlanta. Within Horizon 2, the group identified limitations in supply chains, transportation infrastructure, energy consumption, efficiency, and high capital demands as persistent deeper-rooted dilemmas and potential barriers affecting the city’s ability to achieve the ideal future. These require more of a holistic regional approach and shift in fundamental behavior, in order to truly innovate urban agriculture in Atlanta. The challenges to urban agriculture include high cost of land, availability of clean soil, access to water and compost for fertilization, lack of trained farmers, and high operational costs. In large cities, less than 10% of the land use is likely to competitively support agricultural purposes, making scalability of farming “in the ground” unlikely to be a major source of sustainable commercial food production.

For this reason, the workshop focused on high volume production approaches such as controlled environment agriculture and contract farming. This does not ignore other benefits of urban agriculture, such as improved nutritional food sources, job creation, and social connectivity. However, discussions were focused on needs and opportunities associated with larger scale commercial operations. The interactive facilitation prompted the group to think creatively as they collaborated to explore and identify shared opportunities, challenges, obstacles, and pathways for future change and innovation across the region.

Figure 2. Final Three Horizons Map from the Atlanta Workshop
**Horizon 1: The Present**

Beginning with Horizon 1, the group addressed characteristics of the urban agriculture and food system in Atlanta as it exists today and identified relative phenomena that indicate it might be failing or not sustainable. Overall, there was a recurring theme of “disconnection.” This included disconnections between those with capital (financial, natural, human, knowledge, or technological) and those in need of it; low-skilled jobs and those seeking employment; local suppliers and global distribution networks; and the need for inter-governmental and collaborative private sector decision making and the fragmentation among institutional organizations. Where is the system striving to change?

- **Urban agriculture is making positive advances, but there is still more to be done.** Ad hoc approaches, limited land commitment, poor soil, and difficulty to earn a living wage make scaling difficult. Balanced support, investment and incentives for home gardens, community projects, and scaled for profit local agriculture are needed. Capital investment for scaled and sustainable for profit agriculture in urban areas is difficult to find. Impact in Atlanta will be limited without better planning, education, and business models.

- **Low cost global logistics shifted food production away from local sources, resulting in a distribution infrastructure that inhibits locally grown.** Consumers expect easy access to food from all over the world. However, supply chains have difficulty supplying fruits and vegetables to smaller retail stores, and the global supply chain is ill-suited for collecting and distributing locally sourced food.

- **Fresh nutritional food is too expensive or difficult to get in many areas of the city.** People should have safe and nutritious options in their diets and locally grown fruits & vegetables can fill that market niche. However, participants noted that urban agriculture should not become a moral issue focused on poor nutrition or food deserts.

- **More education and community awareness is needed.** The public lacks knowledge related to food security, including where food is produced, what it contains, and the effect of disruptions.

- **Existing policies do not incentivize local food production in urban areas.** Subsidies and incentives to create scale remain trapped in the model of large-scale traditional farms. Supplying urban areas with perishable fruits and vegetables is not optimized to local needs. Capital investment approaches are limited, and urban farmers find it difficult to earn a living wage.

- **Urban infrastructure does not support a circular economy for food.** Most food waste ends up in the sanitation system, and there is no transportation infrastructure for usable compost to be returned to farms.
HORIZON 2: INNOVATIONS AT PLAY

In Horizon 2, the discussion centered around creating fundamental shifts to spark the necessary changes in the system, whether it is in investment schemes and subsidies, policy, infrastructure development, or behaviors and mindsets, in order to encourage the transition from H1 to H2. The group noted we are already witnessing the shift in business models to meet changing urban demand. For example, Atlanta and its suburban centers are shifting toward multi-use, walkable hubs, which present opportunities for developing a connected urban food production, distribution, and consumption system. To do so though, the city will have to harness and incentivize innovation toward agriculture alternatives in technology, urban planning, and public/private cooperation. This also reflects the overlapping cultural dynamics in which the glow of consumer trends toward local and organic shines on producers and makes “farming cool again.” How might innovation transform urban food infrastructure?

“Hot” technologies are entering the urban agriculture scene. Consumer data analytics can inform consumers of food options and producers of distribution needs. Farm data analytics and low-cost sensor technology can greatly improve optimization of crop cycles and yields. Automation can increase farm efficiency and lower costs, provide new distribution opportunities, and address end user waste and farm compost needs.

New technologies can address the biggest issue with controlled environment farming: energy use. Affordable modular farms can be developed to scale from individual to neighborhood to regional systems, but more cost effective renewable energy generation systems are needed. Local energy pricing regulations could incentivize locally grown food.

Local distribution models optimize for urban logistics needs. Food delivery models are needed that increase access and timeliness and are integrated with other urban transportation uses. New algorithms could help people buy only what they can use. Scale will encourage corporate grocers to shift their business models to meet urban sources and demand.

More access to capital is needed. Additional incentives and new business models are needed to spur growth, encourage innovation, and support local initiatives. Collaborative investment can spur change and institutional buying power commitments can help create scale.
Horizon 3: The Future

Discussion of Horizon 3 captured the future aspirations, emerging practices, and new systems of governance, commerce, education, and technology that might support solutions to the problem. In this future, the role of technology is highly integrated into the web of society in how it leads and facilitates farming practices and system network design. However, urban agriculture will be highly influenced by societal and economic characteristics, infrastructure, demographics, and consumption habits. The group ideated an inclusive supply chain and distribution infrastructure of global and local sources, one that can be designed that includes the “big players” and the “little players”. What do we aspire to?

- Zero food insecurity. Food is removed from the poverty equation and nutrition comes in many accessible forms.
- We built a strong local food system that moves product from farm to table in 1-day. There are several profitable mid-size local companies focused on community values, nutrition, and health. Metro area farming is a vocational track supported by urban education systems, and cultural acceptance has rendered farming “cool.” Farmers’ median age has shifted younger and matches local demographic distributions.
- Agriculture has become a mainstay of city planning. Atlanta’s changing demographics are matched by a food infrastructure promoting cultural values and understanding. Local farms are part of the neighborhoods.
- Sustainable integration of food into urban infrastructure has become the status quo. Less food is transported on the highways; embedded energy in food is vastly reduced. Less chemical fertilizers and pesticides are used in food production, and the risks of water scarcity are mitigated. Technology enabled these transformations by focusing on long-term change and not short-term preservation of current approaches.
Atlanta Workshop Conclusions

Workshop participants thought technology and coordinated planning were the keys to driving future growth in urban food systems.

The Three Horizons discussion uncovered several dilemmas, however, that stand to inhibit growth. These include:

1. **Local farmers have limited supply and distribution networks.** Individual organizations have to build their own rather than tap into existing chains. Traditional agriculture interests can leverage mature supply chains and distribution networks and they are trying to pivot to meet increasing demand, but they struggle to supply smaller local markets. This presents a logistics network imbalance.

2. **Urban growers face high capital costs** – land is expensive, there is no insurance system, living systems are inherently variable, and yet producers are expected to provide a reliable supply at an affordable price. Wages and income from urban farming is accordingly low.

3. **Technology can be applied in several ways to reduce costs and improve efficiency**; however, technology is difficult for most to afford and is only adopted in premium markets.

4. **In the push and pull of market supply and demand for locally grown and processed foods, changes in producer behaviors must also be met** by changes in consumer behaviors and expectations. A culture of sustainability needs to be established that changes not only how suppliers produce and deliver food to the consumer, but also how consumers play a role in closing loops and making the system sustainable. Consumer education and capacity building can shift market preferences for local and fresh foods; alter the normative acceptance of recovering nutrients, water, and energy from waste streams and their subsequent use to grow food; and increase support for small producer collective programs, such as local food hubs for aggregation and distribution of farm foods.

5. **More than traditional agriculture, urban agriculture presents the greatest and immediate opportunity to fully integrate food, energy, and water systems** owing to the proximity of industrial, water, power, and transportation infrastructural resources in cities. Complex system models of combined urban food, energy, water, and transportation are lacking, however, and scant attention is directed towards urban areas as a viable and scalable source of food supply.
Washington DC Workshop Summary

Approach and Facilitation

On 11 February 2016, a workshop held in Washington, D.C. invited experts to shape the dilemmas that surfaced at the Atlanta workshop into research questions and programs of research that NSF could channel and direct funds. Put simply, the group was asked: “What should the nation’s leading research scientists and engineers be working on that will improve the prospects for large commercial scale urban agriculture over the next quarter century?” This section provides the main messages and summary resulting from this workshop.

The workshop was organized into four thematic panels:

- **PANEL 1: A New Kind of Food, Energy, and Water System and its Scaling Potential**
- **PANEL 2: Technology for the Future**
- **PANEL 3: Thinking about Life Cycles, Supply Chains, and Value Chains**
- **PANEL 4: Economic Development and Policy**

**PANEL 1. A New Kind of Food, Energy, and Water System and its Scaling Potential**

*Wil Hemker (CEA Fresh Farms), Jonathan Periera (Plant Chicago), and Don McCormick (Keene Energy and Agriculture Project) with responses by Liz Kramer (UGA), Osvaldo Broesicke (GT) and Group*

The first panel featured several entrepreneurs who are creating innovation at the nexus of food, energy, and water at different points in the food supply chain. The panel opened with major trends in food crops, food production, demand, nutrition, and diets. Innovations in greenhouses, Controlled Environment Agriculture (CEA), and automated production and control highlight models and methods for addressing these trends in urban agriculture areas. The discussion of urban food systems and scaling up of local agriculture introduces a web of actors, processes, and interactions involved in growing, processing, distributing, consuming, and disposing of foods; community education; health; water quality impacts; and biodiversity.
Wil Hemker, Vice-President of Technology at CEA Fresh Farms and an Entrepreneur Fellow at the University of Akron Research Foundation (UARF), made a case that there is a strong market for locally grown urban or peri-urban agricultural produce grown in controlled environments. Controlled Environment Agriculture (CEA) “is a combination of engineering, plant science, and computer managed greenhouse control technologies used to optimize plant growing. CEA enables commercial growers to precisely control the crop environment to desired conditions and remove most variables and risks in growing large-scale quantities of fresh food crops.” The market case for CEA hinged on five points:

- **Customer demands for locally-grown food** that is safe, nutritious, and of known origin.
- **Dependability and consistency** in supply and quality.
- **Assurances of food safety and security** including less risk of food contamination and perishability, elimination of chemical pesticides and herbicides, and production in the USA using fair labor practices.
- **Environmentally responsible** using less water, energy, and land while yielding more product and wasting less.
- **The ability to produce commercial scale quantities.**

Hemker cited the benefits of using automated systems in climate controlled greenhouses to:

- Maintain positive pressure thus eliminating external contaminants and external climate influences.
- Maintain precise temperature, humidity, and CO2 levels for optimizing plant growth and yield.
- Provide a certified clean environment.

**Reduce human error** through the use of computer control systems

Jonathan Pereira is the Executive Director of Plant Chicago, a 93,500 square foot facility in Chicago that houses for-profit food industries in a closed loop environment focused on food processing, retail, and education. The Plant is comprised of a community of 15 food businesses all committed to materials and waste reuse in a circular economy. A circular economy is when “conventional waste streams from one process are repurposed as inputs for another, creating a circular, closed-loop model of reuse.” Among many examples of reuse, Plant Chicago uses spent yeast from a beer brewing process to leaven bread, feeds fish from spent grains also from the brewing process, grows mushrooms in coffee chaff and spent grains, and uses shrimp waste to grow spirulina algae for fish food. There are plans to send food waste that cannot be reused directly to an anaerobic digester to produce biogas, which can

![Figure 3. Customer sign in Ohio grocery store 6 February 2016 (credit W. Hemker).](image-url)
subsequently be fed into the natural gas grid or used to fuel a generator to produce heat and power for the Plant. The cost of the digester and generator, however, is a barrier ($1.8M). Apart from capital, one persistent challenge is a lack of metrics to measure this complex and integrated business ecosystem.

The Keene Energy & Agriculture Project (KEAP) is a one-acre controlled environment greenhouse plus processing center in Keene, NH operated on free renewable heat and power resources. Don McCormick, President of the Local Farms Project, described his experience designing and operating KEAP to grow and distribute produce and fresh fish to the premium local New England market year-round. The project uses methane extracted from the Keene Landfill and Transfer Station/Recycling Center facilities to power and heat an aquaponic greenhouse and research facility. Lessons from the KEAP include:

- Though they may be applied or integrated in new ways, mature technologies should be used, as the margins are not high enough to take risks on new technologies;
- Startup capital costs are high, and therefore it is important to leverage partnerships (e.g. KEAP leveraged a $1M grant from the US EPA and a partnership with the City of Keene, NH for a building site near the landfill/transfer station/recycling center from which methane is provided);
- Integrated Food-Energy Systems (IFES) have strong return on investment potential (startup costs for KEAP were $3.5M but the project is projecting a 5-year return on investment of $3M annually in gross revenues and $1.5M per year net profit);
- Product can be on the retail shelves within 24 hours of harvest with the controlled environment greatly reducing post-harvest processing costs.
- In addition to the difficulty in acquiring startup capital, the slow and deliberate nature of government to provide approvals is a significant barrier.

Subsequent discussion led by Liz Cramer, Director of the Sustainable Food Systems Initiative and Natural Resources Spatial Analysis Laboratory, College of Agriculture and Applied Economics, University of Georgia, and Osvaldo Broesicke, Graduate Student, Brook Byers Institute for Sustainable Systems, Georgia Tech, surfaced the following additional questions and comments:

- The value of CEA is intensification but it must be developed in a sustainable resource model.
- Besides food production, urban agricultural systems can also provide other ecological and social services such as storm water management, urban heat island mitigation, and recreation. Thus, initiatives should consider and model system scale that are larger than closed loop greenhouses or warehouses.
- The types of systems discussed here are not “one-size-fits-all.” An ecosystem services model can help determine the right technology for the right place. Such a model should include the importance of connecting people to the food and acknowledge their varied concerns about nutrition, health, and transparency as well as their...
socioeconomic status (e.g. does CEA only serve wealthy niche markets?).

CEA can optimize for growth conditions, and closed loop systems can minimize for waste. **What are the goals** for an integrated Food-Energy-Water system? What if the goal was to minimize food waste? Or maximize energy production? Or to reuse water? How does the primary goal(s) affect the way the system is designed and operated?

**Are these systems resilient?** What if one link in the system failed or was removed? How is resiliency measured and tested?

**Can these systems scale?** Is it possible to replicate when all the components are not under one roof or under one authority? Must a farm be internally closed-loop or could the loop be closed through external / market means?

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*Figure 4. Plant Chicago closed loop food production and processing demonstration and education facility (credit J. Pereira).*
Prospective Research Areas:

1. **Urban planning models that include commercial scale urban agriculture** as significant land use and use criteria relevant to urban agriculture (e.g. the needs of CEA are different from traditional agriculture) to provide and plan for its future adoption and growth.

2. **It may be appropriate to move from a “Supply Chain” perspective to a “Supply Web” view as systems become more integrated** – not just internally but also with external partners and systems – New models, decision theories, and management practices need to be developed for use by individual agents up through organizations, industries, states, and nations.

3. **The integration of multiple systems requires cooperation and collaboration among previously disparate actors.** Effective data and knowledge sharing methods and tools are needed to help them bridge the linguistic, social, economic, and technological gaps that exist between their domains.

4. **More effort is needed to design and build collection, distribution, and marketing channels that support local producers, processors, retailers, and consumers.** Current logistics of distributing food is well suited for the global production and processing nature of the supply chain. It is less well suited for local production and processing. Chains must be both global and local (Global + Local = Glocal).

5. **Models that enable better planning of urban farming approaches** based on the needs of the local food system and the capacity of the local environment.

6. **Increased research on automation technologies.**
The second panel included experts from academia and industry that are working on research and application of technologies in agriculture and different types of environments, such as urban areas. The panelists discussed current research on sensors and automated sensing and potential application, such as plant sensor detection and controlled environment farming. There is a need for “high technology”, but also simple, “low technology” systems that can maintain themselves.

**Judy Song**, Senior Research Scientist at the Georgia Tech Research Institute opened her comments on Advanced Agricultural Sensing by recognizing that 12% of crops are lost to disease and another 16% to pests with significant economic impact accruing to farmers. She stressed a need for early detection of pests and diseases before any physical symptoms are visible at the plant level. She presented a strategy for a sensing platform that integrated sensors, data collection, data processing, and interpretation to monitor the state of pathogens, hosts, and the environment. However, admittedly “high tech,” the envisioned sensing platform relied on an integration of existing technologies that included:

- Micro Gas Chromatography to detect changes in the emissions of VOCs which can indicate the presence of spoilage caused by pathogens;
- Spectral Imaging to detect plant stress;
- GPS and IMU (Inertial Management Unit) for determining position and attitude; and
- High resolution cameras to acquire imagery that can be used to reconstruct 4-D representations of crops that can be used to detect growth anomalies;
- Robots and Unmanned Aerial Vehicles (UAVs).

![Figure 6. Three sides of agricultural sensing (credit: J. Song).](image-url)
The agricultural sensor system above was envisioned to support traditional agriculture, but it may have greater potential for use in urban agriculture and CEA applications: intensified agriculture may be more susceptible to disease/pests due to confinement. When a problem does occur, the speed of transmission can be very fast, and therefore early detection is more important than in traditional agriculture. Whether such technologies are applied to urban agriculture, traditional agriculture, or CEA, however, they still represent only an incremental advancement. Erico Mattos, Co-Founder and CTO of PhytoSynthetix, is flipping the paradigm of adapting crops and agricultural practices to fit technology (e.g. monoculture planting that is more suited for mechanized labor or genetically modifying species to resist herbicides), and is considering how technology could react to plants.

PhytoSynthetix is developing and trying to commercialize a “biophotonic feedback system” that allows LED lights to communicate with plants providing maximum plant growth with minimum energy consumption. The system monitors chlorophyll fluorescence then dynamically adjusts the LEDs’ light output frequency and duty-cycle to optimize yields. The system saves energy when possible and boosts the lights when needed, as opposed to pre-programmed systems that are not able to sense external variations resulting in energy waste and/or plant under production along the different stages of plant growth cycle. The promise is that this kind of system can increase production while lowering operating costs, but access to capital investments for emerging agricultural technologies is difficult.

![What would the system look like?](image)

*Figure 7. A conceptual integrated agricultural sensing platform (credit: J. Song)*
With a different perspective on capital costs, HATponics has developed a self-contained food production system using Hydroponics, Aquaponics and Terraponics (HAT) farming methods. Ryan Cox, CEO, explained that the motivation for HATponics arose from an international humanitarian perspective in which capital, expertise, and access to materials and supplies are severely restrained. As such, HATponics is less driven by technology, and more concerned with access, cost, and providing systems that meet users’ needs (e.g. small systems for education, larger systems for urban agriculture, and modular, portable, and self-maintaining systems that can be delivered to remote areas). A fully operational system is estimated to be able to provide protein (fish) and produce for 400-600 people per day through a 2.5 acre growing facility that includes a 40’*100’ greenhouse and a 5KW solar array at an initial cost of $85,000, plus $10,000 to $15,000 for shipping, and with ongoing costs ~$120 per month (primarily fish feed). The main concession to higher technology is a remote monitoring system that communicates with a central center to measure and predict system performance.

*Figure 8. The Phytosynthetix system consists of a 1) plant sensor which captures a plant signal and sends this to 2) a processor and control program which uses the plant signal to feed a mathematical algorithm that controls 3) the LED light output parameters for*
Prospective Research Areas:

1. **What is the appropriate balance of technology, affordability, and maintainability for agricultural technologies?** High tech or low tech, all systems must be stable and self-maintaining. Systems must also be designed to recognize that different cultures and different environments may have different abilities and need different services – and systems must be able to adapt to them (more so than people adapting to the systems). One size (and type) does not fit all.

2. **Place-based platform designs** that address design choices and characteristics of the location/local environments, as well as personal choices of the consumers. What is the platform design model for place based systems? Classical platform design methodology. Systems engineering methods & tools for platform-based urban farm design.

3. **Research focused on maturing, lowering costs, and increasing scale of CEA technology** needs to become more of a focus in the U.S. What kind of scale makes it economical? Design programs that address high capital cost of entry. Government technology transition funds are a major need as the commercial investors are not fully involved. Low-cost, safe, and effective biodigesters and bioreactors.

4. **A research program that focuses on the ideal engineered characteristics of plant biology, environment and lighting, resource flows, and feedback/control within the CEA environment is warranted.** Control technologies have to be adapted to living systems. Quality control of living systems is hard. How do you know if a sensor is giving bad info? Optimization of plant biology to controlled environment conditions. Sensors that measure the appropriate biological balance in the system at early stages of imbalance or disruption. Lighting and heating systems that optimize between energy efficiency and plant health. Need for control system research and detection time that effectively bridges the short control loops of the engineered systems and the long control loops of the biological systems.

5. **How to integrate systems across boundaries rather than focusing on self-sustained systems?** There is still a lot of separation between industry, farming, and policy. How to integrate systems across boundaries rather than focusing on self-sustained systems? How to incorporate networks for supplies, energy, industrial bioproduct materials, cultural approach to food source (e.g. animal food products -- factory animal farms vs. factory farms are not acceptable)? We are still in siloes. Thus, how can we connect larger systems? Does it all have to be self-contained? Usually, there is an adjacent system with untapped resources.

6. **Moral choices are important design criterion** that we need to consider. One size does not fit all. Some foods can be grown very efficiently, but may not be culturally acceptable. What is the design choice/measurement set? How to make the food accessible? What is the product? Sometimes the byproduct is more valuable than the primary product.

7. **Energy generation systems that adapt to wide ranges of source materials.**

8. **Low-cost, safe, and effective biodigesters and bioreactors.** A logistics and local transport innovation ecosystem that creates value from efficiently moving product and waste materials between farms and consumers.

9. **Education and education-related research programs focused on “food-system architecture.”**
PANEL 3. Life Cycles, Supply Chains, and Value Chains

H. Scott Matthews (CMU), Greg Keoleian (UM), and Valerie Thomas (GT) with responses by Josh Newell (UM) and Group

The third panel further delved into issues related to the supply chain, along with existing research and opportunities at both the consumer preferences side of food use and at effectiveness the sourcing and supply chain side. As a starting point for the discussion, the group looked at system models and food production for understanding useful metrics to measure trends related to food and food supply chains, using “food miles” and increasing globalization of food supply as an example. A key takeaway from this discussion, which feeds into the broader discussion held throughout the event, was the bigger picture of the issue and importance of applying a life cycle assessment that looks at the supply chain aspect of food, as this can significantly realign and shape understanding of decisions.

From the perspective of sustainability, what you eat matters far more than where it comes from. Scott Matthews noted that 11% of average greenhouse gas emissions in the food chain are due to transport while 83% come from production. As such, a dietary shift to less resource intensive foodstuffs (fish, poultry, eggs, vegetables) can be a more effective means of lowering an average household’s food-related climate footprint than “buying local”. The panel noted that the food monoculture in the USA has led to a lack of geo-spatial diversity in food systems, ultimately creating a supply chain risk. Life cycle sustainability frameworks and summary of key indicators show unsustainable trends of US food system - consumption habits drive all the upstream system, in terms of water use, energy use, and waste creation.

A holistic view of the connection between production and consumption requires a view on nutrition, which is driven by consumer diet. Greg Keoleian presented a framework that linked environmental impact and nutrition. He noted that life cycle assessment in this domain is likely best served with a stress-based model, using location-based models that build on the capacities and needs of the localities. This indicates an approach to look at optimization based on long-term sustainability and resilience-building measures is more useful than short-term resource input or output measures.

The discussion also highlighted the role that large-scale urban and local agriculture can do to reduce food waste. Regional food hubs have emerged as collaborative enterprises for moving local foods into larger mainstream markets, providing scale-appropriate markets for midsized farmers and opportunities for small and beginning farmers to scale up without increasing time spent marketing food. Food hubs also work with farmers to preserve the quality and transparency of locally grown product. Such hubs can also address issues such as labor capacity and access to financing models. They can also address food access and waste by providing localized food gathering and distribution, as well as centralized waste digesters and converters that feed back into the production side of the food chain.
Funding sources remain a concern. Food represents a small percentage of consumer spending in the U.S. and as noted by Scott Matthews, is a daily decision process that limits long-term views. Commercial investment remains focused on high profit large-scale farms, government subsidies primarily target large-scale systems, and research funds for scaling urban agriculture technology have been a low priority. Most urban agriculture funds are from local governments or nonprofits, limiting the development of high intensity, scalable, local agriculture. Research funds focused on making this a competitive market option are needed. Finally, the differences between open-air and closed farming environments should be studied with respect to resource use. Energy and water are two important considerations, but exist in a nexus that also includes clean soils, fertilizers, wastes, land use, labor, and consumer diet. Conversion of nutrient wastes outside of the food enterprise into fertilizers, such as phosphorus, should be pursued in areas where resource shortages are predicted.

Prospective Research Areas:

1. **Increased general research related to controlled environment agriculture.**
   The differences between open-air and closed farming environments should be studied with respect to resource use.

2. **Life cycle assessment models that balance food, water, and energy.** There are many components that can be examined from this topic area. For instance, deeper understanding of the tradeoff between emissions and health systems. Further, capturing what it might look like and how might it behave should different types of systems (food, energy, water) and other systems that operate differently (albeit efficiently), and combine them?

3. **Models that integrate food production, energy and water use, and transport with nutrition and diet.** This would provide deeper to questions raised such as understanding the role and impact of whether we should be buying local to increase 'local' consumption to reduce supply chain risks.

4. **Methods to convert nutrient rich wastes into fertilizers.**

5. **Programs that measure efficacy of urban agriculture as it scales.** Knowing at what scale a system should be closed, whether it be at the city, national or global trade level. Understanding diversity throughout this process and within the supply chain is also important – how diverse does a supply chain need to be so that the system doesn’t fall apart? How do we quantify supply chain equity, urban food security, and urban resilience?

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**PANEL 4. Economic Development and Policy**

*Stan Vangilder (Southern Co.), Costas Simoglou (GA Dept. of Economic Dev.), and Mario Cambardella (City of Atlanta) with responses by Jennifer Clark (GT) and Landon Marston (UIUC) and Group*

The fourth panel brought together those actively in the processes and roles for decision-making and policy-making at industry and government levels. The discussion was initiated by highlighting the overarching goals and action points for the private and public sector to maximize economic development opportunities and community scale. Key policy issues include tax incentive structures that enable urban agriculture investment, regional economic development strategies that unleash private capital, public health/safety/welfare integration, land use permitting, waste compost and conversion permitting, and perhaps new public infrastructure for anaerobic digesting.
The groups talking points focused on three predominant infrastructures related to urban agriculture that drive economic development: food, water, and waste remediation. The group discussions raised questions on how much water will be needed to scale urban agriculture, will the existing water distribution system be used, and what implications does this have on energy for treating water and distribution, wastewater runoff and water infrastructure capacity. Landon Marston, UIUC, discussed the green water/blue water challenges in urban agriculture - in order to scale these farms must not become dependent on urban fresh water distribution. Rainwater capture and wastewater reuse are key technology needs.

There has been a paradigm shift in the global economy (affected by elements, e.g., water, weather, energy, land, food safety, population growth, etc.) and the use of natural resources, particularly the ways in which produce is sourced today. Changes in consumer awareness, such as advantageous eating habits relative to good health, have increased demand for highly nutritious, locally grown, quality foods. The 21st century will keep witnessing massive and rapid urbanization. Urban populations are setting new standards and cities must reinvent themselves with new references. Urban agriculture is one livelihood strategy, which the urban poor use in combination with other strategies. As such, urban land management should aim to put urban land resources into efficient and sustainable use, which is not necessarily only the economic "highest and best use" as postulated by many governments. This requires, first, recognition of the prevailing problems and acceptance of urban livelihood strategies including urban agriculture, but also realization of benefits and opportunities created through productive use of open and green spaces in cities. As Jennifer Clark, Georgia Institute of Technology, noted: the
creation of new enterprises that create jobs can tip priorities towards urban agriculture enterprises. Technology and systems are not the only research needs, the community needs to understand the value chain in urban versus overall food production and focus on products that create appropriate value.

The existing food systems projects in Atlanta serve as both sites of experimental research design and direct, real-time interventions in the built environment and related social, business, and governance systems. Still, as identified in the workshop group discussion; there persist challenges related to the “slowness” of city government and standardization with county and jurisdictional issues - a problem certainly prevalent in metropolitan cities like Atlanta. The state of Georgia is already one of the largest agriculture producing states in the U.S., and it is easy for the benefits of more localized urban agriculture to get lost in the “big ag” enterprise. Despite growing attention among city governments, national and international organizations on the importance of urban food and agriculture, there is a need to shift scale from isolated and temporal projects to larger scale programs and funding; from pilot and individual cities to wider uptake at local and national level.

Prospective Research Areas:

1. **Decision-making models and tools that will enable policy that is more effective and improved permitting strategies.** However, this will require addressing boundaries and redlines, such as how do you standardize county or jurisdictional issues? How can we reduce the “slowness” of city government?

2. **Programs that model and integrate Government/industry/academic clusters.**

3. **Better understanding of the actual supply capabilities and knowledge of what actual demand is in the city.** The ability to define and categorize what is meant by “local”.

4. **Better business models and policies for economic measures.** How can we increase labor capacity and jobs in this area? What is the utility business model of the future?

5. **Establishing clear metrics that can justify policy decisions that will produce benefits.** If we claim certain policy decisions are more sustainable than another, how can this be captured, measured, and identified?
Appendix A: Atlanta Workshop Participation

While the participants provided critical input to the workshop, the results and recommendations emerging from the workshop are attributable only to the authors of this report. The participation of these organizations in the workshop does not imply any endorsement or implied support of the findings presented here. Representatives from the following organizations participated in the Atlanta workshop:

- **Andy Friedberg, Aluma Farm**
  A 3.8-acre farm currently composed of marginal land reclaimed from industrial uses that is being developed in conjunction with the Atlanta BeltLine.

- **Billy Adams, Americold Logistics**
  The global leader in temperature-controlled warehousing and logistics to the food industry, offering the most comprehensive warehousing, transportation, and logistics solutions in the world.

- **Jerald Mitchell, Atlanta BeltLine**
  The most comprehensive transportation and economic development effort ever undertaken in the City of Atlanta and among the largest, most wide-ranging urban redevelopment programs currently underway in the United States. The Atlanta BeltLine is a sustainable redevelopment project that will provide a network of public parks, multi-use trails and transit along a historic 22-mile railroad corridor circling downtown and connecting many neighborhoods directly to each other.

- **Allison Duncan, Atlanta Regional Commission**
  Regional planning and intergovernmental coordination agency for the 10-county Metropolitan Atlanta area including Cherokee, Clayton, Cobb, DeKalb, Douglas, Fayette, Fulton, Gwinnett, Henry and Rockdale counties, as well as the City of Atlanta.

- **Ellen Macht, BetterLife Growers (formerly the Atlanta Lettuce Project)**
  Atlanta’s first large-scale, aeroponic farmer and processor of lettuce and herbs.

- **Wil Hemker, CEA Fresh Farms**
  Controlled environment agriculture company specializing in innovative/advanced closed-environment and grow technologies, commercially-scaled, using current hydroponic production methods – growing year round by optimizing the indoor growing environment.

- **Mario Cambardella, City of Atlanta, Office of Sustainability**
  Reporting directly to the Mayor, this office works with all city departments to balance Atlanta’s economic growth with environmental protection while being mindful of social justice.

- **Bob Drew, Ecovie Environmental**
  Provider of rainwater collection systems, products, and services.

- **Costas Simoglou, Georgia Department of Economic Development**
Plans, manages, and mobilizes state resources to attract new business investment to Georgia, drive the expansion of existing industry and small business, locate new markets for Georgia products, inspire tourists to visit Georgia and promote the state as a top destination for arts events and film, music and digital entertainment projects.

Baabak Ashuri, John Crittenden, Bert Bras, Osvaldo Broesicke, Michael Chang, Renita Folds, Mingyang Li, Zhongming Lu, Tom McDermott, Molly Nadolski, Arezoo Shirazi, Cassandra Telenko, Steve Van Ginkel, Robert Wallace, **Georgia Institute of Technology**
Leading Research University committed to improving the human condition through advanced science and technology.

Alice Rolls, **Georgia Organics**
Member supported, non-profit organization connecting organic food from Georgia farms to Georgia families. Georgia Organics builds supply through grower education and outreach, and grows demand on the consumer and business end by encouraging market opportunities for local food. Georgia Organics is also the fiscal sponsor for the Atlanta Local Food Initiative, a coalition of communities, nonprofits, universities, government agencies, individuals, and corporations working to build a more sustainable food system for metro Atlanta.

Ryan Cox, **HATponics**
Commercial arm of a revolutionary farming enterprise that provides a viable food production option in a compact, resource-saving aquaponics-based farming system, designed to alleviate problems of world hunger, provide sustainable agriculture education and create jobs. Based in Rossville, Georgia and Chattanooga, Tennessee, HATponics has developed the world’s first portable farm and maintains several completely sustainable, organic agriculture ventures internationally, while locally making huge impacts on the Georgia and Tennessee educational systems.

Erico Mattos, **PhytoSynthetix**
Horticultural Lighting company specializing in ultra-high performance LED illumination systems for photosynthetic applications. PhytoSynthetix is developing the pioneering technology “biophotonic feedback system” that allows the LED lights to communicate with the plants providing maximum plant growth with minimum energy consumption.

Stan Vangilder, **Southern Company**
American electric utility holding company based in the southern United States.

Chris Flint, **Sysco**
Global leader in selling, marketing and distributing food products to restaurants, healthcare and educational facilities, lodging establishments and other customers who prepare meals away from home. Its family of products also includes equipment and supplies for the foodservice and hospitality industries. The company operates 196 distribution facilities serving approximately 425,000 customers.

Liz Kramer, **University of Georgia**
American public land-grant and sea grant Research University.
Appendix B: Washington DC Workshop Participation

In addition to some of the same participants that participated in the Atlanta workshop, the Washington, D.C. workshop included a broader array of practitioners and academicians from across the country and included representatives from the following organizations:

- **Todd Levin, Argonne National Laboratory**
  A multidisciplinary science and engineering research center, where “dream teams” of world-class researchers work alongside experts from industry, academia and other government laboratories to address vital national challenges in clean energy, environment, technology and national security.

- **Scott Matthews, Carnegie Mellon University**
  A global research university known for its world-class, interdisciplinary programs in arts, business, computing, engineering, humanities, policy, and science.

- **Wil Hemker, CEA Fresh Farms**
  Controlled environment agriculture company specializing in innovative/advanced closed-environment and grow technologies, commercially scaled, using current hydroponic production methods – growing year round by optimizing the indoor growing environment.

- **Mario Cambardella, City of Atlanta, Office of Sustainability**
  Reporting directly to the Mayor, this office works with all city departments to balance Atlanta’s economic growth with environmental protection, while being mindful of social justice.

- **Neil Mattson, Cornell University**
  A privately endowed research university and a partner of the State University of New York, Cornell is the federal land-grant institution in New York State and makes contributions in all fields of knowledge in a manner that prioritizes public engagement to help improve the quality of life in our state, the nation, and the world.

- **Costas Simoglou, Georgia Department of Economic Development**
  Plans, manages, and mobilizes state resources to attract new business investment to Georgia, drive the expansion of existing industry and small business, locate new markets for Georgia products, inspire tourists to visit Georgia and promote the state as a top destination for arts events and film, music and digital entertainment projects.

- **Bert Bras, Osvaldo Broesicke, Michael Chang, Joy Choi, Jennifer Clark, John Crittenden, Bistra Dilkina, Emma French, Nancey Green Leigh, Subhro Guhathakurta, Jean-Ann James, Heon Yeong Lee, Tom McDermott, Molly Nadolski, Judy Song, Valerie Thomas, Georgia Institute of Technology**
  Leading Research University committed to improving the human condition through advanced science and technology.

- **Ryan Cox, HATponics**
  Commercial arm of a revolutionary farming enterprise that provides a viable food production option in a compact, resource-saving aquaponics-based farming system, designed to alleviate
problems of world hunger, provide sustainable agriculture education and create jobs. Based in Rossville, Georgia and Chattanooga, Tennessee, HATponics has developed the world's first portable farm and maintains several completely sustainable, organic agriculture ventures internationally, while locally making huge impacts on the Georgia and Tennessee educational systems.

- **Don McCormick, Keene Energy and Agriculture Project**
  A one-acre controlled environment greenhouse plus processing center operated on free renewable heat and power resources, and distributing produce and fresh fish to the premium local New England market year-round.

- **Bruce Hamilton, National Science Foundation**
  An independent federal agency that was created "to promote the progress of science; to advance the national health, prosperity, and welfare; [and] to secure the national defense." The NSF is the funding source for approximately 24 percent of all federally supported basic research conducted by America's colleges and universities.

- **Erico Mattos, PhytoSynthetix**
  Horticultural Lighting company specializing in ultra-high performance LED illumination systems for photosynthetic applications. PhytoSynthetix is developing the pioneering technology “biophotonic feedback system" that allows the LED lights to communicate with the plants providing maximum plant growth with minimum energy consumption.

- **Jonathan Pereira, Plant Chicago**
  A non-profit organization that operates The Plant, a groundbreaking food production space designed to be a net-zero, closed loop system in Chicago's Back of the Yards and whose mission is to develop circular economies of food production, energy conservation and material reuse, while empowering people of all backgrounds to make their cities healthier and more efficient.

- **Stan Vangilder, Southern Company**
  American electric utility holding company based in the southern United States.

- **Liz Kramer, University of Georgia**
  American public land grant and sea grant Research University.

- **Landon Marston, University of Illinois – Urbana-Champaign**
  American public land grant Research University.

- **Greg Keoleian, Joshua Newell, University of Michigan**
  A public research university considered one of the foremost research universities in the U.S.