SUSTAINABILITY CERTIFICATION FOR INDOOR URBAN AND VERTICAL FARMS

A SUSTAINABLE APPROACH TO ADDRESSING GROWTH IN VERTICAL FARMING

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Background

As the global population continues to expand, the agricultural industry is challenged with increasing food production on existing land, as it is estimated that agricultural land capacity can only grow by 2%. [1] The world population reached 7.3 billion in mid-2015, and is projected to increase to 8.5 billion in 2030 and to 9.7 billion in 2050.[2] In addition to population growth, the number of people living in urban areas is expected to exceed 6 billion people by 2050, with 90% living in developing countries.[3] Climate change places additional pressure on traditional agriculture, and all of these issues threaten the global food supply.[4] In addition to continued improvement in traditional farming practices, urban and vertical farming techniques have the potential to increase food production and reduce the distance food travels to reach consumers. As opposed to conventional farming, vertical farming refers to the cultivation of plant life on vertically inclined surfaces, minimizing land footprint by stacking upwards instead of outwards. Vertical farming can provide an intensive growing method in urban spaces, offering much higher yields per acre than conventional production techniques, [5] and located in close proximity to city residents. Urban and vertical farming can take many forms, from purpose-built "skyscraper" vertical farms[6] to smaller-scale "Building Integrated Agriculture" that incorporates greenhouse systems in mixed-use buildings to gain efficiencies from cross-utilization of resources.[7]

Urban and vertical farming also have the potential to improve on traditional land-based agriculture, by providing year-round high yield production with limited or zero use of chemicals, and up to 90% less water.[8, 9] By leveraging synergies between buildings and agriculture, resources such as industrial wastewater and waste heat can be used and recycled more efficiently.[10] With food produced close to consumers and in an environment isolated from weather conditions, urban farming can improve cities' resiliency, lowering the risk of food shortages due to the disruption of food production and distribution caused by extreme weather.[11]

New methods of urban and vertical farming have the potential to avoid some of the negative environmental effects of traditional agriculture, including water waste and pollution, soil degradation, and greenhouse gas emissions from food distribution, while increasing food production. However, the industry faces challenges around sustainability and scalability, and a lack of comprehensive research and analysis of the environmental and economic costs of vertical farms.[12] Farms that rely heavily on artificial lighting can require much higher electricity use, while more efficient lighting systems carry a higher cost, and integrating farms into existing buildings can present both technical and zoning challenges. In addition, as the industry is relatively new, there are no established standards for sustainable urban and vertical farming, and practices vary according to location, crops produced, and farming methods. Farms are focused on continuous innovation, which leads to patented technologies and growing mediums, [13] rather than sharing information.

The Association for Vertical Farming (AVF) engaged with Columbia University's Master of Science in Sustainability Management program to research urban and vertical farming practices and existing certification systems, to establish recommendations and create a framework for a sustainability certification system for urban and vertical farms. AVF is an internationally active non-profit organization based in New York City, with 44 members that include individuals, companies, research institutions and universities. AVF's mission is to foster the sustainable growth and development of the vertical farming industry through education and collaboration, and the organization is focused on leading the global vertical farming movement to produce healthy food, create green jobs, and support environmental protection and climate change resilience.[14] To support the goal of long-term sustainable growth, the AVF needs to set standards to enable farms to benefit from sustainable operations and a favorable certification rating.

In the past two decades, the use of sustainability certification systems has increased across the globe, covering a wide range of issues and industries.[15] While there are numerous sustainability certifications that apply to different agricultural practices or buildings (Food Alliance, Rainforest Alliance, LEED, Energy Star, etc.), there is no system that adequately addresses the sustainability of urban and vertical farms integrated into buildings. The goals of this study were to determine key sustainability principles for urban and vertical farms, and develop a certification system that will establish standards for data collection and sustainable practices for the members of the AVF. This report outlines a framework to support the sustainable growth of the urban and vertical farming industry.

Approach

This study investigated the practices and challenges of existing urban and vertical farms through interviews, site visits and third-party research, and identified 7 key attributes for assessing the sustainability of these farms. In parallel, 12 well-established certification schemes focused on farms or buildings were analyzed, to highlight principles that were applicable to urban and vertical farms. Research into these systems identified 9 key sustainability principles that are common to each of the certifications and relevant to these farms. The 7 key areas identified in the farm interviews and research directly aligned with the 9 Common Applicable Principles highlighted in the certification schemes.

The 9 Key principles that inform the sustainability of vertical farms are:

1. Health and Safety / Working Conditions
2. Food Safety and Quality Assurance
3. Pest Management and Pesticide Use
4. Nutrient Management and Fertilizers
5. Water Conservation and Management
6. Community Relations
7. Waste Management
8. Energy and Climate
9. Site and Facility Characteristics

Collecting data on these metrics will provide insight into how farms are performing, and after obtaining information from an adequate sample size, the AVF can begin to set standards for sustainable practices.

The AVF also needs to determine whether to develop a stand-alone certification system or partner with an existing certification scheme to create a module or adapt that system to apply to urban and vertical farms. A fit analysis was developed to assess the certification systems reviewed as part of this study, scoring each on their coverage of the 9 Common Applicable Principles, overall criteria applicability to urban and vertical farms, certification system scope, geographical focus, and inclusiveness of eligibility. Based on the fit analysis, Food Alliance's Greenhouse and Nurseries Certification was identified as the best fit if the AVF has a strong preference for a partnership. However, by partnering with an external organization, the AVF would have limited control to modify the framework over time to address a rapidly evolving industry. The recommended approach is to develop a stand-alone certification system to address the specific elements of urban and vertical farms, and allow the AVF to evolve the framework as the industry expands and new technologies are developed. While the AVF can develop and manage the regulations and standards, it is recommended that the actual certification be administered through a third party accredited body. This recommendation is based on both industry interviews and the practice of existing sustainability certification systems, and will provide additional credibility by separating the creation and administration of the system.

System Framework

The first phase in development of a sustainability certification system for urban and vertical farms is to begin standardizing data disclosure. Research and interviews with farms highlighted the lack of data standardization and peer benchmarking, and the AVF needs consistent data over time to begin to identify best practices and baselines for sustainable operations. This approach also aligns with the AVF's focus on education and collaboration.

Through this research, the Sustainability Assessment of Food and Agriculture (SAFA) framework developed by the Food and Agriculture Organization (FAO) of the United Nations was identified as a reference framework for its focus on many aspects of sustainable food production. SAFA is internationally recognized and builds on existing sustainability initiatives by providing a clear framework for multiple uses, while remaining complementary to and compatible with these initiatives.[16]

Using the SAFA dimensions on sustainability as a reference (Environmental Integrity, Social Well Being, Economic Resilience, and Good Governance), a framework was designed around the 9 Common Applicable Principles identified in order to develop a stand-alone system. These principles aligned into four Assessment Categories – Farm, Product, System, and Community – as shown in Figure 1 below.

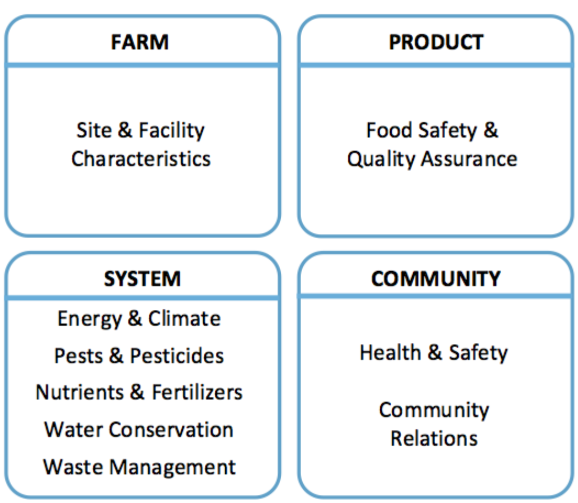

Figure 1: Assessment Categories and Common Applicable Principles

Across the four categories, a comprehensive list of 50 total metrics was developed, with each metric directly relating to one of the 9 key principles, and requiring quantitative or qualitative data.

Phased Development: Data Disclosure

This study recommends a phased approach to create a certification system, with early scoring criteria that recognizes "Certified Members" for standardized disclosure and data submissions for the sustainability principles identified in farm and certification system research, and for progressive management approaches. For standardized disclosure, it is recommended that farms be required to provide a core subset of metrics in Year 1, as it is not realistic to introduce all 50 indicators in the first year. It is recommended that the disclosure of the 50 indicators be divided into three phases (one phase per year). The first phase requires the disclosure of 24 core metrics, the second phase encompasses 16 metrics involving data that is slightly more complicated to collect, and the third phase adds the remaining 10 metrics that include the most difficult data to collect and that may require multiple years of data for context. At each phase, participating farms will be assigned a score based on how many of the metrics they disclose. Figure 2 below shows the disclosure phases and examples.

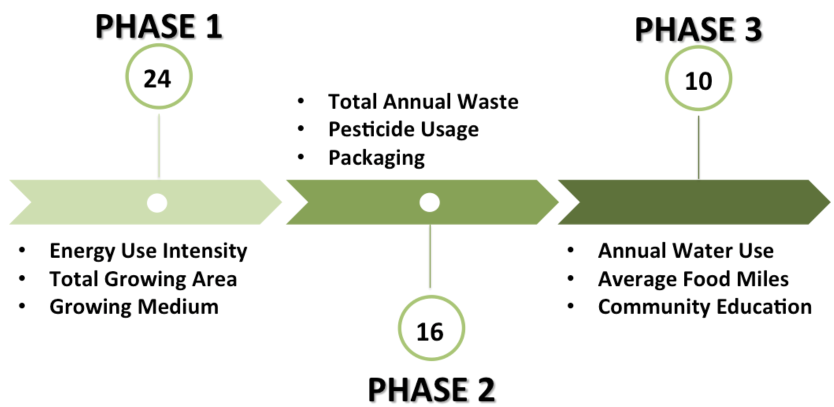

Figure 2: Phased Disclosure Approach

To provide farms with an assessment in the early stages of the certification process, a simple scoring system is recommended, based on the disclosure of data needed to establish performance baselines. Metrics are differentiated between mandatory metrics and non-mandatory. Mandatory metrics are either required to gather key performance data, or used to normalize other metrics that are collected (such as growing medium). All metrics have a value of one point and scores are assessed after each of the three phases. Farms will need to report on mandatory metrics to be eligible for a rating, and then will be given a score based on the total number of metrics disclosed.

Roadmap and Timeline for Certification System Implementation

For a broader look at how the system will be implemented over time, Figure 3 below provides an overview of how the certification will progress from the initial phases to eventual certification based on performance. As noted above, data collection and disclosure for the 50 indicators will be phased in during years 1-3. The system then moves to benchmarking, calibration and ultimately performance-based sustainability certification. This system relies on continuous member feedback, and is modeled after how existing farm and building sustainability certifications were developed over time and incorporated stakeholder input. Examples include Food Alliance, Fair Trade, LEED, and Rainforest Alliance.

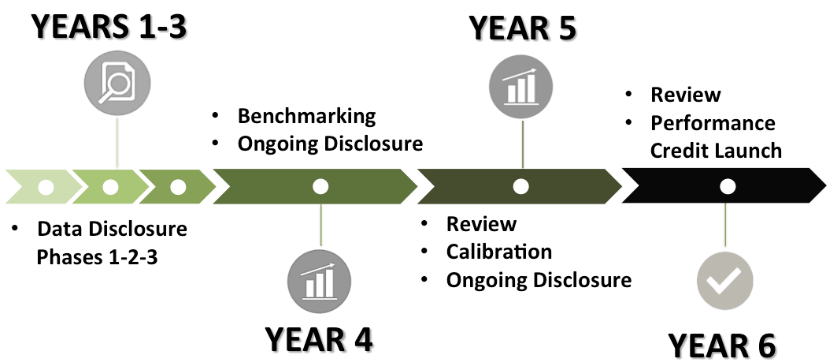

Figure 3: System Development

Based on the research highlighted in this report, with guidance from member farms, and following in the steps of other successful certifications, these recommendations can help the AVF collect and analyze standardized data sets, establish sustainability benchmarks, and catalyze sustainable growth in the urban and vertical farming industry.

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INTRODUCTION: THE NEED FOR URBAN AND VERTICAL FARMING

Challenges to Traditional Agriculture & Food Supply

Agriculture has long supported the growth of civilization, as the cultivation of crops allowed humans to create a more dependable food supply. Today, farming has become an enormous industry, and there are currently over 570 million farms across the globe. Of these farms, over 90% are managed either by an individual or a family. Small farms (less than 1 hectare in size) account for 72% of the world's farms and control 8% of the agricultural land, whereas farms greater than 50 hectares account for only 1% of all farms but control 65% of the world's agricultural land. Family farms produce 80% of the food produced globally.[1] In the US, the average farm totals 178.4 hectares in size, and in Latin America farms average approximately 111.7 hectares in size. In sub-Saharan Africa and Asia, the mean farm size is as small as two hectares.[2] In the United States, family farmers grow 84% of the country's domestically-grown crops, utilizing 78% of the total farmland, and yielding $230 billion in annual sales. Despite the size of the industry, there are large gaps between current and potential yields for main crops, and there is significant hope for increased cultivation through productivity growth on family farms. The development of new farming practices and innovative technologies will contribute to increased productivity.[3]

Technological innovation has been the key contributor for growth in agricultural productivity in all Organisation for Economic Co-operation and Development (OECD) countries, and technology is applied across all farming sectors, from conventional farming to organic. The mission of the OECD is to promote policies that will improve the economic and social well being of people around the world, and environmental, food safety and quality, and animal welfare regulations have increasingly impacted the agricultural industry. While farming technologies have the potential to improve a farm's sustainability, sustainability remains highly variable and dependent upon farmers' adaptations of proper technology and practices specific to their particular location. Technologies used in OECD countries to harvest, transport, store, process and distribute farm commodities are already very efficient, and result in reduced levels of waste than in countries where there is a lack of proper infrastructure and capital. In OECD countries, greenhouse horticulture is moving towards completely closed systems, and new farming techniques are being used more widely.[4]

Although efficiencies have increased, the combined issues of population growth, urbanization, and climate change affect traditional agriculture and in turn threaten the global food supply.[5] According to the United Nations World Food Programme, nearly one billion people worldwide are undernourished.[6] By 2050, the world's growing global population will require an estimated 60% more food than produced today,[7] taking into account the 1.3 billion tons of global food produced that is lost or wasted annually.[8] While demand for food is increasing, land and water resources are finite. Currently, 11% of the world's total land surface is used as arable land,[9] and global projections show that up until 2040, agricultural land capacity can only be increased by another 2% until the earth runs out of space.[10] In the near future, farmers need to grow significantly larger amounts of food, mostly on land already in production.

Along with overall increases in population, the number of people living in urban areas is expected to rise to over 6 billion people by 2050, 90% of whom are expected to live in developing countries.[11] In 2000, the world's mega-cities took up just 2% of the Earth's land surface, but they accounted for roughly 75% of industrial wood use, 60% of human water use, and nearly 80% of all human-produced carbon emissions.[12] As human populations continue to concentrate in cities, urban and vertical farming techniques have been proposed as a way to increase production in land-constrained areas. Vertical farming can be an intensive growing method adapted to urban spaces, which can result in yields per acre that greatly exceed those of conventional production techniques.[13]

Numerous definitions have developed for urban and vertical farming. Vertical farming is the concept of cultivating plants or animal life within skyscrapers or on vertically inclined surfaces.[14] Building Integrated Agriculture (BIA) involves locating hydroponic greenhouse systems on and in mixed-use buildings, leveraging synergies with the building environment. ''Zero-acreage farming'' (Zfarming) covers all types of urban agriculture that do not use farmland or open spaces. Production types are numerous and include rooftop gardens, rooftop greenhouses, edible green walls, indoor farms or vertical greenhouses.[15] The expansion of urban and vertical farming has the potential to produce food on a larger scale using less resources, [16] improving the resilience of the food supply. New methods of urban farming could also generate significant value to the agricultural industry and the global economy, and there is a need to minimize the negative environmental effects of agriculture, particularly with regard to greenhouse gas emissions, soil degradation and the protection of water supplies and biodiversity.

Benefits of Urban and Vertical Farming

In comparison to traditional land-based agriculture, proponents of indoor urban and vertical farming state that the advantages include more efficient use of land and resources, year-round high yield production, protection from severe weather events, enabling food security, limited (or zero) use of pesticides or fertilizers, water savings (70-90% less), energy savings and lower logistical costs.[17, 18] Resources can be better utilized and recycled by leveraging synergies between agriculture and buildings, such as residential or industrial wastewater, waste heat, and much more.[19] Vertical farming also presents an opportunity to reduce the amount of land used by traditional agriculture, providing the opportunity to restore ecological balance in some areas. These restored and more efficient natural systems could help slow or possibly reverse some adverse effects of climate change. Vertical farms also have the potential to contribute to a greater reabsorption of carbon dioxide from the atmosphere in the form of carbon reserves, as less land will need to be converted for agricultural purposes, and could reverse some of the negative effects of conventional farming practices.[20]

One of the important benefits of urban and vertical farming is the potential reduction of water use. Practices such as capturing evaporated water from the greenhouse atmosphere with cooling traps and returning it to the system, conversion of greywater into irrigation water, and the application of hydroponic systems lead to significant water savings. One study found that each hectare of a recirculating hydroponic greenhouse could replace 10 hectares of rural land and save 75,000 tons of fresh water annually.[21] In addition, energy savings are possible when urban and vertical farms are integrated into buildings with other uses – one study found that a combined building/greenhouse structure could save up to 41% in heating compared to standalone greenhouses and buildings.[22] Rooftop greenhouses contribute to building energy savings as they provide additional passive insulating benefits to the building and their climate controls can be directly integrated into the HVAC system of the building below. Low energy cooling methods such as ventilation and evaporative cooling can result in energy savings vs. conventional air conditioning.[23]

With conventional farming, crop production takes place over an annual growth cycle that is fully dependent upon what happens outside – climate and local weather conditions. Vertical farming in urban centers has great potential to allow year-round food production without loss of crops due to climate change or weather-related events. In addition, the soilless methods often applied in vertical farming offer a higher yield than field growing operations, and have the potential to feed more people on a global scale. Gene Giacomelli, Director of the Controlled Environment Agriculture Center at the University of Arizona in Tucson, notes that indoor growing conditions can be controlled with unprecedented precision, and that controlling the light, temperature, humidity, and pollinator preferences is crucial to success.[24] According to a study conducted by the German Aerospace Centre in Bremen, the estimated yield of a vertical farm compared to traditional agriculture increases 512 fold (see Appendix II). [25]

Growing food in cities helps stabilize the otherwise easily disrupted and unpredictable agricultural sector. Urban farming enhances a city's ability to deal with hazards and disasters, improving resiliency. While conventional farming practices rely on consistent weather, farming done within a controlled environment is weather-independent. When climate conditions are not ideal (such as California's extended drought) or natural disasters occur (e.g. Hurricane Katrina in the USA or Typhoon Haiyan in the Philippines), food distribution networks can become compromised and communities can become isolated and face food shortages.[26] Produce grown in California depends on the effectiveness of transportation and logistics systems for it to reach the East Coast.[27] When the long-distance shipping is eliminated, as in local urban farms, communities are granted the opportunity and security to feed themselves. Urban and vertical farms can also provide consumers with fresher food, bringing just-picked produce to cities. "We need to find new ways to grow food," said Benjamin Linsley of New York Sun Works, a sustainable engineering firm. "If you can stick farming anywhere you'd like – and say 'we don't need soil' – then a huge door opens".[28]

In addition to transforming underutilized or neglected space into a public resource, urban and vertical farming provide an opportunity to re-educate the public about their food, and can be used to train the next generation about the integration of technology and agriculture and current best practices. Urban farms can connect local residents with their food system, educate them how to grow food more efficiently, and contribute to further growth of the industry. The Science Barge is a good example, and New York Sun Works is currently installing a demonstration greenhouse on top of a New York City school, an addition which will serve as a hands-on teaching tool while simultaneously supplying fresh, local produce to the school's cafeteria.[29]

Urban and Vertical Farming Challenges

Although urban and vertical farming practices have the potential to solve or alleviate many pressing issues, the industry faces major challenges around sustainability and scalability. Some critics note that while feeding cities more sustainably is vital to food security, other solutions may be more deserving of resources and time investments than indoor farming. According to Dr. Louis Albright, professor of biological and environmental engineering at Cornell University, there is no comprehensive research or analysis of the environmental and economic costs of vertical farms.[30] Due to high construction and integration costs, required human capital and expertise, and a high market price associated with the produce, the industry is not yet practical outside of affluent countries. Depending on system design, urban and vertical farms can use a much higher level of electricity due to lighting, and the most innovative lighting systems carry a high cost.

Combining architecture requirements with food production presents more technological challenges and costs than outdoor urban gardens.[31] When urban farms are integrated into existing buildings, zoning issues and maintenance can present challenges for the building owner and the farm owner. In densely populated urban areas such as New York City, high land and property values mean that urban and vertical farms have to compete with alternative uses that may be more attractive in terms of financial returns. As the industry is relatively new, there is a lack of experienced people to set up and manage farms, and no process for sharing information on best practices.

Urban and vertical farms face a range of environmental and market issues. Both climate control and evenly distributed light across all plants present challenges, and urban farms have to consider humidity/mildew, inhabitants, and the integration of heating and cooling systems.[32] Urban indoor farms are not appropriate for all crops - growing grains such as wheat, corn, and rice indoors does not save as many resources as growing vegetables and fruits indoors, says Ted Caplow, executive director of New York Sun Works, an engineering firm that designs urban greenhouses. In addition, most trees grow too slowly to make greenhouse orchards profitable.[33]

The Need for Standards and Sustainability Certification

Despite growing interest in urban and vertical farming, there is no standardization in technology and practices across the industry, and currently there are no certification programs that set sustainability standards for operations and practices for urban and vertical farms.[34] As urban farms use a wide variety of new, innovative, ever-changing technologies, in conjunction with a wide array of growing practices and growing mediums, industry standardization is a very difficult task.[35] Due to the industry's young age, there is a lot of competition to grow most efficiently, leading to constant innovation and change, as well as patented technologies and growing mediums/materials.[36] By designing and applying a set of sustainability standards relevant to urban and vertical farms, the industry will have the opportunity to start to analyze efficiency and output among the farms. If detailed data is consistently measured and collected, baselines can be developed in multiple areas (e.g. water recycled, electricity used, and waste generated), so that performance can be tracked and compared among urban and vertical farms. The creation of a certification system would also allow for ideas to be more easily shared across the industry, so that innovations can be applied on a wider scale, creating what Milan Kluko refers to as a culture of "co-opetition". [37]

A primary objective of setting standards is to consistently adhere to specific criteria for products, services or processes. The United Nations Food and Agriculture Organization (FAO) states that "certification is a procedure by which a third party gives written assurance that a product, process or service is in conformity with certain standards".[38] The adoption of sustainability standards through certification programs has grown significantly since the 1990s, now encompassing a diverse range of issues.[39] Certification schemes are increasingly utilized to promote social and environmental criteria that are recognized internationally, and businesses, nonprofits and government agencies are supporting the development of sustainability standards. Accreditation Services International advises that effective certification schemes should be "internationally applicable, independently verified and governed by multi-stakeholder coalitions". [40]

While the consumption of goods and services is an increasing segment of global economic activity, it has led to negative social and environmental consequences, as developed countries have contributed to climate change with high levels of non-renewable energy consumption, and the expansion of international trade has contributed to unfair labor practices and disparities in wealth.[41] Better management of the production and consumption of energy and food is essential for sustainability, as it will reduce strain on natural and human capital. There are many global strategies to encourage sustainable production and consumption, including the use of certifications to influence producer and consumer behavior. In the last 15 years, third-party certification schemes have evolved around the globe as an approach to increase sustainability.[42]

Although there are various sustainability certifications and standards in the market, which apply to different agricultural practices (USDA, Good Agricultural Practices, Food Alliance, Rainforest Alliance, HACCP, etc.), as well as sustainable building certifications (LEED, Energy Star, etc.), there is no single system that can address the sustainability of urban and vertical farms integrated into the built environment. The existing farm certifications mainly refer to soil farming, whereas indoor farming frequently involves soilless production methods such as hydroponics, aquaponics and aeroponics. In addition, there is a need to take into account other key metrics which address the sustainability of the farm (including the building), such as energy efficiency, water efficiency, waste management, resource use and product yield. To ensure the sustainable growth of urban and vertical farming, there is a need to standardize key metrics across the industry, and set a baseline of sustainable practices to form the foundation of a certification system.

Client Background and Objectives

To address sustainability challenges and the lack of standards or certification around urban and vertical farming, the Association for Vertical Farming (AVF) engaged with Columbia University's Master of Science in Sustainability Management program to research urban and vertical farming practices, benefits, and issues, in an effort to establish recommendations for a certification system. AVF is an internationally active non-profit organization composed of individuals, companies, research institutions and universities focusing on advancing vertical farming technologies, designs and businesses. AVF's vision is to lead the global vertical farming movement to facilitate healthy food, green jobs, environmental protection and climate change resilience.[43]

This study analyzes and assesses numerous types of urban and vertical farms for their viability, benefits, and challenges, and reviews existing farm, building, and greenhouse certification schemes to identify key sustainability considerations for these farms. The purpose of this research is to develop the groundwork for a sustainability certification system that will establish a common set of standards and requirements for the members of the Association for Vertical Farming.

The voluntary standard will focus on agricultural processes, building infrastructure, technology, relevant innovations, and management practices as they relate to the sustainability of the farms. This framework will not detail capital investments or financial strategies, and instead will focus on social and environmental aspects. These best practices will then be used as a tool for benchmarking urban and vertical farms, to help AVF support sustainable industry growth.

As there are a wide variety of definitions of urban and vertical farms, this research and its recommendations are focused on stand-alone vertical farms and some forms of enclosed urban farming with a controlled environment. As described earlier, the concepts of Building Integrated Agriculture (BIA) and zero acreage farming (ZFarming) were utilized to determine enclosed urban farms that are in scope for the certification recommendations. Combining aspects of each definition, recommendations are focused on enclosed urban farms that have a symbiotic relationship with the building, using either soil or soilless growing methods. As traditional greenhouses already have certification programs, greenhouses located on a rooftop that do not utilize synergies with the building are not considered in the recommendations.

The goals of this study are to determine key sustainability principles for urban and vertical farms, and use those principles to establish a phased approach for development of a certification system for these farms. Using existing certification systems as reference points, the findings from research and interviews will help to identify which principles to extract and analyze. The best practices from existing systems will be synthesized into a final recommendation for the principles, metrics, and methods of data collection for the urban and vertical farming industry.

New York City and Urban and Vertical Farming

New York City presents great potential for urban agriculture, both from vacant land and rooftops. Within the five boroughs, an estimated 5,000 acres of vacant land (1,663 acres of public land and 3,321 acres of private land) could be suitable for urban farming - an area equivalent to six times the area of Central Park.[44] In addition, there are approximately 1 million buildings in NYC, with 38,256 total acres of rooftop area. Considering larger commercial and industrial properties, 5,227 private buildings and 474 public buildings could be appropriate for a larger-scale rooftop farm, and 1,271 of these buildings have a roof area of over half an acre.[45] Combined with the city’s dense urban infrastructure, the vibrant food culture, active transportation network, proximity to multiple educational institutions, large density of consumers, and the access to capital for healthy food projects make NYC a worthwhile urban agriculture candidate.[46]

The focus of this research is the Greater New York City Area as a starting point for an urban and vertical farming sustainability certification system. As further outlined in later sections of this report, multiple local indoor agricultural facilities were evaluated as part of the research for this assessment. To provide a scalable study that will be relevant to a broad range of locations and food systems, indoor agricultural facilities located throughout the U.S. and in other countries were also evaluated as part of this assessment.

Methodology

This research focuses on urban and vertical farms and existing sustainability certification systems for farms, food, and buildings. This report presents data and insights on urban and vertical farms collected from two main resource categories: 1) peer-reviewed and other third-party research, and 2) interviews, tours, and case studies of vertical farms, greenhouses, component manufacturers, and consultants. A review of literature on existing sustainability certification systems was also conducted, including peer-reviewed articles, NGO work, and other sources. The primary goal of this research was to determine which elements of existing certification systems are relevant to urban and vertical farms, to help narrow the focus from the many certification systems in different categories (farms, food, buildings, etc.). Another objective was to get a general understanding of industry best practices as research progressed, as these best practices became the benchmarks for a comparison between the selected certification systems.

Initial research focused on peer-reviewed literature published in the last ten years that addressed sustainability considerations for urban and vertical farming practices. The reviewed literature provided insight regarding the potential benefits and sustainability challenges of indoor agricultural practices, providing examples through data and case studies. Because the industry is relatively new, data from studies, workshops, and guidance from NGOs and nonprofit organizations was included to supplement research from peer-reviewed publications.

Interviewees and case studies were selected to provide an international perspective of various indoor growing methods, and on the basis of availability and willingness to cooperate with this study. The goal was to gain information on a variety of indoor urban and vertical farms, in order to identify similarities and themes across the different types of farms. This study analyzed similarities and differences between vertical farms and greenhouses, urban and non-urban applications, small-scale and large-scale establishments, seasonal versus year-round growing seasons, domestic and international applications, and the use of natural/organic or chemical-based nutrient and pest management methodologies. Interviews covered a series of specific questions, as well as an open discussion with each urban and vertical farm.

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RESEARCH AND DATA COLLECTION: URBAN AND VERTICAL FARMS

Urban and Vertical Farm Interviews

Interviews were conducted with a number of urban and vertical farming professionals, consultants, and affiliates. Some interviews were at the farm and also included a tour, and others were conducted by phone. Interviews were thorough and as consistent as possible, utilizing a standardized questionnaire developed for this study. The questions were developed to obtain information in four main areas (refer to questionnaire in Appendix III):

1. Farm type, size, technology, and production purposes
2. Supply chain methodology, crops, yield, chemical use
3. Resource efficiency: water, energy, waste
4. Opinions regarding existing certifications, recommendations for future certifications, description of attained or explored certifications

During interviews and on-site visits, the farms were asked to provide information about onsite operations - including growing methods, technologies and materials used, employment details, age of the farm, improvements that have been made over time, management approach, innovative practices, and target market. Interview questions also included requests for hard data including square footage of the grow room, number of crops grown, crop yields, packaging methods, distribution practices, food miles traveled, income details, energy costs, water recycled, and daylight hours compared to hours electricity was used for lighting. The interview results varied widely in the areas of operational practices, system design and the farm's mission, and were relatively similar in terms of challenges and community outreach. This research identified that community service was just as important as food quality to urban and vertical farms. Most farms interviewed are for-profit companies, and the most common growing systems used were hydroponics and aquaponics.

In addition, farms were asked for details on certifications they have achieved, certification systems they have considered, their opinion on various certification systems for buildings and produce, and their thoughts regarding a sustainability certification for the urban and vertical farming industry. Interviewees were also asked for their opinion on practices that need to be included in a certification system, and which factors could present roadblocks to adoption. Notes from interviews and site tours are summarized below.

Edenworks, Brooklyn, New York - Interview & Tour

Edenworks is a for-profit aquaponic vertical farm located in Brooklyn, New York. The interior rooftop greenhouse style facility was established in 2013, with planned expansion. The facility was designed using Passive House components, optimizing solar exposure on the south facade, while being super-insulated on the north side. The facility's south face allows the plants to absorb the photosynthetically-active radiation (red and blue light) required for their growth. The Edenworks growhouse includes a Passive House-inspired ventilation system, controlling air circulation within the greenhouse, including a heat recovery ventilator (HRV) that is 70% efficient. The HRV captures heat energy that accumulates at the top of the greenhouse and uses it to pre-heat the incoming air, recycling heat to keep the greenhouse warm and save energy. As the Edenworks facility includes significant glazing, the rooftop vertical farm requires no electrical light during summer, operating almost exclusively by means of natural sunlight. The cyclical aquaponic growing system results in minimal water waste, with 99% of the water within the system recycled daily (1% daily loss due to evapotranspiration). To supplement the nutrients provided to the plants by the fish in the aquaponic system, Edenworks employs the use of natural fertilizers such as chelated iron for plants like tomatoes. The produce is pesticide-free, and Edenworks uses beneficial insects such as ladybugs, and/or sprays plants with diatomaceous earth or liquid clay to control pests. Edenworks currently uses recyclable plastic packaging, and they are searching for alternatives such as suitable compostable packaging. The Edenworks philosophy includes considering user behavior such as landfilling versus recycling.

Edenworks' produce ranges from basil and lavender to rainbow chard, greens, lettuce, micro radish, micro arugula, tomato and peppers. Target markets are chef-driven customers, restaurants and food delivery services such as Maple in NYC's Financial District. Edenworks operates on a hyper-local framework, with the average food miles from farm-to-client totaling a one-mile walk to the distributor. Although not yet cost efficient, after expansion Edenworks plans to hire a refrigerated truck to deliver to Brooklyn, Queens, and Manhattan. Edenworks' produce is priced less than Gotham Greens, and Edenworks' goal is to sell at Baldor prices. Baldor aggregates food from farms and sells organic and conventional produce in bulk to restaurants.

The farm currently follows the Good Agricultural Practices (GAP) standard, designed to ensure final product quality, safety, and environmental sustainability. GAPs include considerations for site location, production system design, incoming seed stock, facility biosecurity, feeding management, harvest, procurement and storage, and cleaning and sanitation basics. GAPs also include a series of considerations, procedures, and protocols designed to foster efficient and responsible aquaculture production and expansion.[1] When asked about their opinion towards existing certification frameworks like certified organic produce, Edenworks' managers suggested that produce rating systems should be made affordable, so that small players are not excluded – as the urban and vertical farm industry is still in its early stages and includes many small players.

Edenworks' aquaponic vertical farm in Brooklyn, NY (10/13/2015). Photo Credit: Maya Ezzeddine.

Sky Vegetables, Bronx, New York - Interview & Tour

Sky Vegetables' farm is an 8,000-square foot hydroponic facility in the Bronx, attached to a LEED Platinum affordable housing building. The facility produces 2400-2500 pounds of produce a week (200 cases). The farm utilizes a hydroponic system with a foam-based material ("Oasis") as a growing medium. This medium is effective and inexpensive, but is not compostable. The produce does not need pesticides due to the secured environments. The farm uses nursery spacing, which is three inches between plants instead of six, requiring additional labor and higher loss due to the higher density. Sky Vegetables' largest expense and challenge is managing staff, as there is high turnover and pay is typically minimum wage. Additionally, more advanced technology will bring higher wages but fewer jobs. There are five employees at Sky Vegetables, including a greenhouse manager and a head grower.

Sky Vegetables grows basil, cress and arugula, and sells produce across NY, as the local community prefers different crops. Sky Vegetables uses a Wadsworth system for greenhouse control that maintains interior temperature, light, rain and light wind. Different vents are opened at specific times to regulate temperature, and a shade cloth is used for heating and energy control. The facility has five reservoirs, allowing for nutrients to be supplied to different crops at different times. A 500-gallon barrel distributes water to different channels while continuously testing the salt, PH and solution levels. Sky Vegetables sells live produce, with the entire plant harvested and inserted directly into a bag, which reduces labor intensity and allows the produce to stay fresh longer. The energy use at the facility was negligible over the summer, and the farm has not yet operated through a winter season. Waste heat is utilized at the facility, but the amount is not enough to supply the entire farm, so commercial heaters have been purchased for backup. Packaging is a huge cost and adds to waste streams.

Sky Vegetables' Andrew Carter explains the hydroponic system at their 8,000 sq ft rooftop facility in the South Bronx (10/13/ 2015). Photo Credit: Kiley Miller.

HARLEM GROWN

Harlem Grown, Harlem, New York - Interview & Tour

Harlem Grown is an independent, non-profit organization founded by Tony Hillery. It was established in 2011 as an educational community garden with the aim to provide Harlem students with environmental education/training in urban farming and healthy nutrition, and contribute to the Harlem community. Harlem Grown consists of three operating facilities – a greenhouse, a garden and school gardens (including an aquaponic demo in school). To build the facility, recycled tire pathways, salvaged wood, salvaged tools and donated growing supplies were used. Their 8,000 square foot greenhouse is based on an interior hydroponic system which operates year round compared to the outdoor garden where the total annual harvest is limited to 7 months. The types of crops grown range from diversified vegetables to fruit trees and herbs. The average distance that food travels is about one mile, as the produce is directly collected by Harlem families (given away in the neighborhood) with minimal distribution to local restaurants. As food is directly harvested and distributed, there is no storage requirement. Organic pesticide (sprays) and fertilizers (organic nitrogen) are applied to grow the crops. The organization's mission is to give produce at no charge to the community, but the price at which Harlem Grown products are distributed to local restaurants are under market rate. The main challenges to run the garden and the greenhouse are lack of sunlight (natural light is available in the greenhouse less than 2 hours/day, soil-pockets of 4-5 hours/day), managing donations of materials, attracting trained labor, consistency of production and distribution, and social and political challenges. Among categories ranging from energy and water efficiency to waste production and food quality, community service was ranked the most important category for Harlem Grown, as this is the most relevant to their mission. Although they do not believe there is a need for certification, they suggest the following metrics should be standardized across the urban and vertical farm industry: resource input, waste diversion, social impact and charitable donations.

Ag-Tech Week tour of the hydroponic greenhouse at Harlem Grown farm (10/13/2015). Photo Credit: Anna Harutyunyan

Center for Urban Agriculture, Seattle, Washington - Interview

Designed in 2007, the Center for Urban Agriculture is a conceptual project by pre-eminent sustainable design firm Mithun. The design for the project combines a multi-family residential building with agricultural features including rooftop and façade-integrated gardens and greenhouses to feed the building's tenants. The building concept was focused on self-sufficiency, and was inspired by the development of the Living Building Challenge certification system. Integrated systems were designed to provide food, water, and electricity for the tenants, including necessary storage measures to account for seasonality. The vertical construction of this project would allow the site to include more than an acre of native habitat and farmland on the buildings 0.72 acre footprint. This project is significant not only in that it represents a self-sufficient prototype, but also in that it represents a complete integration of passive energy efficiency measures combined with both agricultural systems and on-site renewable energy generation. This project is fully designed, but has not begun construction. The inclusion of a systems ecologist as a member of a design team is not common, and could set a precedent for future projects that include agricultural components. Interviews were conducted with the systems ecologist for the project, as well as the lead architect.

Center for Urban Agriculture. Digital image. *Mithun*. N.p., n.d. Web. 12 Nov. 2015. <http://mithun.com/projects/project_detail/center_for_urban_agriculture/>.

Green Spirit Farms
Sustainable Vertical Farming

Green Spirit Farms, New Buffalo, Michigan - Interview

Green Spirit Farms is a private company founded by Milan Kluko with an initial capital investment of $3 million. The company is growing rapidly, with current estimated annual revenue of approximately $75,000. Green Spirit Farms' operations started in 2011 in New Buffalo, Michigan, where their 43,000 square foot uninsulated warehouse building includes a 26,000 square foot grow room and 8,000 square feet of space used for growing seedlings in a nursery, sanitation and nutrient tanks, packaging, and storage. The New Buffalo, Michigan farm services Greater Chicago, an area with 800,000 people concentrated in a 50-mile radius. According to Mr. Kluko, it only takes an hour and 20 minutes to get to downtown Chicago.

Green Spirit Farms is the only vertical farming company with multiple vertical farms, with locations operating or in development in Michigan, Detroit, and West Virginia. On Earth Day, 2015, Green Spirit Farms opened a second farm (Artesian Farms), located in the Brightmore neighborhood of Detroit, Michigan. This farm was established via social investors, and is housed in a 12,000-square foot building which includes a 6,000-square foot grow floor. A third farm is currently under development in Charleston, West Virginia, and expected to be in operation by the end of 2015. To develop this third farm, Green Spirit Farms has partnered with KISRA (Kanawah Institute for Social Change and Action, Charleston, WV), a faith-based organization purchasing not just a growing platform, but rather a full service business model from Green Spirit Farms. KISRA is completing this project through partial funding from the State of West Virginia Agricultural Commission, as the State of West Virginia is attempting to repurpose old buildings in order to eliminate food deserts in the region.

After finding out about the KISRA project, the Omaha Economic Development Corporation (OEDC) hired Mr. Kluko to conduct a feasibility assessment for developing a vertical farm or multiple greenhouses in Omaha. The Omaha area has been designated a food desert, with approximately 750,000 residents. Recognizing that this project has the potential to create a lot of jobs, the OEDC quickly signed an agreement with Green Spirit Farms. Omaha now has the funding to set up a demonstration farm, which is going to be housed in a building in Northern Omaha that the OEDC has owned for ten years but has remained vacant.

Green Spirit Farms' main growing operation in New Buffalo, Michigan, includes a six-level indoor hydroponic vertical farm utilizing a rockwool growing medium. The farm uses their own proprietary system called Multiple Vertical Growing System (MVGS), which has been developed to optimize output and reduce nutrient use and lighting. The system has evolved since Green Spirit Farms' was formed in 2011 and is continuously being upgraded, as the system was designed to allow the replacement of individual components as new technology is available in the market.

BrightFarms, New York, New York - Interview

Bright Farms grew out of the New York Sun Works' 2008 Science Barge project, a self-contained barge greenhouse with solar panels. Using renewable energy in an effort to create a nearly carbon-neutral farm, the Science Barge offers a rooftop garden prototype and a public demonstration of urban farming. Two greenhouses were installed on an old barge, previously parked on the Hudson River at New York City's 68th Street Pier. Roughly 80% of the Science Barge's energy comes from two sun-tracking solar panels, and an array of small windmills and a biodiesel generator supply any additional energy as required.[2] After the Science Barge project, the creators began a consultancy arm called Bright Farms Systems, and later divided, with one starting Gotham Greens and the other leading Bright Farms. Originally, Bright Farms wanted to grow on rooftops, but they found that many NYC roofs lacked structural stability, and it would be expensive to retrofit all of these unsuitable roofs to be able to sustain the weight of greenhouses.

Today, Bright Farms operates a 45,000-square foot non-vertical hydroponic greenhouse in Pennsylvania, using an NFT System and a pond raft system. They started by growing tomatoes and baby greens, but they now only grow baby greens as they found that tomatoes were difficult to grow in a financially sustainable way. The greenhouse is equipped with vents that automatically turn on via a monitoring system, and lights that automatically turn on when the amount of available natural light becomes dim. Water is continuously recycled into the system with minimal losses, and a rainwater catchment tank collects rainwater, which is then pumped into the NFT system.

Bright Farms uses the Non-GMO label on their package. Due to their soilless growing method, Bright Farms could not certify their produce as organic, since currently only soil-based growing methods can qualified as organic. Since Bright Farms uses a lot of natural light in their growing operations, electricity is not their largest expense. Instead, their two main operating costs are the cost of labor and the cost of the growing medium. Bright Farms follows a safety protocol designed using the Pennsylvania Good Agricultural Practices (GAP) Certification checklist, and trains food-packaging staff on GAP methods. These methods include specific criteria for hand washing, gloves, hair nets, food pads at entranceways which sanitize shoes, specific refrigeration temperatures, mouse traps every 20 feet, sanitizing floors, and a log which notes who is in the greenhouse and whether or not they passed the safety protocol trainings. Additionally, workers are subject to periodic surprise food safety checks.

Urban Agriculture Solutions, Noble Rot, Portland, Oregon - Interview & Tour

This Portland, Oregon-based restaurant with a rooftop garden provides fresh produce to its customers, and is a relatively small-scale operation compared to industrial vertical farms. The rooftop requires no artificial light and minimal energy and water use, while providing a very diverse variety of produce on a year-round basis. Small-scale commercial farms are designed differently and face a different set of operational challenges than larger farms, such as structural engineering concerns.

The Noble Rot exists solely to serve the restaurant below, and the rooftop farm grows a diverse selection of seasonal vegetables and fungi that influence the frequently changing menu of the restaurant. The rooftop farm is designed and operated by a subcontractor: Urban Agriculture Solutions, a small organization that serves Portland and the surrounding region. The farm is a soil-based growing operation, and is challenged by structural limitations of the existing building. To address these conditions, Urban Agriculture Solutions designed a system of shallow growing beds, and chooses plants capable of thriving in minimal soil to limit overall load on the building. The farm's growing season is about 8 months long, during which the operator is constantly experimenting with new types of plants. For example, in late season after a bed has been harvested, the leftover stalks and roots are covered with mulching material rich with spores of different types of mushrooms. The farm also hopes to implement an aquaponic system in several beds in the coming year. In this way, the farm is consistently testing the viability of new plants while providing a unique and diverse selection of menu items for the restaurant below. In addition to providing fresh local food to customers, Noble Rot and Urban Agriculture Solutions have shared goals of revitalizing their urban space with organic surroundings and reconnecting city dwellers with the environment and their food.

Noble Rot's Rooftop Farm in Portland, Oregon. Digital image. Noble Rot. N.p., n.d. Web. 12 Nov. 2015. <http://www.noblerotpdx.com/web/garden>

GrowWise Center, Philips Lighting, Eindhoven, the Netherlands - Interview

GrowWise is a project developed by Philips Lighting, and the farm occupies part of a floor in a pre-existing building. Unlike most other farms interviewed during the course of this study, Philips is developing GrowWise as an indoor prototype farm for research purposes only. The location was formerly used for laboratory purposes, so installation of an indoor vertical farm was easily implemented as much of the water piping and other infrastructure was already in place. The farm uses hydroponic methods to grow lettuce and other greens, and almost all of the water used in the system remains in the system--the only water losses are attributed to evapotranspiration. Nutrients are added to the hydroponic system, and no pesticides are used at GrowWise. Packaging is not required due to the research-only nature of the operation. In this operation, Philips is focusing on optimizing the light "recipe" for optimal vertical farm output. Once the optimal balance of light is determined, Philips hopes to expand on a larger scale.

According to Caroline Santamaria of Philips, two main considerations for this study are: 1) focusing on re-educating the consumer, as many consumers may be reluctant to eat produce grown using new techniques such as vertical farming practices. This re-education needs to come not only from those involved in the vertical farming sphere, but also from unbiased sources such as governments or nonprofits. 2) The life-cycle assessment is the most valuable tool in designing a vertical farm certification system. Ms. Santamaria stresses that the certification system should have a full picture approach to vertical farms, since often there are many interlinked characteristics that otherwise go ignored.

Philips GrowWise City Farming research center in Eindhoven, the Netherlands. Digital image. Royal Philips. N.p., n.d. Web. 28 Nov. 2015. <http://www.newscenter.philips.com>.

Feedback Farms, Brooklyn, New York - Interview

Feedback Farms is an on-ground interior farm located in Brooklyn, co-founded by Columbia professor Claire Sullivan in 2014. In addition to production, the farm's primary mission is research and education. The founders of Feedback Farms previously worked in two other farms, and established a restaurant garden and a public school garden. The 4,000 square foot farm produces the following crops: salad mix, kale, Swiss chard, herbs, eggplant, peppers, tomatoes, cucumbers and flowers. Crops are grown in soil with different mobile raised beds, utilizing sub-irrigated planters in some beds. Recycled materials such as repurposed super sacks and scaffolding were used for raised bed construction, and no pesticides are used for growing. The fertilizers used are fish emulsion applied twice a month during peak growing season, compost and cover crops annually. The harvests are typically weekly or biweekly during the growing season.

Feedback Farms' production targets have shifted to local markets and restaurants and The Doe Fund kitchen, and they distribute the produce by foot or car an average of half a mile from the farm. The farm program with The Doe Fund kitchen includes job training curriculum and regular training sessions. The majority of crops are marketed with prices above conventional products and close to prices for organic products. Feedback Farms has not pursued any sustainability certification programs, as they believe that these systems are better suited for vertical farms that are significantly larger than their farm and that operate in a more controlled environment. They have no data on water consumption or waste produced, but energy expense in relation to total operating costs is minimal - around $50-100 from 6 weeks of seed starting for first transplants. The farm's biggest operational challenge is to retain land tenancy. Feedback Farms believes that energy efficiency, water efficiency and start-up costs are the most important metrics that should be standardized across the urban and vertical farm industry. Food quality, community service and management philosophy are of highest focus for the farm.

Feedback Farms' outdoor garden in Brooklyn, NY (10/16/2015). Photo Credit: Anna Harutyunyan.

Key Vertical Farm Findings

Common findings from the interviews were summarized, utilizing third-party research for context. The mean age of the farms is 6 years old, with an average growing facility size of 14,000 square feet. The most common growing systems used are hydroponics and aquaponics, and the most frequent types of crops grown are lettuces, leafy greens, herbs, and tomatoes. From a harvesting perspective, the "one and done" crops (single plantings with immediate replacement – e.g. kale) are harvested on average 23 times per year, while "cut and come again" crops (planting which continue to produce even after being harvested – e.g. basil) are harvested on a weekly or biweekly basis. Most of the farms are less than one mile from either the marketplace where the goods are sold, or from the direct consumer. Responses on energy and water use were vastly varied, but when asked to quantify the importance of energy and water efficiency from 1-5 (5 being most important), the average responses were 4 and 4.3 respectively. The interviewees provided a diverse range of answers regarding innovative practices employed on their farms. Farms also encountered a variety of operational challenges such as raising capital, finding and keeping employees, maintaining structural integrity of roofs, as well as gaining and retaining operational tenancy. Table 1 below summarizes interview results.

Summary of Urban and Vertical Farm Interviews	
Farms Contacted	**18**
Farms Interviewed	9
Declined Interview	3
Did not respond	6
Farm Details	
Average farm age:	6 years
Average amount of locations:	1
Average size of growing facility:	14,000 sf (range of 1500 to 45,000 sf)
Most common crops:	Kale, lettuces, chard, herbs, and tomatoes.
Crop harvests/year:	Average of ~ 23 harvests/year for "one and done" crops
Average miles traveled to consumer:	7.5
Average electricity & water consumption:	65,700 kWh/month (only one farm provided)
Average importance (scale of 1-5; 5 highest):	
Energy efficiency	4
Water efficiency	4.3
Food Quality	4.4
Waste Produced	4
Distribution footprint	3.5
Community service	4.4
Management philosophy	4.1

Table 1: Summary of urban and vertical farm interviews

Key Vertical Farm Attributes for Sustainability Certification

From the information generated from the third-party research, interviews and tours, the following attributes were used to develop the final recommendations for the certification system.

1. Site Location & Building Characteristics

Site selection and building parameters affect all components of sustainability within a vertical farm, including energy use, water use, waste and yield.[3] Site selection is key to the philosophy behind urban and vertical farming, so it is important that the farm either disrupts an existing agricultural system in a more efficient, sustainable way or addresses a current or future food scarcity issue. The context of the farm and the relationship the facility has with its surrounding environment is important when considering the long-term impact of the site.

2. Water Efficiency & Quality

According to Dr. Dickson Despommier, agricultural runoff is the world's greatest source of pollution and has damaged many estuaries. Due in part to estuary contamination, the United States has to import 80% of its seafood.[4] Dr. Despommier presents indoor agriculture as a viable solution to several of the water-related issues associated with traditional agriculture, including reduced run-off and watershed pollution, as well as a reduced dependency on water for irrigation. "Hydroponic farming indoors uses 70% less water than outdoor irrigation, and another technology called aeroponics, which is a take-off on hydroponics in which the roots are actually sprayed with a thin film of water, uses approximately 70% less water than hydroponic farming," explains Despommier.[5] As a result, aeroponic farming can require over 90% less water than outdoor farming.

During the interviews conducted as part of this study, Mr. Milan Kluko explained that from his research, traditional land-based growing methods require 8 to 25 gallons of water per head of lettuce. Mr. Kluko noted that Green Square Farms only uses 0.3 gallons of water per head of lettuce, using 96 – 99% less water and 96% less space to generate the same output of lettuce. In Green Square Farms' growing system, 88% of the water is recycled throughout the system, with 12% loss due to evapotranspiration. Mr. Ben Silverman of Edenworks, an aquaponics farm in Brooklyn, noted that Edenworks' system loses only 1% of water per day via natural evaporation and transpiration. Interviewed representatives from Bright Farms, Harlem Grown, and Philips Lighting all also reported minimal water losses, although they could not confirm the specific percentage of water recycled through their systems.

3. Energy Efficiency

Lighting presents the greatest energy demands for the farms interviewed. Using passive design strategies for lighting is the most ideal way to reduce energy use, but this may not be consistent with the operational strategies of indoor farms. Cooling can also present a significant load, which can be minimized by passive strategies such as evaporative cooling or natural ventilation. Identified best practice would be automated, whole building shading systems to optimize natural light and reduce energy used by artificial lighting.[6]

For farms that implement artificial lighting, LEDs emit a low level of thermal radiation, have no hot electrodes (which affect cooling loads), have no high-voltage ballasts, and have a long operating life, which makes them a practical option for long-term usage involving plant production, and it is possible to modify the irradiation output to approximate the peak absorption zone of chlorophyll. Plant species have different illumination requirements in terms of PPF (Photosynthetic Photon Flux), so the panels are operated at different power levels depending on the PPF requirements of the plant species rather than on maximum power. Furthermore, the desired duration of illumination is adapted to the needs of the plants, leading to 12 - 16 hour periods depending on the plant species.[7]

4. Innovative Practices

Based on the research conducted in this study, urban and vertical farm owners and employees see opportunities for innovation and improvement as technology continues to develop. Interviewees highlighted advancements in lighting technology and efficiency to reduce energy consumption, [8] reusable growing mediums to reduce waste, [9] and the need for easily adjustable growing systems that allow for individual parts to be replaced as more efficient designs come onto the market.[10] Other improvements can be made to the building, such as employing Passive House measures which allow for heat to be recovered and reused within the building.[11] Once an innovative and replicable method has been tested and selected for optimal output, that model can become the standard.[12, 13] In addition to widely adopted technologies, innovation is also farm/site specific. For example, in certain locations a combined heat & power plant that runs off an anaerobic digester fed by organic waste produced on site may be a good example of an innovative practice that increases the sustainability of the operation.[14] Other farms may employ recycled or reused materials to build the facility structure.

5. Fertilizers and Pesticides

Based on the enclosed, climate-controlled nature of indoor agriculture, crops are protected from the elements and from pests and predators which would otherwise threaten crop production. A much smaller suite of pests are able to affect a crop once it is brought indoors and isolated from the rest of the ecosystem. As a result, interviewed farms stated that they rely almost exclusively on natural, integrated methods of pest management. For example, Edenworks and Bright Farms reported the use of ladybugs to control other pests, and Edenworks described their usage of diatomaceous earth—a mixture of clay and water sprayed directly onto the plants to make them more resilient to pests. Despite the reduced needs for pesticides in indoor agriculture, it is vital for an indoor farm to ensure resilience against pests, since the close proximity of the crops can result in a pest epidemic if left untreated or uncontrolled. Fortunately, the natural methods employed by the interviewed farms are reportedly effective in protecting the crops.

In indoor soilless growing systems such as hydroponics, the nutrients are delivered to the plant in a more direct manner than in outdoor farming, where the plant is required to extend its roots to reach and extract nutrients from the soil. With indoor systems, the plants' roots are able to remain small and underdeveloped, as the nutrients are delivered directly to the plant, typically through vitamin concentrates which are added to the recirculating water. While some nutrients are chemical-based, natural alternatives are also available, and the interviewed farms reported a preference for the natural nutrients, based on their desire to be as environmentally-friendly and sustainable as possible.

In aquaponic systems, the fish provide nutrients to the plants via the excretion of fish wastes into the recirculating water, which the plants take up as nutrients. Mr. Silverman explained that in some cases the fish provide enough nutrients for the plants, but some plants require additional nutrients. Edenworks reported that they also employ the use of natural fertilizers such as chelated iron for certain for more nutrient-demanding plants like tomatoes. Although natural fertilizers are most sustainable, even with synthetic nutrients the reduced runoff pollution from indoor farming means that less fertilizer pollutes the watershed and ecosystems.

6. Labor Practices

The biggest challenge that interviewees shared related to operations of their farms is finding and retaining well-qualified and engaged employees, with the additional challenge of managing high turnover. For most farms, employees are often local residents, and several farms noted that they try to make compensation fair and rewarding to attract employees with relevant experience. For example, Green Spirit Farm reported that the lowest pay rate was one dollar above the minimum wage in Michigan, and Feedback Farms (which operates in NYC) noted that their pay range is $15-$20 per hour. However, only two farms shared information on additional benefits to employees, noting that they did not provide insurance. Farms do provide other incentives, such as Green Spirit Farm's $1000 reward for employees that quit smoking, after 6 months of nicotine-free blood test results. To support the goals of safe food production and employee health and safety, interviewed farms stated that employees are required to follow standard operating procedures and safety protocols, such as wearing gloves, using hair nets, hand washing, and sanitizing shoes at entrances. In addition, several farms reported that managers passed the Serve Safe qualification established for cooks. Although some farms expressed the opinion that farming tends to be dominated by males, the actual reported figures of gender breakdown varied from farm to farm - several farms had more women in operations, and others reported a 50/50 breakdown.

7. Social Connection

Interviewees were asked to rate the importance of seven distinct factors in the operation of their vertical farms: energy efficiency, water efficiency, food quality, waste produced, distribution footprint, community service, and management philosophy. On average, farmers rated community service as a factor of highest importance to their operation, tied at 4.4 out of 5 with food quality, and every farm that was interviewed talked about the importance of working to involve community members. Most farms have some sort of educational outreach programs to engage community members, especially students, to inform them on the importance of knowledge about their food supply. Other community engagement comes in the form of free tours or providing food to homeless shelters. From educational programs for children to tours and speaking events, community involvement is a key way to educate consumers about the benefits of urban farming, and reconnecting urban dwellers to food and the natural environment.

Limitations and Challenges

The majority of the farms interviewed did not keep track of metrics like monthly energy usage, water usage, precise yield, waste diversion, air quality, and amount of pesticide or fertilizer use. Some of the farms had certain types of data that they were interested in collecting and analyzing for their own purposes, but lacked the technical capacity to do so - waste diversion was a primary example. In addition to many farms lacking quantitative data, the ones that did have information reported in a non-standardized way. An example is water usage - one farm reported watering for 1 hour/day, while another reported that

8.5 gallons were used for a head of lettuce. Lack of standardization and lack of data present a significant obstacle to the establishment of a performance baseline. As data is not collected in a standardized manner across the urban and vertical farms interviewed, qualitative questions were used for context. To further address the lack of data and standardization across the urban and vertical farming industry today, this study also integrates information from peer-reviewed studies and other sources throughout this report, providing further context for the analysis of practices across the industry.

RESEARCH AND DATA COLLECTION: URBAN AND VERTICAL FARMS REFERENCES

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RESEARCH AND DATA COLLECTION: SUSTAINABILITY CERTIFICATION SYSTEMS

Overview of Farm and Building Sustainability Certification Schemes

In parallel with research into urban and vertical farms, research was conducted on existing farm, building, and greenhouse certification systems. Numerous sustainability-focused certification standards have developed in recent decades for agricultural commodities, and an inventory compiled in 2010 includes 440 certification schemes that were established since 2000.[1] Representing a growing portion of the world's food supply, certified agricultural goods are seen as beneficial for multiple stakeholders. Farmers are increasingly interested in adhering to standards and acquiring certifications, as they can increase the sustainability of their operations and receive price premiums and better market access by differentiating their products.[2] Certifying agricultural commodities allows producers to meet consumer demand for premium products that embody environmental sustainability, ethical, or lifestyle attributes, such as organically grown and fairly traded foods. Continued advocacy and interest in sustainable agriculture on the part of consumers, combined with increasingly stringent supply chain standards, will contribute to growth in certified sustainable agriculture practices and products.

The value of farm and food-based certifications increases when large companies such as Walmart and Unilever commit to purchasing certified commodities, motivated by corporate responsibility and sustainability goals, minimizing supply chain risks, and offering premium products to consumers.[3, 4] Downstream demand for sustainable agriculture appears to be continually growing as both shareholders and consumers express concern over environmental, social, and corporate governance (ESG) factors. Corporate sustainability reporting indicates trends to mitigate greenhouse gas (GHG) emissions, increase supply chain traceability, and support farming communities.

Buildings are one of the largest contributors to GHG emissions that cause global warming, and making buildings more energy efficient is one of the most immediate and measurable ways to address this issue. During their construction, occupancy, renovation, repurposing, and demolition, buildings use energy, water, and raw materials, generate waste, and emit potentially harmful atmospheric emissions. These issues led to the creation of green building standards, certifications, and rating systems intended to reduce the environmental impact of buildings through sustainable design.[5] Many states and local governments, and some federal agencies, now recommend or require that construction projects earn Leadership in Energy & Environmental Design (LEED), Building Research Establishment Environmental Assessment Methodology (BREEAM), German Sustainable Building Council (DGNB), Energy Star or other sustainable building certification systems. It is estimated that there are nearly 600 green product certifications in the world, with nearly 100 in use in the U.S., and the numbers continue to grow.[6]

The increasing importance of both farm and building sustainability certifications presents an opportunity to apply appropriate principles to urban and vertical farms, although no existing certification system covers all aspects of urban and vertical farming. This study researched certifications from the farm, greenhouse and building sectors, as each area is relevant to vertical farming. To identify systems to research in more detail, principles and indicators relevant to urban and vertical farming were considered, as well as transparent certification structure, fair and open application process, and successful examples in the market. Certifications that were solely U.S.-focused or that have no presence in the United States were eliminated. For example, CASBEE is primarily targeted at Japan, DGNB is focused on Germany, Pearl is used in the Middle East, and Green Star does not currently include international certification, [7] so these were not explored in detail.

SAFA: FAO's Sustainability Assessment of Food and Agriculture Systems

Along with research into various sustainable food and agriculture certification schemes, the Sustainable Assessment of Food and Agriculture Systems (SAFA) framework created by the Food & Agriculture Organization (FAO) of the United Nations was selected as a reference framework for concepts related to all aspects of sustainable food production. The FAO's purpose in developing SAFA was to create a commonly accepted framework and definition of sustainability amongst stakeholders in the food and agriculture space, and the framework was built with extensive engagement from 250 stakeholders in 61 countries. SAFA is comprehensive in its coverage of four key sustainability dimensions: Governance, Environmental Integrity, Economic Resilience, and Social Well-being. In its inclusion of the concept of "sphere of influence", SAFA promotes measuring the sustainability impacts of an enterprise not only in its direct activities but also in its influence on different stages of the supply chain.[8]

SAFA builds on other sustainability initiatives by providing a clear framework for multiple uses, and can be viewed as an impact assessment tool that is complementary to and compatible with most existing sustainability initiatives.[9] SAFA is not a certification standard as it does not set precise specifications for sustainability management, and it is not a reporting framework because it is focused on analyzing what data means in regards to sustainability performance rather than just reporting. Figure 4 on the following page illustrates the SAFA framework and its compatibility with and inclusiveness of many of the standards evaluated in this study.

Although SAFA allows for self-assessment through use of the SAFA Tool, the SAFA Guidelines and Indicators provide a reference point for sustainable food and agricultural practices, in which other tools can be used to apply the overall framework. The SAFA Tool is a freely downloadable and open source software tool that can be used by enterprises to self-assess their sustainability performance against the SAFA Guidelines and Indicators. The reporting content of the Tool directly reflects the content of the overall framework, including the default themes, sub-themes and indicators found within the SAFA framework, but the assessor may choose to disregard reporting on irrelevant sub-themes and may change the indicators of performance to better suit their context.

As a sustainability certification system for urban and vertical farms needs to create a benchmark for sustainable practices in multiple dimensions while allowing for a reasonable degree of flexibility in the indicators reported, the system must balance the need to optimize the comparability of assessment results between farms with the need to contextualize indicators to individual types of farms and systems. Pilot applications of the SAFA guidelines showed that the level of compliance can be compared between organizations, even when "different indicators and different spheres of influences are applied".[10] This balance of context and industry standards will be useful for the AVF to consider when developing a tool for the initial data collection phase of a new sustainability certification system for urban and vertical farms. The tool can ensure that data is gathered consistently across the farms, but provide an opportunity to focus on areas most relevant to the size and type of farm.

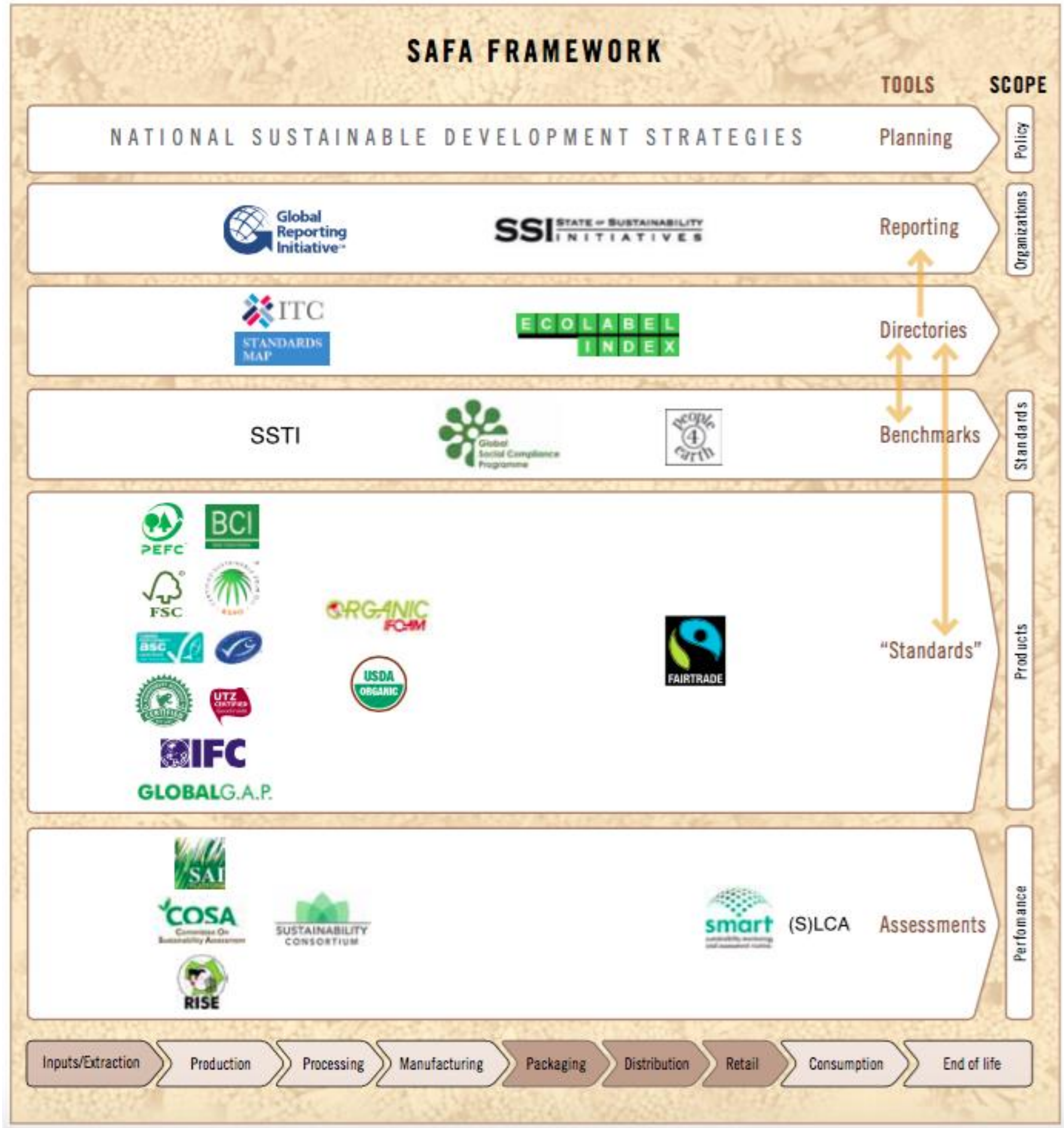

Figure 4: SAFA Landscape of Sustainability Initiatives [11]

Overview of Benchmarking Certification Schemes

Key Findings

From the initial research, 12 sustainability certification systems were selected to research in detail, after eliminating certifications that are not well known, lack international coverage, etc., as noted above. Data was compiled for each system, with the goal of finding key principles that apply to urban and vertical farming, based on key findings from vertical farming research. The 12 certification schemes that were analyzed are as follows:

Farm certification schemes:

- Rainforest Alliance (RA)
- Food Alliance (FA)
- Whole Foods Responsibly Grown (WFRG)
- United States Department of Agriculture Organic (USDA-O)
- United States Department of Agriculture Good Agricultural Practices (USDA GAP)
- Fair Trade USA (FTU)

Greenhouse certification schemes:

- Certified Greenhouse Farmers (CGF)
- Nursery and Greenhouse Standard (FA-GN)

Building certification schemes:

- LEED
- Energy Star
- BREEAM
- Living Building Challenge

As transparency is important for the majority of these certification programs, relevant data was obtained via each certification system's website, along with data from third-party research. To obtain additional data, interviews were conducted with some of the organizations administering existing sustainability certification programs (refer to interview questionnaire in Appendix IV). While insights from the interviews were useful in gathering further details on the certification schemes, few interviews were conducted, as individuals were either reluctant to share information on the certification systems or were unavailable. The most in-depth and informative data was derived from publicly available information on the certification schemes.

General principles of the certification schemes were reviewed, and numerous areas of overlap with the key principles in the urban and vertical farms interviews and research were identified. Each certification scheme main principle (e.g. energy efficiency) has a list of various criteria areas that must be met in order for a farm, greenhouse or building to become certified, and an analysis was performed to identify which certification schemes had the highest percentage of criteria that are applicable to urban and vertical farming.

Farm Certification Schemes

Rainforest Alliance

Founded in 1987, the Rainforest Alliance works to conserve biodiversity, protect ecosystems, and improve livelihoods by promoting and evaluating the implementation of globally respected sustainability standards. The internationally recognized Rainforest Alliance Certified seal symbolizes environmental, economic and social sustainability. The Rainforest Alliance auditing division, RA-Cert, is responsible for conducting independent and transparent audits to the Sustainable Agriculture Network (SAN) standards.[12] Farms that meet SAN standards can use the Rainforest Alliance Certified seal.

The Rainforest Alliance first started certifying farms in 1992. Agricultural products that bear the seal originate from Rainforest Alliance certified farms, which are managed according to rigorous criteria designed to conserve wildlife, soil and water, while supporting workers and local communities. Over 1.19 million farms covering 3 million acres in 40 different countries are Rainforest Alliance Certified (Figure 5), benefiting close to 4.4 million people around the globe.[13] The Rainforest Alliance label can be found on different agricultural products such as coffee, tea, chocolate, and fruit.

Figure 5: Global Impact: map of farms working with Rainforest Alliance [14]

***Interview: Rainforest Alliance** - Brittany Weinke, Communications and Media Outreach Associate; and **RA-Cert -** Heather Saam, Agriculture Specialist, Quality Assurance*

Each farm that meets Sustainable Agriculture Network (SAN) standards can be certified, and recertification is only needed every 5 years. However, an inspection audit is done annually, and additional verification and non-programmed audits are carried out in response to specific circumstances. RA-Cert (the Rainforest Alliance certification body) has around 150 contract auditors. RA-Cert only collects fees related to the auditing process, and collects participation fees from brands (e.g. Chiquita), which go back to the organization to fund field work. RA-Cert's 4 primary regions are: Mesoamerica (Mexico and Central America, office based in Costa Rica), South America (office in Bolivia), Africa (Kenya and Ghana), and Asia Pacific (Indonesia). All certified farms are in Latin America, Africa, the Middle East and Asia. Field offices manage the administration of certification programs in their region, using local auditors. The minimum general score that a farm can achieve in order to obtain SAN certification is 80%, and to obtain certification, a farm must be in full compliance with all critical criteria.

Food Alliance

Food Alliance (FA) started in 1993 as a project involving Oregon State University, Washington State University, and the Washington State Department of Agriculture, and was founded as an independent 501(c)(3) nonprofit organization in 1997. FA operates a voluntary single-level certification program built on standards focused on sustainable agricultural practices. Farms, ranches and food processors must meet Food Alliance's standards, as determined by a third-party site inspection, in order to use FA certification. Food Alliance launched its certification program in 1998, and there are over 330 certified farms and ranches in Canada, Mexico, and 23 U.S. states. The majority are mid-sized or smaller family owned and operated businesses.[15] Scores are assigned from 1 through 4 for each category, and farms must score 75% (Level 3) minimum in each category in order to receive certification. In addition, each company sets 1, 2, and 3 year plans for goals they wish to reach.

- Level 1: Meets legal requirements, or, in the absence of law, minimum expectations
- Level 2: Common practice or industry standard
- Level 3: Progressive management with demonstrated environmental stewardship & social responsibility
- Level 4: Visionary management with exceptional effort to meet, and achievement of, social and environmental goals/ best practices for next 10 years

The Domestic Fair Trade Association (DFTA) evaluates certification programs that include fair trade principles, to determine if these programs meet DFTA criteria. The DFTA found that Food Alliance does not adequately address provisions on fair working conditions, and falls short of other certification programs in transparency and monitoring.[16]

***Interview: Food Alliance** - Matthew Buck, Acting Director*

Matthew Buck stressed that recalibration is very important as well for Food Alliance, with updates done as needed. However, recalibrations must be done in small increments, and it takes 12-18 months for these updates to be completed. Inspection is needed every three (3) years to remain certified. FA targets the top tier farms in order to create value for buyers, and lower scores are typically seen for farms seeking supply chain risk management, as these farms are often unaware of flaw within their supply chains. In contrast to Whole Foods Responsibly Grown, fees are imposed due to the use of accredited third party certification bodies to conduct the inspections. Fees paid to the certification bodies vary from $750-$1200 in a three year cycle. In addition, facility inspections cost $1250-$4000 annually. FA's revenue comes from licensing fees and brand collateral, and fees are based on percentage of sales that varies by gross volume.

Whole Foods Responsibly Grown

Whole Foods Market developed the Responsibly Grown rating system to monitor and measure the practices of their suppliers in relation to sustainability standards and indicators. Launched in the fall of 2014 and applicable to all farms that supply produce to Whole Foods stores, the scheme promotes food production practices that safeguard human and environmental health.[17] It offers Whole Foods customers greater transparency in the sourcing of products they buy, and demands the traceability of products. The key categories measured by the rating system are soil health, energy and air quality, waste reduction, farm worker welfare, water conservation and protection, ecosystems and biodiversity, and pest management.

***Interview: Whole Foods Responsibly Grown** - Matt Rogers, Senior Global Produce Coordinator*

The recalibrating of standards and indicators was stressed as a priority for Responsibly Grown. Matt Rogers noted that these will be adjusted annually at a minimum, but also on an as-needed basis moving forward, guided by advances in research and technology related to sustainable practices. The program requires recertification on an annual basis, the most frequent of the certification systems evaluated in this study. Whole Foods conducts random and risk-based audits of certified suppliers, with pesticide policies having a greater precedence for audit. Reducing pesticide applications (in certain geographies) and performance in the advanced energy metrics (such as the integration of renewables) are cited as two areas where participants have struggled to comply with the standards. The only subscription fee charged is for "Barn", an information collection and management system tool for Whole Foods suppliers. Subscription cost varies based on volume of certified product.

The Responsibly Grown Certification is awarded to farms complying with certain core requirements of farming practices and pesticide use and by achieving a point total above the minimum threshold of 80 points. After the threshold is achieved, farms are categorized into Good, Better and Best, based on the potential to earn different amounts of points for performance in each category. The weighting system is highlighted in Table 2 below.

Whole Foods Responsibly Grown	*Points Available*	*Weighting*
Farming Practices	40	13%
Pesticide Use Policy	40	13%
Certification Base Points	20	7%
Advanced Pest Management	40	13%
Ecosystems and Biodiversity	25	8%
Air, Energy and Climate	25	8%
Soil Health	50	16%
Waste	10	3%
Water Conservation and Protection	25	8%
Farm Workers	30	10%
Total	**305**	

Table 2: Responsibly Grown Certification weighting system

USDA Organic

The United States Department of Agriculture (USDA) is "committed to helping organic agriculture grow and thrive", and has defined a set of standards to produce organic food. Since its inception in 2002, the USDA Organic seal has become a leading global standard for organic agriculture. These standards encompass general organic principles that were defined by congress in the *Organic Foods Production Act*, as well as specific organic standards defined by the USDA, and cover pest control, water and soil quality, etc.[18]

According to the USDA, the organic industry is one of the fastest growing agricultural segments in the United States, with sales of almost $35 billion in 2012. Over 25,000 farmers, ranchers and businesses are USDA Organic certified. Once farms achieve all of the established requirements, they receive certification and are allowed to label their products as "organic" and use the USDA seal. Through annual inspections, the USDA confirms that organic farmers update their farm plan to ensure the standards for organic food production are being followed.[19]

USDA GAP Certification

The USDA (United States Department of Agriculture) implemented the USDA Good Agricultural Practices (GAP) audit verification program in 2002 to "address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products".[20] The program works to develop codes, standards and regulations for the food industry, its producers, governments and non-governmental organizations that are focused on establishing best management practices for various commodities. The certification is a voluntary standard that is offered to those in the fruit and vegetable industry and works to combat the increasing instances of foodborne illnesses throughout the United States.[21] While it is not possible to completely eliminate risk, the GAP verification offers a strict and encompassing standard, which growers can implement at the farm level to ensure water and soil quality, pest management, and general safe handling of the produce. The USDA GAP principles (soil, water, harvest processing, energy and waste management, human welfare, health and safety) provide growers with the technical skill for implementing food safety standards through teaching best practices and expertise. Further, the GAP standards ensure safety throughout the food chain, highlight new market insights through better governance, and improve natural resource use, as well as working conditions.[22]

Fair Trade USA

Fair Trade seeks to "empower family farmers and workers around the world, while enriching the lives of those struggling in poverty".[23] In order to empower farmers, Fair Trade ensures workers receive fair prices, work in safe conditions, and receive decent wages, through direct and equitable trade. In addition to empowerment, core values of Fair Trade include integrity, sustainability, innovation, personal development, community, fairness and impact. The Fair Trade model aims to protect the environment along with farmers and local communities, and the criteria includes environmental standards, such as protecting water resources, restricting the use of pesticides and fertilizers, and properly managing water, energy and waste. Promoting Fair Trade products in the United States, Fair Trade USA is a third-party certified non-profit organization that works with over 800 companies in the United States to audit and certify products that comply with the international Fair Trade standards. The mission of Fair Trade USA is to support more equitable global trade that benefits farmers, workers, consumers, industry and the environment, by certifying and highlighting Fair Trade products.[24]

Certified Greenhouse Farmers Certification

The purpose of this voluntary standard was to establish a common set of requirements, covering both building infrastructure and agricultural production for greenhouses. The Certified Greenhouse Farmers (CGF) organization aimed to establish guides that declared best management and operational practices in order to develop a mechanism for internal benchmarking within the greenhouse industry. CGF clearly outlines the main goals for their certification, which are to (1) establish core requirements for a certification system that separate field growers and greenhouse growers, (2) provide a framework that provides a clear distinction between certified and non-certified growers through detailed requirements, and (3) encourage growers to implement better structural, management, resource and operational practices. This certification, although used to certify 50 different greenhouses internationally, is no longer being used due to a lack of interest from the industry inhibiting their ability to form an efficient member-base.

The framework proposed by the CGF addresses multiple industry issue areas including prerequisites, greenhouse design and operations, ecosystem management (optional criteria), and integrated water and pest management. In each of these main categories, the certified greenhouse must comply with multiple criteria, starting with prerequisites and moving to certification requirements for Tier 1 accreditation and further best management practices for Tier 2. To achieve Tier 1, producers must conform to all critical requirements and at least 90% of Tier 1 requirements. Tier 2 certified producers must meet all critical requirements of Tier 2 and conform to 90% of Tier 1. This framework also has a conformance section, along with four other main elements. In the conformance section, a greenhouse must comply with certain food and agriculture safety standards such as GAP, GMP, Food Pathogen Prevention, and US Food Safety Guidance. The other areas of the certification are Greenhouse Design and Operation (Greenhouse structure and environmental controls, water management, integrated pest management, plant nutrition management), Integrated Waste Management (Packaging Resource Minimization, Management of Product Waste and Non- Other Chemical Wastes) and Ecosystem Management and Protection.

Food Alliance – Nursery and Greenhouse Standard

The FA Nursery and Greenhouse Standard can apply to nursery and greenhouse operations in North America that produce one or more of the these products: woody ornamentals, annuals, perennials, foliage plants, potted flowering plants, and cut flowers. Food Alliance developed this standard in 2012 because of industry request and with encouragement from Oregon Association of Nurseries, [25] and it was made available for growers to use as a self-assessment tool. Growers can currently request the nursery evaluation tool, which includes all of the criteria and indicators needed to self-assess their farm, and then they have the option to apply and pay for inspection for certification.

Building Certification Schemes

Leadership in Energy & Environmental Design (LEED)

LEED is a widely used green building certification program that recognizes sustainable building strategies and practices, for new and existing commercial, residential, and institutional buildings. The US Green Building Council (USGBC) was formed in 1993, and the LEED 1.0 pilot was launched in 1998. By March 2000, 12 buildings had been certified, and LEED 2.0 was released after extensive revisions during the pilot period.[26] Building projects need to meet prerequisites and earn points to achieve different levels of LEED certification - certified, silver, gold and platinum. LEED v4 offers five rating systems to cover multiple project types: Building Design and Construction (BD+C) for new construction projects, Interior Design and Construction (ID+C), Building Operations and Maintenance (O+M), Neighborhood

Development (ND), and Homes. Each rating system consists of a mix of credit categories, containing prerequisites that projects must satisfy and a range of credits projects can focus on to earn points.[27] LEED presents an official credit library as well as a pilot credit library. The LEED Pilot Credit Library allows projects to test potential credits that have not been through USGBC's drafting and balloting process, and this includes several agricultural pilot credit areas. Prospective LEED projects that want to participate in a pilot credit program will have the opportunity to earn 1 pilot credit out of 100 credits needed to obtain different levels of certification – the pilot credit is not an additional, separate module or certification program. LEED for Existing Buildings includes a pilot credit that rewards projects for using local food/beverages, and LEED for Neighborhood Development has a pilot credit that rewards projects supporting local gardens and agriculture. LEED SSpc 82 Local Food Production pilot credit rewards a project team that demonstrates on site food production or partnership with a Community Supported Agriculture program or local farm.[28] This credit does not require that food is produced onsite, and is allowed under the LEED BD+C, ID+C or EBOM certification rating systems. For onsite production, requirements of the credit are defined as space standards and primarily focused on residential or community-focused properties - for example, at least 10% of the site or 50% of usable roof top space will be a vegetated area, or at least 1,000 sf in a school facility of 500- 1000 students.[29]

In 2008, the USGBC created the Green Building Certification Institute to manage its accreditation and AP testing process. Beginning in January 2009, GBCI took over the certification process as well. The USGBC will now handle all the development of LEED and green building practices, and the GBCI will handle all credentialing and certification, ensuring an independent third-party verification of the testing and certifying processes.[30]

Energy Star

Energy Star is a voluntary program established by the EPA in 1992, under the authority of the Clean Air Act. It helps identify and promote energy–efficient products and buildings in order to reduce energy consumption, improve energy security, and reduce pollution through voluntary labeling or other forms of communication. Energy Star also helps businesses and individuals save money by utilizing more energy-efficient products. The certification has been adopted by leading organizations across the United States because it offers a simple way to evaluate measured energy use. The EPA makes it easy to compare the energy performance of your manufacturing plant or building with similar facilities nationwide, and Energy Star offers a 1 – 100 benchmarking scale.[31] Based on the information entered about the building - size, location, number of PCs, it is estimated how much energy the building would use if it was the best performing or the worst performing, and can compare where your building ranks relative to its peers. For example, a score of 50 is average, while a 30 reflects a building that is only more efficient than 30% of peer facilities. A score of 75 or greater indicates performance eligible for Energy Star certification.[32]

Recognizing the widespread adoption of the Energy Star score in the commercial marketplace, the EPA continually updates the technical approach to ensure accurate, equitable scores. The overall objectives of the Energy Star score are to evaluate energy performance for the whole building, reflect actual metered energy consumption and to provide a peer group comparison.[33]

Building Research Establishment Environmental Assessment Methodology (BREEAM)

BREEAM is an environmental assessment method and rating system for buildings, and sets standards for best practice in sustainable building design, construction and operation. BREEAM encourages designers, clients and others to think about low carbon and low impact design, minimizing the energy demands created by a building, and has become one of the most comprehensive and widely recognized measures of a building's environmental performance. BREEAM assesses measures of building performance set against established benchmarks, to evaluate a building's specification, energy frame, construction design, and use. The measures represent a broad range of categories and criteria from energy to design. They include aspects related to energy and water use, the internal environment (health and human well-being), pollution, materials, waste, ecology and management processes. BREEAM is internationally as well as locally focused. BREEAM offers country-specific development schemes that are adapted to cultural, climatic and societal conditions.[34]

Living Building Challenge

The Living Building Challenge is a building certification program and philosophy that defines the measures of sustainability in the built environment. There are three pathways to certification under the Living Building Challenge, recognizing that the achievement of even a portion of the program is a significant step forward for the market. The three pathways are Living certification, Petal certification, and Net Zero Energy Building certification. A project achieves full Living certification by obtaining all Imperatives assigned to its Typology. Petal certification requires achievement of at least three of the seven Petals, one of which must be the Water, Energy or Materials Petal. In addition, Imperative 01: Limits to Growth and Imperative 20: Inspiration and Education must be achieved.[35]

Net Zero Energy Building certification is the third pathway. It requires four of the Imperatives to be achieved: Limits to Growth, Net Positive Energy, Beauty + Spirit, Inspiration + Education. The requirement for Net Positive Energy is reduced to 100% on-site production, and no on-site storage is required. Regardless of the pathway pursued, certification is based on actual, rather than modeled or anticipated, performance. Therefore, projects must be operational for at least 12 consecutive months prior to certification.[36] An integrated design process is critical to meeting the Net Positive Energy Imperative. Most housing projects are designed to meet a building code, following a prescriptive set of design strategies. In contrast, Living Building projects develop a solution determined by the climate and the solar carrying capacity of the site. Living Building projects must analyze the available renewable energy resources on the project site and then optimize building form, day lighting, construction assemblies and system design to reduce energy consumption to levels often much lower than best practice.[37]

Certification Sustainability Principles Analysis

Each certification scheme has a list of principles or standard areas, which have a certain number of specific criteria that have to be met to achieve certification. With thorough review of these schemes, their principles and criteria for certification, a set of 9 common principles were identified that are applicable for urban and vertical farms, as they directly overlap with the 7 priority items identified as key urban and vertical farm attributes for sustainability certification during the urban and vertical farm interviews and research.

These Common Applicable Principles are listed here and reflected in the table below:

- Health and Safety / Working Conditions
- Food Safety and Quality Assurance
- Pest Management and Pesticide Use
- Nutrient Management and Fertilizers
- Water Conservation and Management
- Community Relations
- Waste Management
- Energy and Climate
- Site and Facility Characteristics

	Vertical Farming Principles	Common Applicable Certifications Principles
1	Labor Practices	1. Health and Safety / Working Conditions 2. Food Quality Maintenance
2	Fertilizers and Pesticides	3. Pest management, pesticide use 4. Nutrient management, fertilizers
3	Water Efficiency & Quality	5. Water conservation and management
4	Social Connection	6. Community relations
5	Innovative Practices	7. Waste Management
6	Energy Efficiency	8. Energy & Climate
7	Site Location & Building Characteristics	9. Site and Facility Characteristics

Table 3: Vertical Farming Principles and the Common Applicable Certifications Principles

As shown in Table 3 above, all 7 key areas for urban and vertical farms were included in these 9 Common Applicable Principles found in the 12 certification schemes.

Common Indicators and Themes

Within these specific principles, all the relevant criteria for urban and vertical farming were further reviewed in detail, and common themes and indicators were identified from the existing farm, greenhouse and building certification schemes. A summary of these commonalities is found in Table 4 below. Within these indicators, the certification systems often allow for different levels of reporting, which may or may not influence scoring, and the certification schemes differ in the amount of content (and weighting) attributed to different principles.

Farm and Greenhouse Certifications

Common themes and indicators among the farm and greenhouse certification schemes include energy, water, waste, health and safety, crop management, operations, and community relations, as detailed below.

Common Themes and Indicators – Farm and Greenhouse Certifications	
Theme	Indicator Details
Energy	The tracking of energy usage and GHG emissions, integrating renewable energy resources into the farms, and the design of regular energy 'outlooks' (goals, plans and activities) to increase future energy efficiency.
Water	The tracking of water usage, integrating a water-use efficiency tool along with the technologies and practices that optimize water usage according to specific crop requirements, and preventing the discharge of contaminated wastewater into the natural and surrounding environment.
Waste	The tracking of recycling rates for various materials (metals, plastics, glass, paper) used within the daily operations of the farm, tracking the food-waste stream, identifying and acting upon opportunities to increase the recycling and reuse of materials in operations and reduce the food-waste stream, and identifying and acting upon opportunities to reduce waste and increase reusability of packaging.
Occupational Health, Safety, and Equity	Developing policies and procedures that promote the sustained physical and mental health of employees, including their preparedness for occupational risks and access to regular medical exams.
	The storage and application of agrochemicals, including the chosen technologies and training methods, must be designed in a way that minimizes health risks to employees and the environment.
	Ensuring the ability of employees to collectively organize and negotiate working conditions, and participating in a third-party-verified program that guarantees the fair treatment and equitable pay of employees.
Integrated Crop Management	Harnessing ecological strategies of physical, mechanical, cultural and biological control to prevent losses from pests, diseases, weeds, nematodes etc. and reducing the use of agrochemicals to the greatest extent possible. When agrochemicals or pesticides are required, ensuring protocols are in place to optimize planning, application, recording and risk mitigation associated with the use of these substances, as well as collecting and recording data on the incidences of pest infestation.
	Complying with bans or restrictions on chemicals and substances that may be used in agriculture, as determined by the relevant jurisdiction.
	If nutrients are applied, ensuring protocols are in place to optimize their application based on specific crop requirements, and focusing efforts to increase nutrient efficiency (nitrogen & phosphorus) in the system.
Operations and Management Practices	Adhering to all local, state and national codes, laws and regulations as they pertain to agricultural production.
	Upholding traceability of food products and their inputs, and maintaining transparency of food production processes. Holding suppliers accountable to rigorous environmental, social, and labor standards.
	Committing to the continuous improvement of management practices and business processes, through monitoring and recording of performance, re-planning, and goal development.
Community Relations	Considering and minimizing the potential negative environmental, economic and social impacts of farming activities on the surrounding community, engaging in environmental and agricultural education efforts, and collaborating with stakeholders and industry peers in research related to the improvement of food systems.

Table 4: Common Themes and Indicators – Farms and Greenhouses

Building Certifications

Common themes and indicators can also be found among LEED, BREEAM, Energy Star and Living Building Challenge certifications. These are related to the principles of energy, occupational health and safety, building operation and maintenance, building materials and construction, and HVAC, heating, cooling, and lighting systems.

Common Themes and Indicators – Building Certifications	
Theme	Indicator Details
Energy	The tracking of energy use and greenhouse gas emissions, measures in place to conserve energy, and percent of overall field and facility operations powered by wind, solar or geothermal energy sources.
	The practice of installing new, or use existing, building-level energy meters, or sub meters that can be aggregated to provide building-level data representing total building energy consumption (electricity, natural gas, etc.).
Occupational Health and Safety	Occupational health and safety program with policies, procedures, personnel and the resources necessary for reaching its objectives.
	Focus on physical health (especially for employees in dangerous work), annual medical checkups.
	Protection from agrochemical exposure, examinations for workers that handle agrochemicals, proper storage and handling.
Building Operation and Maintenance	Commitment to provide whole-building energy and usage data.
	Data tracking during projects certifying under design and construction rating systems.
Building Materials and Construction	Reducing waste and full disclosure of material ingredients, including publicly available inventory of all ingredient, Health Product Declaration.
	Appropriate measures for the safe collection and storage of materials.
HVAC, Heating and Lighting Systems	Increase daylight access, avoid or address poorly installed heating, ventilation and electricity systems.
	Indoor air quality management plan during construction and occupancy stages of the building.

Table 5: Common Themes and Indicators – Buildings

The key sustainability principles, indicators, and themes identified in the certification systems and farm research formed the basis for analysis to develop recommendations for a sustainability certification framework for urban and vertical farms.

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ANALYSIS AND RECOMMENDATIONS

Areas of Focus for Sustainability Certification for Urban and Vertical Farms

Based on the interviews with urban and vertical farms and insights from the AVF, three challenges and priorities that a certification scheme should address have been identified:

1. Farms have difficulty in tracking the impacts and performance of their operations, based on interviews and attempts to collect standardized data.
2. Metrics specific to urban and vertical farming have not been established to adequately assess sustainability considerations of this emerging industry.
3. AVF wants to accelerate progress on their mission to *"foster sustainable growth and development of the Vertical Farming movement through education and collaboration"*.[1]

Reviewing Opportunities to Partner with Existing Certifications

After establishing the challenges that a comprehensive certification framework should address for the urban and vertical farming industry, the AVF needs to consider whether these objectives could be effectively met by partnering with an existing certification framework. As the AVF looks at the feasibility of establishing a sustainability certification system, this is the first decision.

1) Establish a stand-alone certification system.

OR

2) Seek partnership and create a branch/extension of an existing sustainability certification tailored for urban and vertical farms.

To address this question, this analysis gives a qualitative rating of "fit" between the AVF and other certification bodies. The following certifications were evaluated for partnership feasibility:

- Rainforest Alliance – Sustainable Agriculture Network
- Food Alliance
- Whole Foods Responsibly Grown
- USDA Organic
- USDA GAP/GHP – Good Agricultural/Handling Practices
- Fair Trade
- Certified Greenhouse Farmers
- Food Alliance – Greenhouses and Nurseries
- LEED
- BREEAM
- Energy-Star Certified
- Living Building Challenge

A number of factors should be considered to determine whether a partnership is a good option for a new industry certification. This analysis includes a qualitative assessment to determine if identified Common Applicable Principles are included within existing certification frameworks. In addition, stated criteria within these certification frameworks were evaluated for applicability to urban and vertical farming practices. Other organizational factors were also reviewed to provide a more robust assessment of partnership feasibility.

Using a scale of "1 to 3" ratings representing Poor to Fair to Good, these certifications were ranked based on the following characteristics through research into each system.

Rating Factors	
Factor:	Description:
Principle Coverage	Are the 9 Common Applicable Principles addressed within the certification framework?
Criteria Applicability	Are the certification's existing criteria applicable to urban and vertical farms?
Certification System Scope	Determines number of criteria within the existing certification framework.
Geography	Where does the certification focus on evaluating organizations?
Inclusiveness of Certification Eligibility	How difficult is it to be certified under this system?

Table 6: Rating factors

Principle Coverage

Based on the Common Applicable Principles identified in certification system research, each certification system was evaluated to identify which of the 9 Common Applicable Principles were measured within the framework. Each system received a percentage of applicability for these principles (as seen in Table 5 below). Based on the applicability percentage, certification systems received a rating:

- Below 50% = Poor (1)
- Between 50 and 80% = Fair (2)
- Above 80% = Good (3)

Under the structure shown above, coverage of 5-7 principles is considered "Fair" while 8 or more would be rated as "Good" scoring a value of 3. For example, Rainforest Alliance has principle applicability of 89% as shown in Table 5 below, and thus receives a "Good" score with 3 points. However, Food Alliance only meets 44% of the applicable principles, and so gets a Poor score of 1 point.

			Food Certifications						Greenhouse Certifications		Building and Energy Certifications			
	Vertical Farming Principles	**Common Applicable Certifications Principles**	**Rainforest Alliance**	**Food Alliance**	**Whole Foods**	**USDA Organic**	**USDA GAP-GHP**	**Fair Trade USA**	**Certified Greenhouse Farmers**	**FA Greenhouse and Nurseries**	**Energy Star**	**LEED**	**BREEAM**	**Living Building Challenge**
1	Labor Practices	1. Health and Safety / Working Conditions	1	1	1		1	1		1	1	1	1	1
		2. Food Quality Maintenance	1		1	1	1	1	1	1				
2	Fertilizers and Pesticides	3. Pest management, pesticide use	1	1	1	1	1	1	1	1				
		4. Nutrient management, fertilizers	1	1	1	1		1	1	1				
3	Water Efficiency & Quality	5. Water conservation and management	1	1	1		1	1	1	1	1	1	1	1
4	Social Connection	6. Community relations	1										1	1
5	Innovative Practices	7. Waste Management	1		1		1	1	1	1	1	1	1	1
6	Energy Efficiency	8. Energy & Climate	1		1			1	1	1	1	1	1	1
7	Site Location & Building Characteristics	9. Site and Facility Characteristics							1		1	1	1	1
		Total Principles Applicable	**8**	**4**	**7**	**3**	**5**	**7**	**7**	**7**	**5**	**5**	**6**	**6**
		Total Principles Applicable (%)	**89%**	**44%**	**78%**	**33%**	**56%**	**78%**	**78%**	**78%**	**56%**	**56%**	**67%**	**67%**
		Rating Points	**3**	**1**	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**

Table 5. Sustainability Principles for Certifications Applicability Analysis

The table above highlights the existing certification systems that are most comprehensive in coverage of the Common Applicable Principles. Generally, food based sustainability certifications showed higher scores in this area due to their ability to encompass both growing practices as well as the energy requirements that go into agriculture. While certifications related to the built environment are both relevant and important towards urban and vertical farming practices, scores in this area are inherently lower due to gaps in food-related topics.

Criteria Applicability

This analysis then compared criteria within the certifications to assess the percentage of criteria that could be applied to urban and vertical farming, based on literature review and interview insights. The detailed sustainability requirements and criteria for the 12 certification schemes were collected and synthesized in a comprehensive Excel document. The document includes all existing criteria that are requirements for an organization to become certified in a given area (farm, building, or greenhouse).

The criteria areas that are directly relevant for urban and vertical farms were identified, and included in an applicability analysis calculation:

- Less than 45% = Poor (1)
- 46-64% = Fair (2)
- 65% or greater = Good (3)

Applicability of criteria was determined based on evaluating relevance towards an enclosed urban or stand-alone vertical farm. After studying the dispersion in Criteria Applicability percentages, 9 out of 12 certifications showed scores between 47%-71%. Given this grouping within a tight range of percentages, it was important to derive ratings that still reflect differences between our studied certifications. To help break-out this grouping for a fit analysis, a certification was given a "Good" rating if approximately two-thirds of the criteria were deemed relevant towards urban and vertical farming (66% or greater).

Topics related to the area the farm is built on were not included, such as criteria on ecosystems, wildlife, and groundwater. Food quality related criteria such as soil nutrients and general nutrient management were included, as urban and vertical farming can use soil or soilless growing methods. However, additional criteria areas that were not directly related to urban and vertical farms were excluded from the applicability calculation. For example, indicators were not considered applicable if they related to soil erosion and forestry management. Other examples of non-applicable criteria relate specifically to organic meat, such as livestock living conditions, health, and feed, as in the USDA Organic certification.

The total percentage of criteria that were relevant to urban and vertical farms was calculated for each certification scheme in the applicability analysis. As the certification systems vary in terms of areas that are relevant or not applicable for urban and vertical farming, specific weights were not assigned to the criteria. As an example, in Rainforest Alliance 69% of the criteria areas are relevant for urban and vertical farms. For Food Alliance 70% is relevant. However, only 47% is relevant in USDA Organic (refer to Table 6 below for summary and Appendix V for detailed analysis.

	Certification Criteria Applicability	
	Certifications Researched	Applicability to VF
	Farm Certifications	
1	RA-SAN	69%
2	Food Alliance	63%
3	Whole Foods Responsibly Grown	71%
4	USDA Organic	47%
5	USDA GAP-GHP	58%
6	Fair Trade USA	49%
	Greenhouse Certifications	
1	Certified Greenhouse Farmers	67%
2	FA Greenhouse and Nurseries	71%
	Building and Energy Certifications	
1	LEED	54%
2	Energy Star	100%
3	BREEAM	38%
4	Living Building Challenge	30%

Table 6: Percentage of certification criteria applicable to urban and vertical farming

Certification System Scope

A higher number of certification criteria were viewed as unfavorable – this assumes more criteria increases barriers to become certified, which conflicts with the objective to encourage early adoption of the certification system.

- More than 200 criteria = Poor (1)
- 100-200 criteria = Fair (2)
- Less than 100 criteria (3)

Geography

This factor evaluated if a system favored operations in advanced economies where growth in the urban and vertical farming industry is occurring.

Inclusiveness of Certification Eligibility

Favorable scores were given to certifications that did not have a theoretical limit or percentile of organizations targeted for certification.

Weighting each of the factors into a "Fit Analysis"

The qualitative model weighted Principle Coverage and Criteria Applicability characteristics most heavily, as these characteristics were established by comprehensive research in the analysis of existing certifications. The other three characteristics are intended to provide further context on the requirements of the certification systems, and as complimentary variables are weighted slightly lower in the fit analysis. Weighting is summarized in Table 7 below.

Associated Weighting for Certifications	
Characteristic	**Weighting**
Coverage Rating	27.5%
Applicability Rating	27.5%
Scope Rating	15.0%
Geography Rating	15.0%
Inclusiveness Rating	15.0%

Table 7: Certifications and Associated Weighting

Results of the "Fit Analysis"

The fit analysis reveals that among all certifications evaluated, Food Alliance's Greenhouse and Nurseries Certification emerges as the most attractive option if the AVF feels strongly about partnership with an existing framework. This certification was the only framework indexing above a 2.5 out of 3 overall rating (2.58) among the 12 frameworks reviewed. While this indicates that the Food Alliance Greenhouse and Nurseries framework stands out with the best overall score for fit, other factors should also be considered to determine if the AVF should create a partnership and extension of an existing certification. Most notably, if the AVF defers control and responsibility to an external certification system, it may limit the AVF's ability to evolve the framework over time. Refer to Appendix VI for detailed tables and results from the fit analysis.

Proposed Certification Framework for the AVF

Stand-alone framework focused on standardizing data disclosure

As the urban and vertical farming industry quickly expands, it is imperative to address the lack of data standardization and peer benchmarking. It will be difficult to achieve traction if the AVF creates a certification that attempts to segment performance without a robust view of best-in-class industry practices and trends in operational data points. Additionally, this certification design needs to align with the mission of the AVF to expand membership through education and collaboration. The certification system should be inclusive and maximize a farm's potential to be recognized for good organizational practices in the early stages of the industry.

The recommendation is for the AVF to establish this proposed framework as a stand-alone certification, to allow for maximum control over its evolution as well as the ability to track performance with an internal database. This will ensure that unique industry insights are viewed within the context of urban and vertical farming's purpose to feed people in cities. Alternatively, if the AVF wishes to pursue partnership for factors outside of this report, it is recommended to engage with the Food Alliance to determine if their Greenhouses and Nurseries certification could be adapted to apply to urban and vertical farms.

Third Party Auditor for Implementation

While the AVF should develop and "own" the regulations and standards, a further recommendation is for the actual certification to be administered through a third party accredited body. This organization would audit prospective and existing vertical and urban farms through a checklist that meets AVF standards, and the farm could then apply to receive the AVF sustainability certification. This recommendation is based on industry interviews and analysis of existing sustainability certification systems. During interviews with industry stakeholders, a concern regarding legitimacy of the certification process and standard was highlighted if the AVF both creates and administers the certification. These concerns emphasized the possibility of bias (or perceived bias) in certification allocation, insufficient resources and capital to properly build, administer and review system standards, and quality of governance. Further, it was suggested that if these concerns are not properly addressed, any resulting certification or sustainability standard could have a negative impact on the young and developing industry.[2]

In addition, each of the certification standards analyzed throughout this process (with the exception of Whole Foods Responsibly Grown), represent or utilize a third-party verification body. The most common reasons for separating the development process from the auditing and certification processes were:

- To increase consumer confidence in safety and product quality.[3]
- To increase credibility at both the farm and industry level.[4]
- To allow the standard owner to remain "free of any conflict of interest".[5]

By partnering with a third-party verifying body, the AVF can increase industry and stakeholder confidence in its ability to establish a credible certification process.

Phased, consensus-based approach to setting industry performance standards

This study recommends that the AVF establishes a phased approach to create a certification, with early scoring criteria that recognizes "Certified Members" for the following:

1) Standardized disclosure and data submissions for the sustainability principles identified in farm and certification system research
2) Progressive management approaches across Product, System and Community

This allows the AVF to assess and reward good practices for standardized data disclosure, while recognizing evolving management approaches that support sustainable aspects of urban and vertical farms. Ongoing collection of standardized data disclosures across the industry will allow the AVF to objectively build a database of relevant metrics. This will enable better segmentation across typologies while quantifying the true impact of these farms across a wide variety of sustainability aspects.

After an initial certification phase targeted towards data collection, the AVF will be able to analyze industry trends and potentially establish minimum performance standards. At this stage, it will be critical to engage with stakeholders to define and review these standards. The certification could evolve to adopt other common approaches including tiers of certification (e.g. Gold, Platinum) and minimum thresholds for key dimensions (e.g. top 50th percentile for energy or yield).

This phased, consensus-based approach to establishing a sustainability certification system was followed by a number of the respected certification systems reviewed in this report. Refer to Appendix VII, which provides details on the evolution of the Food Alliance, Fair Trade USA, Rainforest Alliance, and LEED certification frameworks, which followed a phased approach. It is recommended that the AVF pursues a similar process in developing an industry standard and certification framework for sustainable urban and vertical farming.

CASE STUDY - LEED

LEED rating systems are developed through an open, consensus-based process led by US Green Building Council (USGBC) member-based volunteer committees, subcommittees, and working groups, in conjunction with USGBC staff, and are then subject to review and approval by the LEED Steering Committee and the USGBC Board of Directors prior to a vote by USGBC members.[6] Development of LEED began in 1993 through an inclusive process that included non-profit organizations, government agencies, architects, engineers, developers, builders, product manufacturers and other industry stakeholders. Pilot Version 1.0 launched in 1998, and by March 2000, only 12 buildings had been certified under the pilot program. After extensive revisions during the pilot program, USGBC launched LEED version 2.0. This seven-year process of data collection, improvements, revisions and learning was crucial to the success of LEED's building certification framework. Since the initial launch, private and public sector demand has spurred the creation of a portfolio of rating system products that serve specific market sectors, to address the complexity and variation of buildings across different sectors.[7]

LEED has made requirements increasingly more stringent, and LEED v4 (launched in 2013) set higher benchmarking goals and introduced new prerequisites for certification. LEED v4 is a market-driven, consensus-based, evolving framework that adapts and integrates new technologies, as well as new ideas and input from industry professionals. LEED v4 is the result of three years of rigorous critical review, incorporating public and market comment, and refining and improving all aspects of LEED.[8] The evolution of LEED highlights the importance of a collaborative, continuously improving process over time to develop a successful certification framework.

Certification Prerequisites

Based on the definition and scope of urban and vertical farming outlined earlier in Client Background and Objectives, the following criteria should be met for certification eligibility within AVF's framework:

- The primary food production purpose of the farm is for human food consumption.
- The farm is contained within an enclosed, man-made system and environment.
- The farm is integrated into the building.

The prerequisites are broad to accommodate various design and system types that are classified as urban and/or vertical farms. The farm must be in an enclosed, man-made system that provides the capability to grow year-round rather than being reliant on suitable climate conditions outdoors. The framework is targeted for farms that focusing on food production for humans, as different requirements and standards may be required for urban and vertical farms targeted at R&D or other purposes.

Assessment Categories and Alignment

Beyond basic prerequisites, the framework should include initial Assessment Categories specific to the urban and vertical farming industry. These categories were identified using a combination of findings from industry literature and guidance from the Food and Agriculture Organization (FAO) of the United Nations. As noted in the certification system research, the Sustainability Assessment of Food and Agriculture (SAFA) framework developed by the FAO was chosen as context for analysis of certification systems, and recommendations for the AVF framework. Within the SAFA model, the performance of an enterprise (be it a farm or a company) is assessed in terms of economic, environmental, social and governance sustainability. SAFA builds on other sustainability initiatives by providing a clear framework for multiple uses, and can be viewed as an impact assessment tool that is complementary to and compatible with most existing sustainability frameworks.[9] According to the FAO, "there is a strong interest in aligning with a global reference framework".[10]

Utilizing SAFA as a reference framework, there are four critical dimensions of sustainability when evaluating agricultural practices. Within these dimensions, SAFA provides key themes to assess:

- **Environmental Integrity** [11]
  - Defined as assessing whether organizations are minimizing negative environmental impacts and fostering positive impacts.
  - Key themes include Water (water use and quality) as well as Materials and Energy (material use, energy use, waste reduction & disposal)

- **Economic Resilience** [12]
  - Defined as evaluating how well organizations generate cash flow and create value for local economies.
  - Key themes include Vulnerability (stability of production via yield and market via diversity of customer base), Product Quality & Information (food safety and quality) and Local Economy (value creation).

- **Social Well-being** [13]
  - Defined as satisfying basic human needs as well as aspirations for a better life.
  - Key themes include Decent Livelihood (quality of life via wages, capacity development via training), Equity (non-discrimination), Human Safety & Health (workplace safety and health provisions)

- **Good Governance** [14]
  - Defined as the process of making and implementing decisions in the economic, environmental and social spheres.
  - Key themes include Accountability (systematic review of performance), Participation (stakeholder engagement, grievance procedures and conflict resolution), Rule of Law (legitimacy in following laws)

Based on findings from research into urban and vertical farms, initial measurement topics should cover four broad Assessment Categories:

1. **Farm Characteristics** – describing the type of farm and design factors.
2. **Product** – focused on evaluating the food produced which generates monetary value
3. **System** – focused on evaluating performance/efficiency of operations
4. **Community** – focused on social value creation

There is a natural fit between recommended AVF Assessment Categories and the SAFA sustainability dimensions. To illustrate, refer to Figure 6 below, which shows how the SAFA dimensions and themes align to the 4 AVF assessment categories (refer to Appendix G for SAFA topic allocation). One notable difference is in the recommendation to integrate governance aspects across Product, System and

Community categories – as shown in the illustration. This differs from the SAFA approach to governance as a standalone dimension.

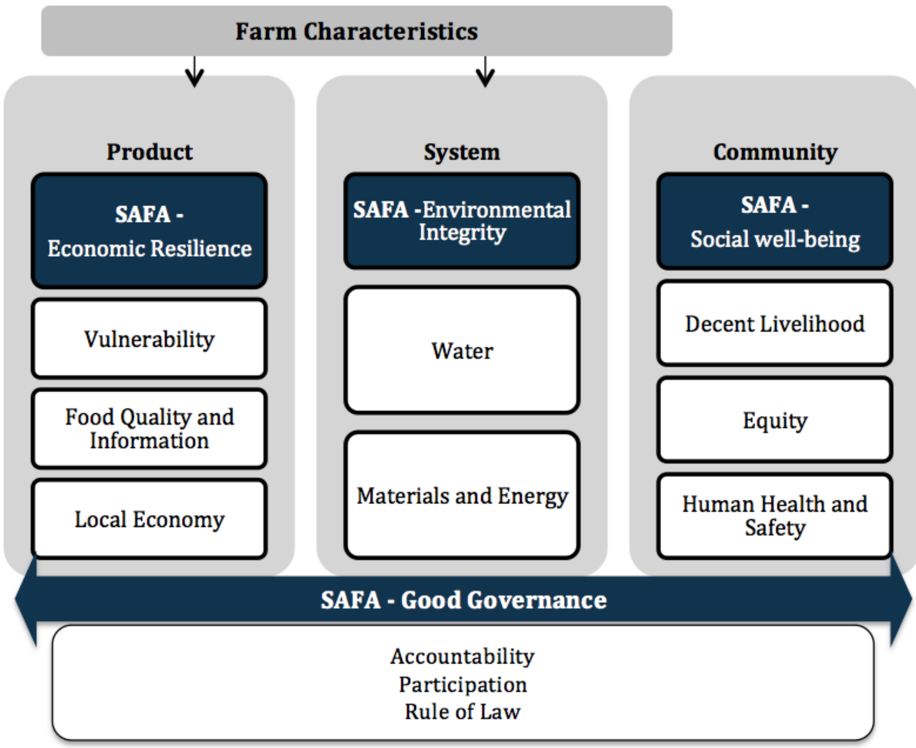

Figure 6: Proposed Alignment of Assessment Categories and SAFA Dimensions

By using SAFA as a reference framework, proposed areas of measurement would be allocated under an Assessment Category (Product, System, Community) based on their relation to a SAFA dimension and theme outlined in the image above. At the same time, areas of measurement will provide adequate coverage for each of the 9 Common Applicable Principles. With this in mind, the Common Applicable Principles will apply to multiple Assessment Categories.

Dimensions to Measure

To measure and track progress within the four Assessment Categories, a comprehensive list of "Dimensions" was developed for use by participating urban and vertical farms. Dimensions can be defined as areas of measurement that seek to quantify and categorize the type, scale and performance of each farm.

The Dimensions were derived from synergies between the urban and vertical farming principles and certification principles described in this study. Through this research, a list of topics were identified as relevant towards 1) describing urban and vertical farming operations and 2) measuring the Common Applicable Principles. Table 8 below shows this alignment, as well as corresponding SAFA theme for many of the Dimensions.

Assessment Category	Dimension	Common Applicable Principle	SAFA Theme
Farm Characteristics	FC_1 - Total Growing Area	Site and facility characteristics	n/a
	FC_2 - Total Facility Area	Site and facility characteristics	n/a
	FC_3 - Growing Area / Total Facility Ratio	Site and facility characteristics	n/a
	FC_4 - Food Types Grown	Site and facility characteristics	n/a
	FC_5 - Business Model	Site and facility characteristics	n/a
	FC_6 - Operating Hours	Site and facility characteristics	n/a
	FC_7 - Urban and Vertical Farm Type	Site and facility characteristics	n/a
	FC_8 - Building Integration Type	Site and facility characteristics	n/a
	FC_9 - Nutrient Delivery Method	Site and facility characteristics	n/a
	FC_10 - Growing Mediums Used	Site and facility characteristics	n/a
	FC_11 - Crop Spacing	Site and facility characteristics	n/a
Product	P_1 - Annual Yield per food type	Site and facility characteristics	Vulnerability
	P_2 - Annual Harvest count per food type	Food Quality Maintenance	Vulnerability
	P_3 - Fertilizer / added nutrient usage	Nutrient management / fertilizers	Food Quality & Information
	P_4 - Share of PT labor from local communities (%)	Community Relations	Local Economy
	P_5 - Reservoir Flushing Frequency	Nutrient management / fertilizers	Food Quality & Information
	P_6 - Pesticide usage	Pest Management / Pesticide use	Food Quality & Information
	P_7 - % Breakdown of customer base	Community Relations	Vulnerability
	P_8 - Average Food Miles to reach customer	Energy and Climate	Local Economy
System	S_1 - Annual Energy Consumption	Energy and Climate	Materials & Energy
	S_2 - Total Annual Waste	Waste Management	Materials & Energy
	S_3 - Waste Diversion Rate (%)	Waste Management	Materials & Energy
	S_4 - Packaging	Waste Management	Materials & Energy
	S_5 - Water Quality	Food Quality Maintenance	Water
	S_6 - Annual Water Consumption	Water Conservation and Management	Water
Community	C_1 - PT Labor Hourly Wage and FT Salary	Health and Safety / Working Conditions	Decent Livelihood
	C_2- Community Donations (lbs)	Community Relations	Participation
	C_3 - Labor Breakdown of PT and FT workers	Health and Safety / Working Conditions	Decent Livelihood
	C_4 - Injury and Incident Rates	Health and Safety / Working Conditions	Human Health & Safety
	C_5 - Community Education (hrs)	Community Relations	Participation

Table 8: Dimensions alignment with Common Applicable Principles and SAFA themes

Measurement Recommendations for Farm Characteristics

Table 9 below table provides a brief description of the Dimensions in the Farm Characteristics category, and notes the source used for guidance. These Dimensions are intended to provide high-level descriptive data about the type and size of farm that is being evaluated. This information will help to segment performance by farm typologies and foods grown. In addition, critical data on farm size and operating hours will help to normalize data across a diverse set of urban and vertical farming organizations.

Assessment Category	Dimension	Measurement Recommendation	Guidance Source
Farm Characteristics	FC_1 - Total Growing Area	Square Feet	Living Building Challenge
	FC_2 - Total Facility Area	Square feet	Energy Star: Gross Floor Area in ft^2
	FC_3 - Growing Area / Total Facility Ratio	Ratio or Percent of Floor Area for allocated growing purpose	Living Building Challenge: Floor Area Ratio **(FAR)**
	FC_4 - Food Types Grown	***Select all that apply:*** Fixed list of food variety based on PLU Database **[Category >> Commodity >> Variety]** **+** **Specify any other unique characteristics**	**PLU or Price Look-Up** database from International Federation for Produce Standards. http://www.ifpsglobal.com/Identification/PLU-Codes
	FC_5 - Business Model	***Select One:*** For profit Non-Profit	Developed based on VF interview results
	FC_6 - Operating Hours	# of Hours per week	Energy Star: Criteria for Rating Building Energy Performance: Operating Characteristics
	FC_7 - Urban and Vertical Farm Type	***Select One:*** Rooftop Facade Interior	Developed based on VF interview results
	FC_8 - Building Integration Type	***Select One:*** New Build Add-on Converted space	Developed based on VF interview results
	FC_9 - Nutrient Delivery Method	***Select all that apply:*** Hydroponic Aeroponic Aquaponic Surface soil - 6" or more Surface soil - less than 6" Soil based containers / planters	Developed based on AVF typologies
	FC_10 - Growing Medium	***IF SOILESS @ FC_9, select one per food type grown:*** Rockwool Grow Rock Coconut Fiber Perlite Oasis Cubes	Per Pilot feedback. Mediums taken from ttp://www.homehydrosystems.com/mediums/mediums_page.html

		Floral Foam River rock Pine shavings Composted/aged tree bark Rice Hulls Water Crystals Sand Polyurethane Foam Other, specify.	
	FC_11 - Crop Spacing	***Select one per food type grown***, specify spacing in inches between crops: less than 1" 1" 2" 3" 4" 5" 6" 7" 8" 9" 10" More than 10"	Per Pilot Feedback

Table 9: Farm Characteristics Dimensions with Measurements and Guidance

Measurement Recommendations for Product

Product Dimensions are intended to provide a quantitative look into the economic resilience of the farm. Dimensions such as Annual Yield and % Breakdown of Customer Base provide useful data when evaluating SAFA's Vulnerability theme, by contextualizing stability of production and stability of market by verifying a diversified income structure. The Food Quality and Information theme is adequately covered through P_3, P_5 and P6, while value creation in the Local Economy theme is evaluated via quantifying average food miles and percentage of workforce that is local. Table 10 below summarizes Product Dimension measurements and guidance source.

Assessment Category	Dimension	Measurement Recommendation	Guidance Source
Product	P_1 - Annual Yield per food type	Report # in Lbs / Growing Area Square Feet per food type	**USDA and National Agricultural Statistical Services:** Reports Crop Yield in Tons / Acre - this will provide similar methodology in a converted format for small-scale operation.
	P_2 - Annual Harvest count per food type	# of times each food type is harvested per year	Developed based on VF interview results. - Reveals insight into cut-and-come again practices vs. one-and-done methods

	P_3 - Fertilizer / added nutrient usage	***Select: Yes / No*** ***IF Yes;*** - Types used - Volume used per lb of applicable crop - Application frequency per week	**Certified Greenhouse Farmers:** 5.4.1. Tier 1 Requirements for Plant Nutrition Management 5.4.1.1. Planting Media and Additives
	P_4 - Share of PT labor from local communities (%)	% of labor from local community	**Rainforest Alliance:** 7.3 Community Relations
	P_5 - Reservoir Flushing Frequency	***IF SOILESS @ FC_9, select one from below:*** More than once per week Once weekly Once every 2-3 weeks Once monthly Once every 2 months Once every 3 months Once every 4-5 months 1-2 times Annually	Per Pilot Feedback
	P_6 - Pesticide usage	***Select: Yes / No*** ***IF Yes;*** - Types used - Volume used per lb of applicable crop - Application frequency per week	**Certified Greenhouse Farmers:** 5.3. Integrated Pest Management
	P_7 - % Breakdown of customer base	% Wholesale % Local restaurants % Non-food organization (shelter, community non-profit, etc) % Individual consumer	Developed based on VF interview results
	P_8 - Average Food Miles to reach customer	***Weighted Average Source Distance (WASD)*** - amount of food transported in weight and the distance that it travels from the place of production to the place of sale	**ATTRA - National Sustainable Agriculture Information Service:** Fruits and vegetables and other items consisting of only one ingredient would utilize the WASD formula - developed by Annika Carlsson-Kanyama in 1997.

Table 10: Product Dimensions with Measurements and Guidance

Measurement Recommendations for System

Dimensions in the System category are designed to provide a quantitative look into the environmental integrity of the farm. Dimensions such as Energy, Packaging and Total Annual Waste provide useful data corresponding to SAFA's Materials and Energy theme. In addition, providing Dimensions on Water Use and Water Quality aligns with SAFA's Water theme. Table 11 below provides a description of recommended measurement and guidance source for each System Dimension.

Assessment Category	Dimension	Measurement Recommendation	Guidance Source
System	S_1 - Annual Energy Consumption	***EUI with hours of operation normalization*** - Divide the total energy consumed by the farm in one year (measured in kBtu or GJ) by the total gross floor area and annual hours of operation.	**Energy Star:** EUI Guidance with an added normalization recommendation for operating hours to account for differences in growing season
	S_2 - Total Annual Waste	Pounds per square feet of facility	**Fair Trade USA** - Waste Management Principles
	S_3 - Waste Diversion Rate (%)	***Waste Audit-*** Calculate diversion rate by dividing the amount of recyclable material by the total volume of waste that was generated.	**Fair Trade USA -** Waste Management Principles
	S_4 - Packaging	***Level 1.*** Nursery neither employs nor considers low-impact packaging ***Level 2.*** Manager communicates some knowledge of the use of low-impact packaging - limited plan with no proven implementation. ***Level 3.*** Manager communicates detailed plan and demonstrates implementation for using low-impact packaging for some products. ***Level 4.*** Manager communicates detailed plan and demonstrates implementation for using low-impact packaging for all products.	**Food Alliance** - Greenhouse & Nurseries standards, pg. 58
	S_5 - Water Quality	**Quality Control -** Validate measures have been implemented related to the installation of water filtration or other treatment systems. • Provide 3rd party LAB test results from the past 12 month reporting period.	**Fair Trade USA** - Soil and Water; EPA Federal Water Quality Standards Requirements – Section 1-3 related to irrigation for crops.
	S_6 - Annual Water Consumption	Gallons per square foot of facility-Measure and Fulfill	**Whole Foods Responsibly Grown:** Wastewater management and water conservation principles

Table 11: System Dimensions with Measurements and Guidance

Measurement Recommendations for Community

Community Dimensions were developed to provide a quantitative look into the social well-being that the farm delivers to its employees and stakeholders. Dimensions such as Part-Time (PT) Labor Hourly Wage and Full-Time (FT) Salary align well to SAFA's Decent Livelihood theme, and Injury and Incident Rates provide data relating to the Human Health and Safety theme. In addition, Community Donations and Community Education can measure quantifiable impacts on external stakeholders. Table 12 below outlines the recommended measurement for each dimension, as well as guidance source.

Assessment Category	Dimension	Measurement Recommendation	Guidance Source
Community	C_1 - PT Labor Hourly Wage and FT Salary	Dollars per hour (PT) or year (FT)	**Rainforest Alliance:** 5.5 Fair Treatment and Good Working Conditions for Workers
	C_2 - Community Donations (lbs)	***Provide all data that applies:*** - Dollars donated - Hours donated - Pounds of produce donated	**Rainforest Alliance:** 7.4 Community Relations
	C_3 - Labor Breakdown of PT and FT workers	# hours worked per day	**Rainforest Alliance:** 5.7 Fair Treatment and Good Working Conditions for Workers
	C_4 - Injury and Incident Rates	# of injuries/incidents	**Rainforest Alliance:** 6.1 Occupational Health and Safety
	C_5 - Community Education (hrs)	# of hours per year helping with local environmental or agricultural education efforts	**Rainforest Alliance:** 7.5 Community Relations

Table 12: Community Dimensions with Measurements and Guidance

Governance – Management Approach indicators

Based on "Proposed Alignment of Assessment Categories and SAFA Dimensions" (refer to Figure 4), the recommended certification framework for the AVF needs to integrate aspects of Governance across the Product, System and Community Assessment Categories. Governance is measured through a list of proposed Management Approach (MA) indicators. These indicators are defined as established policies, processes and/or procedures that describe proactive management steps taken to operate farms safely and efficiently.

Similar to the approach in establishing Dimensions, this study reviewed commonalities in existing certifications regarding their approach to governance aspects, as well as relevance to Common Applicable Principles for urban and vertical farms. Table 13 below summarizes the proposed list of Management Approach indicators, aligned to Common Applicable Principles and SAFA themes.

Assessment Category	Management Approach	Common Applicable Principle	SAFA Theme
Product	MA_P1 – Practices and policies in place for minimizing food contamination.	Food Quality Maintenance	Food Quality & Information
	MA_P2 – Targets for volume of food produced and logging data for volumes harvested.	Food Quality Maintenance	Accountability
	MA_P3 – Practices and policies in place for food sanitation processes (i.e., cleaning equipment, worker cleanliness, etc.)	Food Quality Maintenance	Food Quality & Information
	MA_P4 – Adherence to Good Agricultural Practices (GAP)	Food Quality Maintenance	Food Quality & Information
	MA_P5 – List of food related local, state and national laws, codes and regulations management complies with	Food Quality Maintenance	Rule of Law
	MA_P6 – Discussion of efforts to hire local workers in the communities in which they serve.	Community Relations	Local Economy
	MA_P7 – Practices and policies in place to comply with local, state and national laws, codes and regulations on application of farm inputs.	Nutrient management / fertilizers	Rule of Law
	MA_P8 – Discussion on Integrated Pest Control/Management procedures	Pest Management / Pesticide use,	Food Quality & Information
System	MA_S1 – Process to track data on energy, water and waste consumption internally over time	Energy and Climate	Accountability
	MA_S2 – Procedures for establishing and monitoring set points on growing system (i.e., to ensure proper for temperature/lighting/water flow, etc).	Energy and Climate; Water Conservation and Management	Materials & Energy
	MA_S3 – List of building related local, state and national laws, codes and regulations management complies with	Energy and Climate	Rule of Law
	MA_S4 – Practices and policies in place to comply with building related local, state and national laws, codes and regulations	Energy and Climate	Rule of Law
	MA_S5 – Practices and procedures to minimize waste, manage crop residues, product waste and other non-chemical waste.	Waste Management	Materials & Energy
Community	MA_C1 – Health and safety policy intended to identify and minimize workers' occupational risks	Health and Safety / Working Conditions	Human Health & Safety
	MA_C2 - Policies and procedures in place that prepare workers to handle hazardous equipment/materials?	Health and Safety / Working Conditions	Human Health & Safety
	MA_C3 – Policies for employee benefits (i.e. Health or insurance plans)	Health and Safety / Working Conditions	Decent Livelihood
	MA_C4 – Discussion of practices in place to reward workplace excellence, compensation practices, bonuses.	Community Relations	Decent Livelihood
	MA_C5 – Policies and procedures in place for sexual harassment, non-discrimination and/or grievances.	Health and Safety / Working Conditions	Equity & Participation
	MA_C6 – Employee training and skills development programs implemented	Community Relations	Decent Livelihood
	MA_C7 – Employee performance review process. If yes, how often does this review process take place? (i.e., quarterly, annually, etc.?)	Health and Safety / Working Conditions	Accountability

Table 13: MA Indicator alignment with Common Applicable Principles and SAFA themes

Management Approach measurement recommendations – Product

Management Approach indicators for the Product Assessment Category were developed to provide a qualitative look into the economic resilience of the farm. For example, "Targets for volume of food produced" helps to evaluate the SAFA theme of Accountability within Good Governance by verifying systematic reviews of performance. In addition, requests for implemented policies and procedures related to sanitation and minimizing food contamination help to provide further context when evaluating the Food Quality and Information theme. Finally, the Rule of Law theme is covered through a request for management to list laws, regulations and codes adhered to as well as processes in place to ensure compliance. Table 14 below provides a summary of information reported for each Management Approach indicator for the Product category and related guidance source.

Management Approach	Requested information	Guidance Source
MA_P1 – Practices and policies in place for minimizing food contamination.	Attachment of policy	Food Alliance; Principle - Integrated Crop Management, 8.2, 9.3,
MA_P2 – Targets for volume of food produced and logging data for volumes harvested.	Discuss approach to maximize volume	Whole Foods Responsibly Grown, Pesticide Use Policy,
MA_P3 – Practices and policies in place for food sanitation processes (i.e., cleaning equipment, worker cleanliness, etc.)	Attachment of policy	USDA; §205.201 Organic production and handling system plan.
MA_P4 – Adherence to Good Agricultural Practices (GAP)	Yes or No, and attachment of policy or discussion	USDA GAP policy principles
MA_P5 – List of food related local, state and national laws, codes and regulations management complies with	Specify list of codes/regulations	USDA; §205.201 Organic production and handling system plan.
MA_P6 – Discussion of efforts to hire local workers in the communities in which they serve.	Discuss hiring approach	Rainforest Alliance, Community Relations, 7.3
MA_P7 – Practices and policies in place to comply with local, state and national laws, codes and regulations on application of farm inputs.	Discuss approach to comply with laws	Food Alliance, Safe and Fair Working Conditions
MA_P8 – Discussion on Integrated Pest Control/Management procedures	Attachment of policy or discussion	Food Alliance; Integrated Pest, Disease and Weed Management; Pesticide Risk Reduction, Criteria 1,2.3,4

Table 14: Management Approach indicators for Product Assessment Category

Management Approach measurement recommendations – System

Management Approach indicators for the System Assessment Category are intended to provide a qualitative look into the environmental integrity of the farm. The indicator "Process to track data on energy, water and waste consumption" helps to evaluate the SAFA theme of Accountability within Good Governance by verifying systematic reviews of performance. In addition, requests for implemented policies and procedures related to establishing set points on the growing system and minimizing waste help to provide further context when evaluating the Materials and Energy theme. The Rule of Law theme is covered through a request for management to list building laws, regulations and codes adhered to as well as processes in place for compliance. Table 15 below summarizes Management Approach indicators for the System category and guidance source for reference.

Management Approach	Requested information	Guidance Source
MA_S1 – Process to track data on energy, water and waste consumption internally over time	Discussion or documents outlining data tracking capability.	USDA; §205.201 Organic production and handling system plan.
MA_S2 – Procedures for establishing and monitoring set points on growing system (i.e., to ensure proper for temperature/lighting/etc.).	Attachment of policy or discussion	USDA GAP; Facility/Ice/Temperature Control, 6-6, 6-7, 6-8,6-9.6-10
MA_S3 – List of building related local, state and national laws, codes and regulations management complies with	Specify list of codes/regulations	Whole Foods Responsibly Grown, Farming Practices, Compliance with Laws
MA_S4 – Practices and policies in place to comply with building related local, state and national laws, codes and regulations	Attachment of policy or discussion	Whole Foods Responsibly Grown, Farming Practices, Compliance with Laws
MA_S5 – Practices and procedures to minimize waste, manage crop residues, product waste and other non-chemical waste.	Attachment of policy or discussion	Rainforest Alliance, Integrated Waste Management, 10.2, 10.3, 10.4, 10.5, 10.6

Table 15: Management Approach indicators for System Assessment Category

Management Approach measurement recommendations – Community

To provide a qualitative view into the social well being that farms deliver to employees and stakeholders, Management Approach indicators were developed for the Community Assessment Category. "Employee performance review process" helps to evaluate the SAFA theme of Accountability within Good Governance by verifying systematic reviews of labor performance. In addition, requests for implemented policies and procedures related to minimizing occupational risks and handling hazardous materials help to provide further context when evaluating the Human Health and Safety theme. Participation and Equity themes are addressed via management disclosures related to policy for non-discrimination, sexual harassment and grievances. Decent Livelihood is covered through a request for policies for employee benefits, training and rewarding workplace excellence. Table 16 below outlines the MA indicators for the Community category and guidance source.

Management Approach	Requested information	Guidance Source
MA_C1 – Health and safety policy intended to identify and minimize workers' occupational risks	Attachment of policy	Rainforest Alliance, Occupational Health and Safety, 6.1, 6.2, 6.3, 6.4
MA_C2 - Policies and procedures in place that prepare workers to handle hazardous equipment/materials?	Attachment of policy	Rainforest Alliance, Occupational Health and Safety, 6.4, 6.5
MA_C3 – Policies for employee benefits (i.e. Health or insurance plans)	Attachment of policy or discussion	Food Alliance, Safe and Fair Working Conditions, Employee Benefits
MA_C4 – Discussion of practices in place to reward workplace excellence, compensation practices, bonuses.	Attachment of policy or discussion	Food Alliance, Safe and Fair Working Conditions, Compensation practices
MA_C5– Policies and procedures in place for sexual harassment, non-discrimination and/or grievances.	Attachment of policy	Rainforest Alliance, Fair Treatment and Good Working Conditions for Workers, 5.11
MA_C6 – Employee training and skills development programs implemented	Attachment of policy	Food Alliance, Safe and Fair Working Conditions, Work force development and new skills training
MA_C7 – Employee performance review process. If yes, how often does this review process take place? (i.e., quarterly, annually, etc.?)	Attachment of policy or discussion	Rainforest Alliance, Health and Safety, 6.1

Table 16: Management Approach indicators for Community Assessment Category

Designing a Manageable Way to Recognize and Rate Disclosure

Annual Reporting Cadence

As many urban and vertical farms have limited time to focus on reporting organizational data, an annual reporting cadence would provide the required data, while allowing adequate time to aggregate data and structure responses ahead of a pre-determined deadline for submission. At the same time, an annual cadence would effectively capture differences between years of operation - including operating hours, food types grown, staffing, etc.

Phasing in Disclosure of Indicators

When the recommended list of Management Approach indicators are combined with the Dimensions indicators, the certification framework will include a total of 50 areas to measure. Based on this study's vertical farm interviews, there will be varying degrees of difficulty in providing data for specific metrics. For example, providing square footage of the growing facility is inherently much easier to quantify compared to volume of water consumed, as some farms may not have access to sub-meters within their building. In addition, from the experience of farms interviewed, farm management is likely to have very limited time to devote towards disclosure and reporting.[15]

As a result, it is not recommended to introduce all 50 indicators within the first year of launching the certification framework, as this is unlikely to produce accurate data and may discourage farms from participating. An example of phasing in different aspects of disclosure can be drawn from the CDP –

formerly the Carbon Disclosure Project. Based on the CDP timeline of development (Refer to Appendix IX), the first Climate related request for information was made in 2002 while a questionnaire for Water Disclosure was launched after 2009.

In a much shorter timeframe for phasing in areas of disclosure, it is recommended farms provide a core set of metrics in Year 1 with the remaining indicators phased in by Year 3 of the Certification launch. Indicators being phased in during Years 2 and 3 would be considered as either:

1) More difficult to quantify

OR

2) A more stable data point year-over-year and where Year 1 disclosure is not considered vital

With proper guidance from the AVF ahead of Years 2 and 3 of disclosure, urban and vertical farms would have time to adequately prepare internal processes for quantifying certain areas of operation. In addition, a phased approach would keep the quantity of data manageable for the AVF as processes around data collection and storage are established.

Given the recommended phased approach spanning 3 years of disclosure, Table 17 below provides a breakdown of suggested metrics to include each year after launching the certification framework.

Phase	Category	Indicator
Phase 1 (Year 1)	**Farm Characteristics**	FC_1 - Total Growing Area FC_2 - Total Facility Area FC_3 - Growing Area / Total Facility Ratio FC_4 - Food Types Grown FC_5 - Business Model FC_6 - Operating Hours FC_7 - Urban and Vertical Farm Type FC_8 - Building Integration Type FC_9 - Nutrient Delivery Method FC_10 - Growing Medium
	Product	P_1 - Annual Yield per food type P_2 - Annual Harvest count per food type P_3 - Fertilizer / added nutrient usage P_4 - Share of PT labor from local communities (%) MA_P1 – Practices and policies in place for minimizing food contamination. MA_P2 – Targets for volume of food produced and logging data for volumes harvested. MA_P3 – Practices and policies in place for food sanitation processes (i.e., cleaning equipment, worker cleanliness, etc.) MA_P4 – Adherence to Good Agricultural Practices (GAP)
	System	S_1 - Annual Energy Consumption MA_S1 – Process to track data on energy, water and waste consumption internally over time

	Community	C_1 - PT Labor Hourly Wage and FT Salary C_2 - Community Donations (lbs) MA_C1 – Health and safety policy intended to identify and minimize workers' occupational risks MA_C2 - Policies and procedures in place that prepare workers to handle hazardous equipment/materials?
Phase 2 (Year2)	**Farm Characteristics**	FC_11 - Crop Spacing
	Product	P_5 - Reservoir Flushing Frequency P_6 - Pesticide usage P_7 - % Breakdown of customer base MA_P5 – List of food related local, state and national laws, codes and regulations management complies with MA_P6 – Discussion of efforts to hire local workers in the communities in which they serve.
	System	S_2 - Total Annual Waste S_3 - Waste Diversion Rate (%) S_4 - Packaging S_5 - Water Quality MA_S2 – Procedures for establishing and monitoring set points on growing system (i.e., to ensure proper for temperature/lighting/water flow, etc). MA_S3 – List of building related local, state and national laws, codes and regulations management complies with
	Community	C_3 - Labor Breakdown of PT and FT workers MA_C3 – Policies for employee benefits (i.e. Health or insurance plans) MA_C4 – Discussion of practices in place to reward workplace excellence, compensation practices, bonuses. MA_C5 – Policies and procedures in place for sexual harassment, non-discrimination and/or grievances.
Phase 3 (Year 3)	**Product**	P_8 - Average Food Miles to reach customer MA_P7 – Practices and policies in place to comply with local, state and national laws, codes and regulations on application of farm inputs. MA_P8 – Discussion on Integrated Pest Control/Management procedures
	System	S_6- Annual Water Consumption MA_S4 – Practices and policies in place to comply with building related local, state and national laws, codes and regulations MA_S5 – Management practices and procedures to minimize waste, manage crop residues, product waste and other non-chemical waste.
	Community	C_4 - Injury and Incident Rates C_5 - Community Education (hrs) MA_C6 – Employee training and skills development programs implemented MA_C7 – Employee performance review process. If yes, how often does this review process take place? (i.e., quarterly, annually, etc.?)

Table 17: Phased Approach for Disclosure

Indicators Required as Mandatory for Disclosure

Beyond the recommended phased approach, it is necessary to set a minimum amount of disclosure needed from urban and vertical farm organizations. Without establishing a minimum level of disclosure across critical indicators, there is significant risk that data from farms cannot be adequately categorized or normalized for further analysis and benchmarking purposes. In order to adequately assess and segment their vertical farming operations, a subset of the indicators above should be defined as “Mandatory” in order to be eligible for an Overall Rating through the AVF certification framework. The list of Mandatory Indicators is shown in Table 18 below:

Mandatory Indicator
FC_1 - Total Growing Area
FC_2 - Total Facility Area
FC_3 - Growing Area / Total Facility Ratio
FC_4 - Food Types Grown
FC_5 - Business Model
FC_6 - Operating Hours
FC_7 - Urban and Vertical Farm Type
FC_8 - Building Integration Type
FC_9 - Nutrient Delivery Method
FC_10 - Growing Medium
P_1 - Annual Yield per food type
S_1 - Annual Energy Consumption

Table 18: Mandatory Indicators

As shown above, most Mandatory Indicators are derived from the Farm Characteristics category. These ensure descriptive metrics are captured about each farm while enabling the AVF to normalize data across a multitude of different farm types. For example, square footage and operating hours are necessary to consider when evaluating Energy Consumption across various sizes and types of farms. Failure to provide these indicators would drastically limit the AVF’s ability to provide an objective evaluation.

Additional Mandatory Indicators include ‘P_1 - Yield per food type’ and ‘S_1 - Annual Energy Consumption’. Yield is set as mandatory as it is required to normalize statistics on pesticide usage and added fertilizers/nutrients. Annual Energy Consumption was the only System indicator flagged as Mandatory. This assumes that at a minimum, farms have the ability to calculate their energy consumption via utility billing. Additionally, as research on urban and vertical farming suggests that energy intensity related to climate control and lighting will continue to be scrutinized within the industry, it is mandatory to prioritize this metric. Each of the Mandatory Indicators is scheduled for a Phase 1 release during the first year that farms are expected to provide disclosures to the AVF.

Scoring Indicators within an Overall Rating

For the initial framework design, weighting each of the 50 recommended indicators equally is sufficient. An Overall Rating would consist of 50 points after the entire framework is phased in during Year 3, and disclosure on each indicator would yield 1 point. Scoring should be allocated across Dimension and Management Approach indicators as in the Table 19 below.

Indicator Type	Disclosure Type	Point
Dimension	Data Submitted	1
Dimension	Data Missing	0
Management Approach	Submitted Policy/Procedure Document	1
Management Approach	Discussion on management process	1
Management Approach	No Document or Discussion on established process/policy/procedure	0

Table 19: Scoring Indicators

While this initial certification recognizes each indicator as contributing equally to an overall rating, the AVF may find it useful to assign different weightings among Dimension and Management Approach indicators. Evaluating differential factors of importance for each indicator goes beyond the scope of this study.

Overall Rating Scheme

If a farm provides disclosures on each of the Mandatory Indicators, the AVF can derive the percentage of indicators that the farm addresses by providing the required information. To simplify ratings for external stakeholders, the recommendation is to convert these percentages into a letter grade:

- 0-49% = Non-Satisfactory
- 50-69% = C
- 70-84% = B
- 85%-100% = A

The above rating scheme is a suggested starting point, and it is recommended that the AVF finalize this rating scheme based on additional industry input.

Overall Rating example

As an example, if Farm A and Farm B are seeking certification, Table 20 below shows a condensed framework of indicators equally weighted with some being flagged as Mandatory.

Indicator	Mandatory	Score	Farm A disclosed?	Farm B disclosed?
1	X	1	Yes	
2	X	1	Yes	Yes
3		1		Yes
4		1	Yes	Yes
5		1	Yes	Yes

Table 20: Indicators example

Based on each farm's submission to the AVF, Overall Ratings would be assigned as in Table 21 below.

	Farm A	Farm B
Eligible for Overall Rating?	Yes	No
Score	80%	-
Overall Rating	B	-

Table 21: Rating example

Evolving the Certification Framework

Defining Quantitative Indicators and Performance

To evolve the system from to include quantitative analysis, the AVF needs to include numerical measures with verifiable data. For urban and vertical farms, these would involve data that quantifies the inputs and outputs of a farm (e.g. energy usage, water usage, or yield). These numerical data points are expected to naturally emerge, allowing the AVF to establish benchmarks for the industry and set expected standards for performance. Meeting these standards could eventually be incentivized by introducing credits for performance within the Certification Framework, with Overall Ratings going beyond recognition for disclosure. For example, indicator 'S_1 - Annual Energy Consumption' can evolve into a performance-based credit where verifiable data tracked over time will result in valid benchmarks and standards for industry comparisons.

Performance Credit Indicators

Based on the research and framework defined above, the AVF can consider evolving the following list of indicators into performance-based credits:

- FC_3 - Growing Area / Total Facility Ratio
- P_1 - Annual Yield per food type
- P_3 - Fertilizer / added nutrient usage
- S_1 - Annual Energy Consumption
- C_1 - PT Labor Hourly Wage and FT Salary
- C_2 - Share of PT and FT labor from local communities (%)
- C_3 - Local Donations (lbs)
- P_5 - Pesticide usage
- S_2 - Total Annual Waste
- S_3 - Waste Diversion Rate (%)
- S_4 – Packaging (average or minimum Level)
- S_5 - Water Quality
- P_7 - Average Food Miles to reach customer
- S_6- Annual Water Consumption
- C_5 - Injury and Incident Rates
- C_6 - Local Education (hrs)

Expected timeline for performance benchmarking

When determining an appropriate timeline to begin benchmarking performance among AVF members, we considered the development of comparable certification programs. Specifically, the development of LEED began in 1993 through a broad-based consensus process.[16] LEED Pilot Version 1.0 launched in 1998 (5 years later), and by March 2000, only 12 buildings had been certified under the pilot program.[17] After extensive revisions during the pilot program, the USGBC launched a LEED-NC (New Construction) Green Building Rating System version 2.0 in 2005.[18] This seven-year process of data collection, improvements, revisions and learning was crucial to the success of LEED's building certification framework.

It is extremely important to draw benchmarking conclusions based upon multiyear datasets. We are choosing 3 years of data collection for each phase of indicators based on Energy Star's approach. Specifically, the EPA provides a set of benchmarks that can be used to assess energy performance for many building types and these benchmarks are developed from a national survey conducted every 4 years by the U.S. Department of Energy's Energy Information Administration. The Commercial Building Energy Consumption Survey (CBECS) gathers data on building characteristics and energy use from thousands of buildings across the United States. Using this data, the EPA creates a list of energy performance targets that are based on average energy use as calculated across different types of buildings.[19]

Given that the EPA conducts a review of CBECS data every 4 years, we suggest a 3-year minimum to collect data before a benchmark can be established for a specific indicator.

Sample Timeline for Establishing Performance Credits

Based on LEED's 6 year period of development before launching a Pilot as well as Energy Star's 4 year cycle to review CBECS data, we are suggesting the timeline detailed in Figure 7 for evolving previously identified indicators into performance based credits.

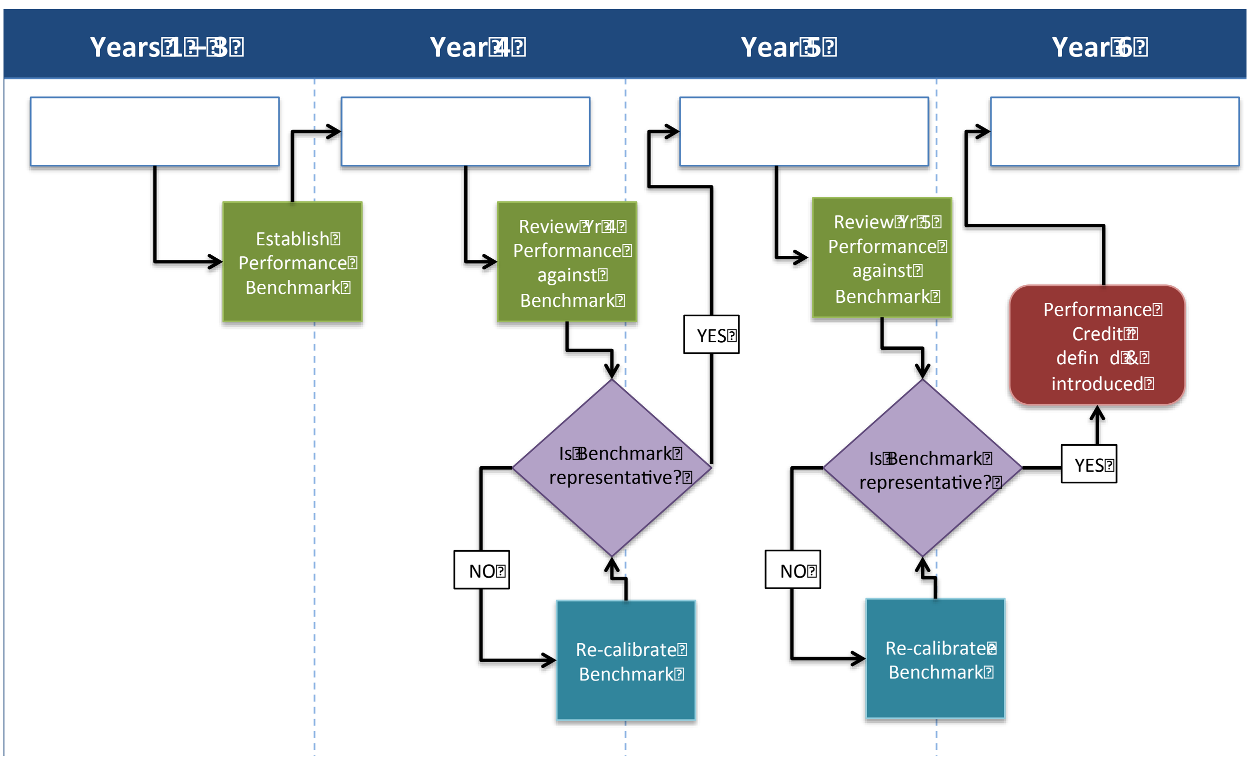

Figure 7: S1 – Annual Energy Consumption (measured by EUI)

Based on the flowchart above, a benchmark for Energy Use Intensity (EUI) would be established after Year 3 of data collection. Once established, the AVF would continue with data collection in Year 4, and farm performance for that year could be compared against the EUI benchmark. This would allow the AVF to determine whether the EUI benchmark is representative of desirable performance (e.g. top 25th percentile). It is likely that these benchmarks will need to be re-calibrated to align expected EUI performance with actual industry EUI.

Beyond Year 4 review and calibration, Year 5 would represent a similar process, and the AVF could release a pilot standard for EUI based on the verified benchmark from Year 4 performance. While this pilot standard would not be formally considered as part of the Certification and Overall Rating, it would allow the AVF to test a well-defined standard among a sample set of farms to allow for feedback, input and eventual consensus. Once this benchmark is reviewed and verified against Year 5 performance, the EUI could become a well-defined performance credit to integrate within the certification ratings ahead of Year 6 data collection.

It should be noted that this is a conservative estimate of time needed to go beyond recognizing disclosure and establishing valid benchmarks and standards. The AVF may wish to expedite this timeline, but this could potentially risk the quality of Performance Credit development.

Certification Roadmap

Based on the recommendations for reporting cadence, phasing in sections of the framework, and a timeline for developing performance credits, an 8-year outlook is provided for launch and ongoing management of this certification.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Disclosure & Data Collection								
Distribute Surveys and Guidance								
Disclosure on Phase 1 Indicators								
Disclosure on Phase 2 Indicators								
Disclosure on Phase 3 Indicators								
AVF Data Analysis								
Analyze Results								
Report Farm Ratings for Certification								
Publish Industry Insights (optional)								
Performance Benchmarking								
Aggregate Years 1-3 Data								
Establish Industry Benchmarks								
Evaluate Farm Performance against Benchmarks								
Calibrate Credit Expectations for Performance				*				
Introduce Performance Credits in Farm Ratings						1	2	3

Figure 8: Annual Snapshot of Roadmap

Notes:
* denotes pilot calibration of performance credits for Phase 1 indicators
[1] denotes performance credits introduced for Phase 1 indicators
[2] denotes performance credits introduced for Phase 2 indicators
[3] denotes performance credits introduced for Phase 3 indicators

Assuming Phase 3 disclosures are launched in Year 3, selected indicators within this phase would be benchmarked after Year 5 and integrated as performance credits ahead of Year 8 data collection.

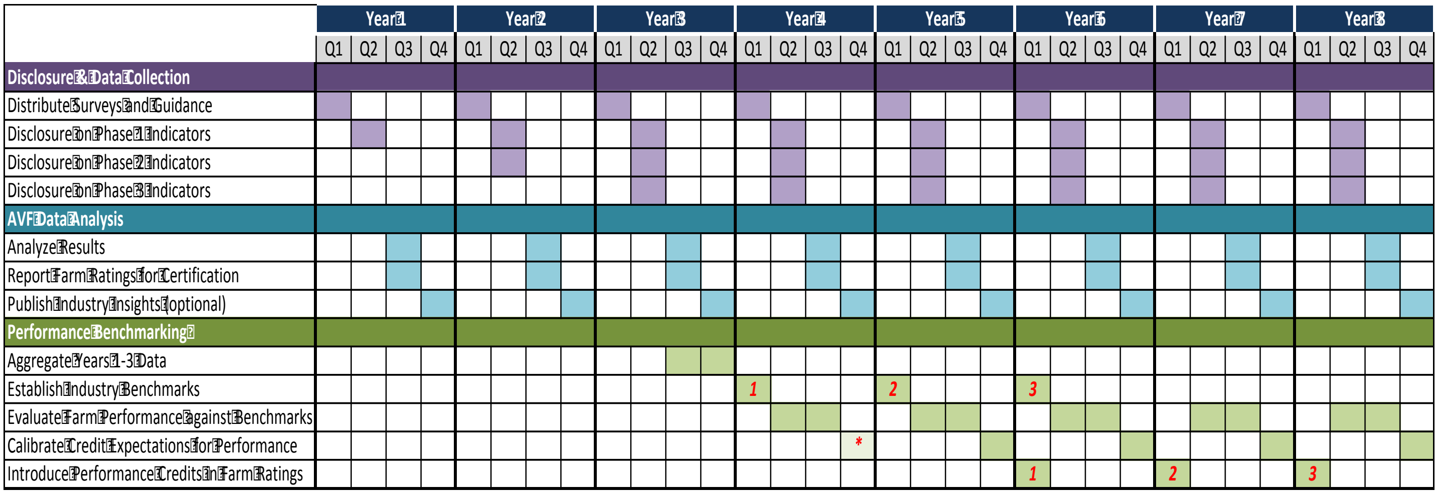

Figure 9: Quarterly Snapshot of Roadmap

The quarterly snapshot in Figure 9 above provides an approximate idea of the time that the AVF could allocate within each year of the roadmap.

- **Q1 (Jan-Mar)**
  - AVF will distribute surveys and specific disclosure guidance for industry members
  - Inform members on future indicators to be included in upcoming years
  - Establish benchmarks based on past year performance (years 4-6)
  - Integrate finalized Performance Credits (years 6-8)
- **Q2 (Apr-Jun)**
  - Farms will submit data before end of Q2
- **Q3 (Jul-Sep)**
  - Analysis of data
  - Reporting farm ratings
  - Evaluate current year performance against benchmarks (year 4 and on)
- **Q4 (Oct-Dec)**
  - Publish industry insights (optional report or newsletter to participating members)
  - Calibrate credit expectations and standards for performance based on disseminating how expected benchmark tracked against current year data (years 4-7)

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CONCLUSION

As the world population is expected to grow to 9.7 billion in 2050,[1] it is clear that conventional agriculture will not be able to meet demand in a sustainable manner. Urban and vertical farming practices have been developed in response to the growing pressures and challenges in the agricultural sector, and to bring food production closer to the more than 6 billion people expected to reside in urban areas by 2050.[2] Innovative companies have reinvented the agricultural system and designed farms that can address many of the challenges faced by conventional agriculture. Urban and vertical farms have great potential to provide cities with local food systems that are not limited by seasonality or adversely affected by weather conditions, and that do not involve the costs and environmental impacts of traditional food distribution. However, while urban and vertical farms can overcome many challenges, the industry is growing at such a rapid rate that it is not being monitored and regulated to encourage sustainable practices. From the interviews conducted with these farms, it is apparent that many urban and vertical farms do not currently collect data on basic metrics such as energy and water use and precise yield, and if information is collected it is not in a standardized format.

The Association for Vertical Farming had the vision to develop a certification system to support and encourage the sustainable growth of urban and vertical farms. The work above examines the aspects of existing certification systems that are applicable for urban and vertical farms, and identifies nine key sustainability principles from these certification systems and the urban and vertical farms interviewed. These Common Applicability Principles inform the sustainability of urban and vertical farms, and a fit analysis was created to evaluate existing farm and building certification systems to determine if the AVF should pursue a partnership to extend one of these systems to urban and vertical farms. Based on the fit analysis and the desire for the AVF to continue to adapt the certification system for a rapidly changing industry, this research recommends the development of a stand-alone certification system.

The system framework was designed around the nine Common Applicability Principles, aligned into four Assessment Categories – Farm, Product, System and Community. Across the four categories, a comprehensive list of 50 indicators was developed to capture both quantitative and qualitative data, with each metric directly relating to one of the nine principles. In order to create appropriate sustainability standards for urban and vertical farms, it is necessary to design a system that begins with data collection and benchmarking, in order to create an internal database of these metrics and begin to analyze industry practices. A phased disclosure approach is recommended, as it is not realistic to introduce all 50 indicators within the first year. Urban and vertical farms will be required to provide a core set of metrics in the first year, with remaining metrics phased in during years 2-3. To provide farms with an assessment from the outset, a simple scoring system is recommended based on the disclosure of data needed to establish performance baselines. Farms will be required to report on mandatory metrics to be eligible for a rating, and then will be given a scoring assessment based on the number of metrics disclosed. Once sufficient disclosed information is collected, the data can be used for benchmarking, and standardized quantitative criteria can eventually be applied for a performance-based certification system. This system will rely on continuous feedback from member input and is modeled after how other organizations developed their certifications, such as Food Alliance, Fair Trade, and LEED.

Utilizing the recommended measures and approach for the development of a sustainability certification for urban and vertical farms, the proposed framework design is expected to yield the following benefits for the AVF:

i. **Provide guidance on standard measures** that urban and vertical farming organizations need to measure.

ii. **Enable the AVF to establish a database** on these measurements and better define industry benchmarks over time.

iii. **Create an inclusive system early on** that allows the AVF to grow a network of certified members disclosing performance on key topics.

iv. **Promote a shared learning platform** that highlights key trends and best practices for participating industry members.

The mission of AVF is to "foster the sustainable growth and development of the Vertical Farming movement through education and collaboration".[3] The recommended framework will support this mission through the phased development of a performance-based sustainability certification system that will allow the industry to thrive and grow sustainably.

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APPENDIX I: Glossary of Terms[1]

Agriculture: is a broad term used to describe cultivation of plants, livestock, fungi, and other life forms to serve human interests in the form of resources.

Aquaponics: (or pisciponics), is a food production system that combines conventional aquaculture, (raising aquatic animals such as snails, fish, crayfish or prawns in tanks), with hydroponics (cultivating plants in water) in a symbiotic environment. The goal of aquaponics is to be a more efficient and sustainable form of food production.

Artificial light: any lighting that is not sunlight

Blue light: blue grow lights are used to foster vegetative growth of plants, and have a wavelength between 400-500 nm.

Building integrated agriculture (BIA): the practice of locating high performance hydroponic greenhouse farming systems on and in mixed use buildings to exploit synergies between the built environment and agriculture.

Carbon dioxide (CO_2): a colorless, tasteless and odorless gas that is a necessary input to the photosynthetic process. It occurs naturally in the atmosphere at approximately 400 parts per million.

Controlled-environment agriculture (CEA): is any agricultural technology that enables the grower to manipulate a crop's environment to the desired conditions. CEA technologies include greenhouse, hydroponics, aquaculture, and aquaponics. Controlled variables include temperature, humidity, pH, and nutrient analysis.

Energy: is power derived from either physical or chemical resources, which is mostly used to create light or heat, or to power machinery. Energy can be produced from sustainable sources such as solar or wind power, or from non-renewable resources such as coal or natural gas.

Fertilizer: is material that is added to either soil or, in the case of hydroponics, the nutrient solution that provides one or multiple necessary nutrients. It can be derived from synthetic or naturally-occurring sources, and can be either organic or inorganic.

Food safety: refers to the conditions and practices that preserve the quality of food to prevent contamination and foodborne illnesses.

Food security: refers to the availability of food and one's access to it.

Greenhouse: (also called a glasshouse) is a building in which plants are grown. These structures range in size from small sheds to industrial-sized buildings.

Harvest: as an action, to collect plants (or their fruits) for consumption or use. As an event, time of growing season when crops are harvested.

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Horticulture: is the branch of agriculture that deals with the art, science, technology, and business of plant cultivation. It includes the cultivation of fruits, vegetables, nuts, seeds, herbs, sprouts, mushrooms, algae, flowers, seaweeds and non-food crops such as grass and ornamental trees and plants. It also includes plant conservation, landscape restoration, landscape and garden design, construction, and maintenance, and arboriculture.

Hydroponics: is a subset of hydroculture and is a method of growing plants using mineral nutrient solutions, in water, without soil. Terrestrial plants may be grown with their roots in the mineral nutrient solution only or in an inert medium, such as perlite, gravel, mineral wool, expanded clay pebbles or coconut husk.

Indoor farming: is often done to foster a controlled environment for whatever plants are being grown. It's a great method for growing all year around (even in Winter), and hydroponics is often employed.

Integrated pest management (IPM): an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Also referred to as integrated pest control (IPC).

Light emitting diode (LED): is a relatively inexpensive and efficient lighting option for any grower. The spectrum LEDs provide can be easily customized, as a wide variety of color options are now offered.

Nutrients: are components in food that are utilized by organisms to survive and grow. They are typically divided into macronutrients, which provide the majority of energy needed, and micronutrients, which aid in metabolism.

Organic: refers to any material that is, or is derived from, living matter. The term is also used in food production, referring to food that is produced without synthetic fertilizers or pesticides (and other rules and regulations that differ per location).

Perennial: crops that return season after season.

pH: stands for "potential of hydrogen", and represents the acidity or alkalinity of a solution. Soil pH typically falls between 4 and 8, with optimal nutrient availability for most plants existing between 6.5 and 7.0.

Photosynthetic photon flux (PPF): the number of micromoles of photosynthetically active radiation (PAR) irradiating a square meter of space every second.

Recirculating system: any hydroponic system that operates as a closed loop and does not have any runoff as part of normal operation. Also known as a recovery system.

Red light: red grow lights are used to foster flowering in plants, and have a wavelength between 600-700 nm.

Reservoir: in general terms, a reservoir is an area, usually man-made, where a liquid is stored. In hydroponics, it refers to the area of the setup where nutrient solution is stored.

Rockwool: is also commonly known as mineral wool or stone wool, is widely used in commercial hydroponic applications and for plant propagation. Most of the tomatoes you see in your local store are grown hydroponically using rockwool. However, rockwool can be used in various hydroponic set-ups to grow a whole host of delicious crops. Rockwool itself is an inert medium, which is made by melting basaltic rock. This melted mixture is then spun into thin fibers, which are cooled by air.

Seedling: a young plant developing out of a plant embryo from a seed.

Soilless agriculture: broadly refers to, and is based on the concept that plants do not require soil to grow. A variety of methods are employed, all of them allowing for significant environmental benefits (see hydroponics).

Transpiration: the passage of water through a plant from the roots through the vascular system to the atmosphere.

Urban agriculture: is the practice of cultivating, processing, and distributing food in or around a village, town, or city.[1] Urban agriculture can also involve animal husbandry, aquaculture, agroforestry, and horticulture. These activities also occur in peri-urban areas as well.

Vertical farm(ing): is a closed vertically stacked growing system. It enables farmers to achieve constant production of plants – all year round without seasonal, regional or climatic influences. The modern idea of vertical farming uses Controlled Environment Agriculture (CEA) technology, where all environmental factors can be controlled. These facilities utilize artificial control of light, environmental control (humidity, temperature, gases) and fertigation. Some vertical farms make use of techniques similar to greenhouses, where natural sunlight can be augmented with artificial lighting.

APPENDIX II: Estimated Yield of a Vertical Farm Compared to Traditional Agriculture[2]

Crops	Yield in VF due to Tech (tons/ha)	Field Yield (tons/ha)	Factor increase due to Tech	Factor increase due to Tech and Stacking
Carrots	58	30	1.9	347
Radish	23	15	1.5	829
Potatoes	150	28	5.4	552
Tomatoes	155	45	3.4	548
Pepper	133	30	4.4	704
Strawberry	69	30	2.3	368
Peas	9	6	1.5	283
Cabbage	67	50	1.3	215
Lettuce	37	25	1.5	709
Spinach	22	12	1.8	820
Total (Average)	**71**	**28**	**2.5**	**516**

Source: Designed in a CE Study by the author at DLR Bremen.

[2] Banerjee, Chirantan and Lucie Adenaeuer. "Up, Up and Away! The Economics of Vertical Farming." *Journal of Agricultural Studies.* 2.1. (2014): 40-60. Web. 5 Nov. 2015.

APPENDIX III: Urban and Vertical Farm Questionnaire

QUESTIONNAIRE

1. Farm Name.
2. Farm Type (Rooftop/Facade/Interior/On Ground/Underground/Other).
3. Full Address.
4. Year Established.
5. Number of campuses & approximate operating hours per campus per week.
6. Size (SF) of Each Facility.
7. Types of Crops.
8. Growing Method (Hydroponic/Aquaponic/Aeroponic/Soil/Other).
9. Are there any special design specifications within your system that are particularly innovative? Describe.
10. # of Harvests/Year per crop.
11. Length of Growing Season (months) per crop.
12. Production (lbs/yr) per crop.
13. Production (lbs/day) per crop.
14. Production purpose/target market.
15. Method of product distribution/transportation.
16. Avg. miles food travel from farm to clients.
17. Fertilizers: Type, quantity and frequency of use per crop.
18. Pesticides: Type, quantity and frequency of use per crop.
19. Packaging methods & types used per crop. Any preservatives used?
20. Product price comparison to market price of conventional product.
21. Product price comparison to market price of certified organic product.
22. Biggest Challenges / Issues in Operations and Sustainability.
23. Have they tried to certify? What types of certs? Why or why not?
24. Opinion on Bldg Rating Systems & Relevance to VF: LEED, Passive House, Energy Star, BREEAM, etc.
24. Opinion on Certified Organic & other produce rating systems and applicability to VF.
25. Is CO_2 Captured at facility? How?
26. Is air quality tracking system in place? Describe.
26. Annual quantity of water consumed, in cubic feet or meters.
27. Is water saved/harvested? How? How much (gallons)?
28. What kind of lighting system used at facility?
29. How much natural day lighting available at facility? (Hrs/day or % of day).
30. Annual electricity consumption (kWh).
31. % of energy expense in relation to total operating costs.
32. List annual quantity of each fuel used, in BTU or Therms.
33. Volume of waste produced by system (lbs/yr) - list by waste type, including food waste.
34. How much waste diverted from landfills (composted/recycled)? Diversion rate in %.
35. Please describe food sanitation practices at your facility.
36. Did you use any recycled material in building your facility?
37. What types of metrics do you think should be standardized across the VF industry?
38. Please indicate importance of the following practices in being a successful and sustainable vertical farm.
    Assign importance to each category on a scale from 1 (least important) to 5 (most important):
    - Energy Efficiency

- Water Efficiency
- Food Quality
- Waste Produced
- Distribution/Supply Chain Footprint
- Community Service
- Management Philosophy/Approach/Policy

39. Any additional comments? Information? Guidelines? Recommendations?

OPTIONAL EMPLOYMENT/OPERATIONS QUESTIONS

1. What is your employee breakdown by gender? (%)
2. What is your employee breakdown by race? American Indian or Alaskan Native/Caucasian/Black or African American/Pacific Islander/Other.
3. What is your employee breakdown by ethnicity? Hispanic or Latino/Not Hispanic or Latino.
4. What is the average salary per employee?
5. What is your estimated annual revenue?
6. What is your estimated operating profit?
7. What is your turnover percentage?
8. Do you provide any on-the-job training to employees? If yes, please explain.
9. Do you provide health insurance to employees?
10. Does your organization record injury rates? If yes, please provide incidence rate.
11. Other employment comments or information.

APPENDIX IV: Certification Systems Interview Questionnaire

1. **How many participants/organizations submit applications annually?**
    - 0-50
    - 50-150
    - 150-250
    - 250 or more

    Specify # if possible: ___________________________________

2. **Do you segment performance by set categories or geography?**
    Select all that apply.
    - Categories (i.e. Building or food category)
    - Regions
    - Country
    - Other, specify: ____

3. **How do you award certification?**
    - Percentile (i.e. Top 25%)
    - Total Points above threshold
    - Other, specify: ______________________________

4. **Is the certification a single threshold or segmented into levels of certification?**
    - Tiered – i.e.) Silver, Gold, Platinum
    - Single threshold – i.e.) Energy Star

5. **Is participation voluntary or mandated by government/industry regulation?**
    - Voluntary
    - Mandatory

6. **How is performance benchmarked? Is there a publicly available dataset for the industry or is it based on evaluation of participating peers?**
    - Based on performance among <u>participating</u> peers
    - Compared against universal dataset (i.e. CBECS)
    - Existing point system – LEED based on industry consensus
    - Other, specify: ____

7. **Is there a fee to be certified?**
    - Yes
    - No

    IF yes, is fee based on per…
    - Application
    - Volume of certified product

8. **How often is certification or recertification required?**
- One time
- Annual
- Every 5 years
- Other, specify

9. **How do you assign weighting to categories?**
Select all that apply

- Industry consensus
- Analysis of impact on overall performance/desired goals
- Expert review
- Other, specify: ______________________________

10. **How long does it take to award certification/review/validate data?**
- Less than 4 weeks
- 1 month to 2 months
- More than 2 months
- Other, specify

11. **How often are benchmarks recalibrated for new certifications and recertifications?**

- Annually
- 2-5 years
- 5-10 years
- More than 10 years
- Never

APPENDIX V: Sustainability Principles

Refer to attached spreadsheet entitled 'Sustainability Principles for Certification'.

APPENDIX VI: Detailed Fit Analysis Tables and Results

	Principle Coverage Score	Coverage Rating	Criteria Applicability	Applicability Rating	Scope of Certification (# of Criteria)	Scope Rating	Geography	Geography Rating	Inclusiveness of Certification Eligibility	Eligibility Rating	Total Average Rating
RA-SAN	89%	3.00	69%	3.00	100.00	2.00	Tropical subtropical(1)	1.00	minimum general score in order to obtain SAN certification is 80%. Must be in full compliance with all critical criteria.	1.00	**2.25**
Food Alliance	44%	1.00	63%	2.00	40.00	3.00	North America	3.00	Must achive average of 3 out of 4 demonstrating progressive management while meeting legal/industry standards	2.00	**2.03**
Whole Foods Responsibly Grown	78%	2.00	71%	3.00	41.00	3.00	United States	3.00	Applies only to farms which Wholefoods selects for procurement	1.00	**2.43**
USDA Organic	33%	1.00	47%	2.00	47.00	3.00	United States	3.00	Farms using organic production must comply with the USDA organic regulations for materials and adopt standard growing practices	2.00	**2.03**

	Principle Coverage Score	Coverage Rating	Criteria Applicability	Applicability Rating	Scope of Certification (# of Criteria)	Scope Rating	Geography	Geography Rating	Inclusiveness of Certification Eligibility	Eligibility Rating	Total Average Rating
USDA GAP-GHP	56%	2.00	58%	2.00	213.00	1.00	North America	3.00	Standards and requirements to combat the increasing instances of foodborne illnesses throughout the United States	3.00	**2.15**
Fair Trade	78%	2.00	49%	2.00	332.00	1.00	Developing economies	1.00	Products given label based on meeting requirements on levels of traceability, labor practice and environmental standards	2.00	**1.70**
Certified Greenhouse Farmers	78%	2.00	67%	-	61.00	-	North America	-		-	-
FA Greenhouse and Nurseries	78%	2.00	71%	3.00	48.00	3.00	United States	3.00	First introduced as a self assessment tool but now follows traditional FA certification requirements	2.00	**2.58**

	Principle Coverage Score	Coverage Rating	Criteria Applicability	Applicability Rating	Scope of Certification (# of Criteria)	Scope Rating	Geography	Geography Rating	Inclusiveness of Certification Eligibility	Eligibility Rating	Total Average Rating
Energy Star	56%	2.00	100%	3.00	23.00	3.00	Australia, Canad,Europe , United States	3.00	Top 25th percentile will be E-Star Certified	1.00	**2.43**
LEED	56%	2.00	54%	2.00	136.00	2.00	Global	3.00	Point rating system - above 40 is considered Leed Certified	2.00	**2.15**
BREEAM	67%	2.00	38%	1.00	236.00	1.00	Europe	1.00	Benchmarks and minimum standards - Pass: Top 75% of UK new non-domestic buildings (standard good practice)	2.00	**1.43**
LIVING BUILDING CHALLENGE	67%	2.00	19%	1.00	21.00	3.00	Global	3.00	"Defines the most advanced measure of sustainability"	1.00	**1.88**

APPENDIX VII: The Evolution and Development of Existing Certification Systems

Food Alliance

The Food Alliance certification was originally developed in 1994 as a project to establish market incentives for the adoption of sustainable agricultural practices.[3] This proposal, called The Northwest Food Alliance, began in 1995 with the primary purpose of sponsoring *on-farm research and data collection* through collaborating with growers and various other industry players. Focusing on both the supply and demand side of the food system, the Northwest Food Alliance incorporated farm research and consumer interest data to understand the market potential and popularity of a sustainable certification.[4] Once the Northwest Food Alliance realized the market potential of this project in 1997, this started the process that eventually led to the development of today's Food Alliance.

The organization then developed "stewardship guidelines" (focusing on fair labor practices, pest and disease management, and soil and water conservation) that defined sustainable agricultural practices for fruit and vegetable growers.[5] With these guidelines in place, the Food Alliance continued to expand their reach by harnessing the power of an eco-labeling program for suppliers (as a way to distinguish their products in a growing marketplace), and by pushing demand through developing programs to raise consumer awareness of certified products.[6] Within the first year, the Food Alliance had 16 participating farms with over 80 varieties of fruits and vegetables. Through this success, the Food Alliance continued to grow through *strategic partnerships* (such as with the Cooperative Development Services and the Land Stewardship Project) to expand its system to include various other standards.[7] A volunteer Stewardship Council of industry stakeholders was then created to continually affairs, labor, animal welfare and the environment, representatives of the food industry continually advise on and refine its certification standards.[8] This led to a partnership with the International Certification Service and a proliferation of 175 certified farms and over 200 products entering multiple markets.

The Food Alliance utilized initial farm and market research to establish a toolkit that allowed the organization to understand supply and demand patterns, allowing them to evolve with emerging needs. This process can be replicated by the Association for Vertical Farming as the organization develops standards and a certification framework for sustainable urban and vertical farming. Following the Food Alliance's approach, the AVF can take the initial steps of data collection before beginning to develop a certification system. AVF can also utilize strategic partnerships to continuously expand its reach and offerings.

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[3] "History of Food Alliance." — *Food Alliance*. Web. 4 Dec. 2015.
[4] Ibid.
[5] Ibid.
[6] Ibid.
[7] Ibid.
[8] Ibid.

Fair Trade USA

Since Fair Trade USA (FTU) was established in 1998, it has evolved to become the leading third-party certifier of Fair Trade products in the United States.[9] FTU certification involves buying from certified farms and organizations that pass rigorous supply chain audits. FTU uses SCS Global Services to provide assistance in the revision, piloting and implementation of FTU's standards.[10] SCS is an independent third-party certification body with 30 years' experience, and they handle the technical aspects of FTU's evaluation tools used for inspection. SCS provides a certification manual that includes the prerequisites for participation in FTU's program, a step-by-step description of the certification process, and the fee schedule for auditing.

The process to draft standards involves consulting key experts and stakeholders, such as certification bodies, for guidance. The VP of Standards approves the first draft, and another party (disclosed in the project plan) approves the public draft. This public draft standard is published on FTU's website in order to solicit feedback from stakeholders via teleconferences, meetings, personal conversations, webinars and written submissions, for a period of 60 days. The comments are considered and a new draft is created for a second round of public stakeholder feedback, and the last step is executive approval of the final version of the standard. A public summary of the comments received for each consultation round and how they were considered, is published on the Fair Trade USA website.[11] The process of collecting stakeholder feedback and making enhancements in line with suggestions allows certification frameworks to dynamically evolve with industry feedback.

Rainforest Alliance

The Rainforest Alliance is another notable and respected sustainable agriculture certification body that has developed its certification framework over time. Similar to the development of the AVF, the Rainforest Alliance formed out of the need to structure a growing industry. The group developed out of a concern for declining forest-cover in Ecuador and Costa Rica due to the massive growth in the banana industry between 1988 and 1994, and the Rainforest Alliance was able to step in as a mediator between those concerned about the environmental damage the industry was having, and the growers making a profit.[12] The organization, with Costa Rican conservationists, developed a study to assess the social and environmental issues that the banana industry was causing. Through a detailed study and "on-the-ground" data collection, the Rainforest Alliance was able to develop a proposal to create sustainable standards for the banana industry. This standard considered each major issue (ecosystem conservation, wildlife conservation, fair treatment and good conditions for workers, community relations, integrated pest management, integrated waste management, soil conservation, and environmental planning and monitoring) identified through the data collection and analysis process, and then developed a

[9] "About Fair Trade USA." *Fair Trade USA.* 2015. Web. 12 Oct. 2015.
[10] Ibid.
[11] Ibid.
[12] "Rainforest Alliance." *Frequently Asked Questions About RA-Cert*. Web. 4 Dec. 2015.

comprehensive action plan to effectively enact change. [13] Through the convening of multiple relevant stakeholders, the Rainforest Alliance was able to create nine general guiding principles and a detailed account of best farm management practices. These were then successfully tested on two independent banana producers (one in Hawaii in 1992, and one in Costa Rica in 1993).

The Rainforest Alliance began its certification process through physical data collection and understanding the pressures of current market needs. The organization consulted with various industry stakeholders to develop a strict yet realistic management approach, which was then proven successful through the initial pilot studies. This success then launched the Rainforest Alliance into an international governing body, greatly expanding its reach, influence and ability, and this model can be followed by the AVF.

LEED

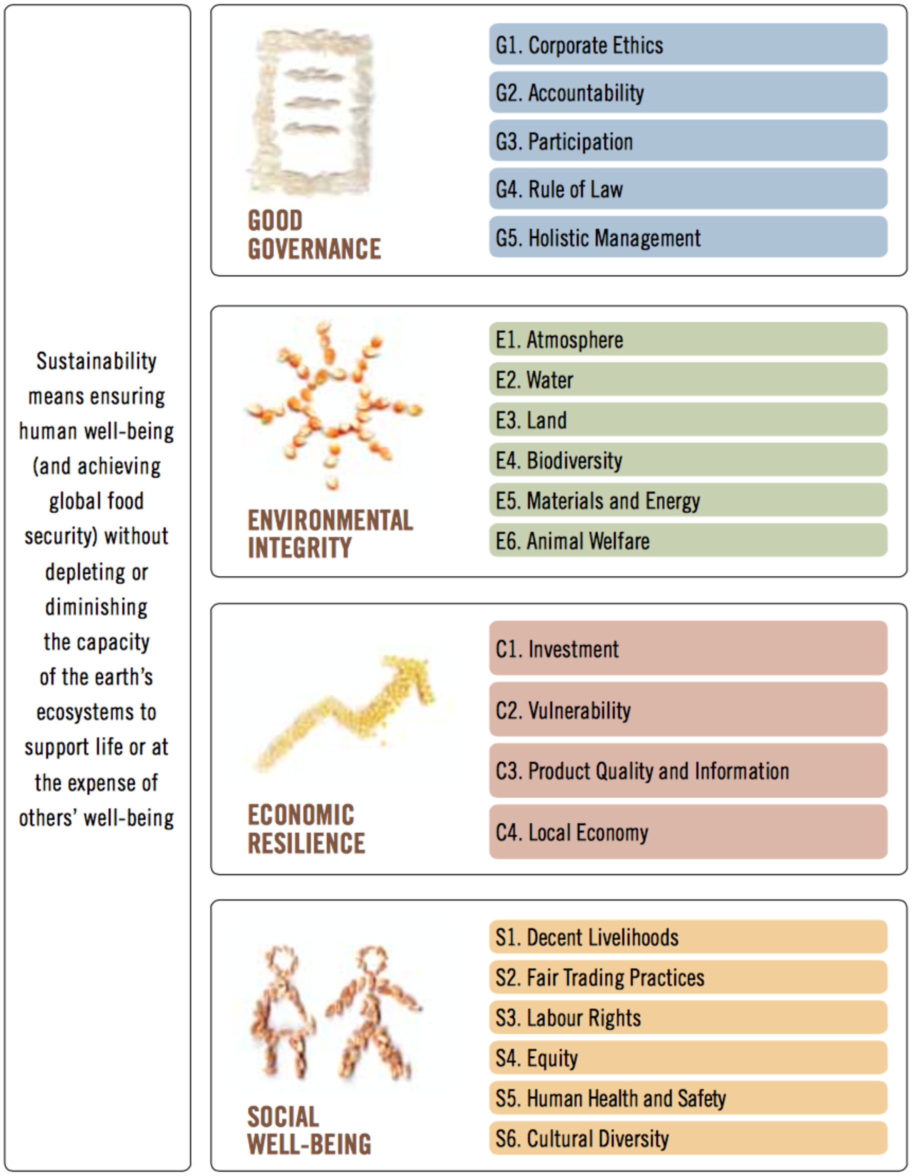
LEED rating systems are developed through an open, consensus-based process led by US Green Building Council (USGBC) member-based volunteer committees, subcommittees, and working groups, in conjunction with USGBC staff, and are then subject to review and approval by the LEED Steering Committee and the USGBC Board of Directors prior to a vote by USGBC members.[14] Development of LEED began in 1993 through an inclusive process that included non-profit organizations, government agencies, architects, engineers, developers, builders, product manufacturers and other industry stakeholders. Pilot Version 1.0 launched in 1998, and by March 2000, only 12 buildings had been certified under the pilot program. After extensive revisions during the pilot program, USGBC launched LEED version 2.0. This seven-year process of data collection, improvements, revisions and learning was crucial to the success of LEED's building certification framework. Since the initial launch, the certification system has grown to include a portfolio of rating system products that serve specific market sectors including: Homes, Neighborhood Development (ND), Commercial Interiors (CI), Core and Shell, New Construction (NC - and Major Renovations), Existing Building (Operations and Maintenance), Schools, Retail (CI), and Healthcare. Private and public sector demand led to the creation of the range of LEED certifications, to address the complexity and variation of buildings across different sectors.[15]

LEED has made requirements increasingly more stringent, and LEED v4 (launched in 2013) set higher benchmarking goals and introduced new prerequisites for certification. LEED v4 is a market-driven, consensus-based, evolving framework that adapts and integrates new technologies, as well as new ideas and input from industry professionals. LEED v4 is the result of three years of rigorous critical review, incorporating public and market comment, and refining and improving all aspects of LEED. LEED v4 will increase technical stringency and maintain new, more rigorous requirements and will represent significant improvement in carbon reduction and human health.[16]

[13] "Our History." *Rainforest Alliance.* Web. 4 Dec. 2015.
[14] "About | U.S. Green Building Council." *U.S. Green Building Council*. Web. 4 Dec. 2015.
[15] "LEED | U.S. Green Building Council." *U.S. Green Building Council*. Web. 4 Dec. 2015.
[16] Richards, Jennie. "Green Building: A Retrospective on the History of LEED Certification." Institute for Environmental Entrepreneurship. (2012): Web. 03 Dec. 2015.

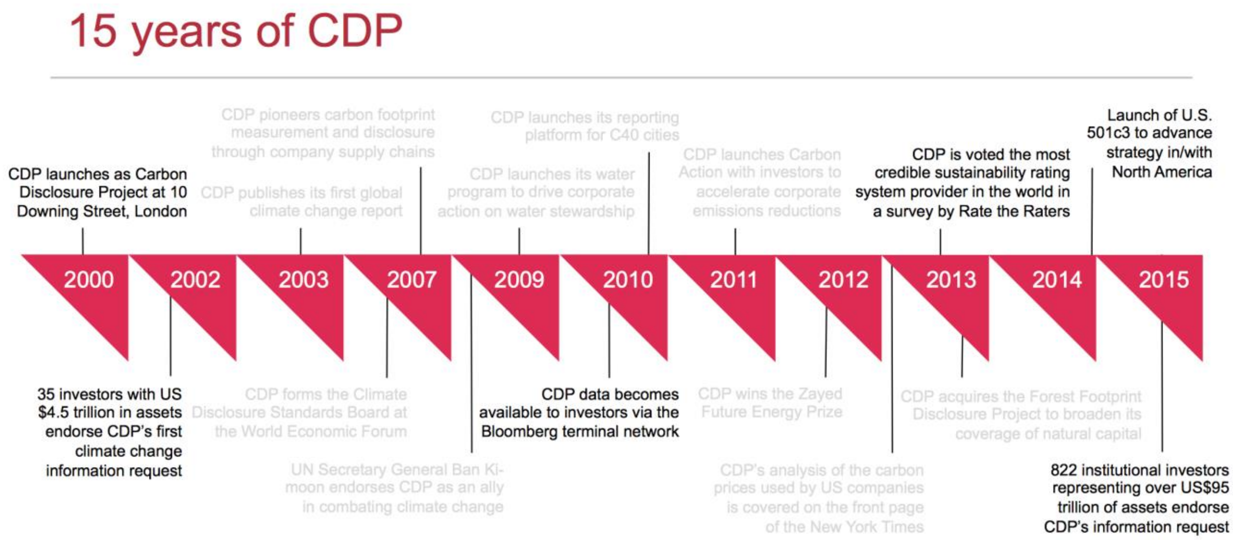
The evolution of LEED highlights the importance of a collaborative, continuously improving process over time to develop a successful certification framework. The evolution and development of LEED and the other certifications mentioned above illustrate a critical need for certification systems to conduct a lengthy and robust process for data collection and learning. The incorporation of strategic partnerships with industry stakeholders will further inform this process and allow for growth, and the AVF can pursue a similar process in developing an industry standard and certification for sustainable urban and vertical farming.

APPENDIX VIII: SAFA Sustainability Dimensions and Themes[17]



[17] "Sustainability Assessment of Food and Agriculture systems" SAFA Guidelines." *Food and Agricultural Organization of the United Nations* V3.0, pg. 20 (2013): Web. 03 Dec. 2015.

APPENDIX IX: CDP Development Timeline[18]



18 "CDP Questionnaires". *CDP Driving Sustainable Economies*. 2015. Web. 05 Dec.2015