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Eco-Entrepreneurship Final Report

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Brief Description of Eco-E Venture

OrganicMatters manufactures certified organic fertilizer out of poultry waste from the egg industry. Our process brings a food system byproduct into the mainstream organic fertilizer market and lowers farmers' production costs and environmental risks. Our mission is to provide certified organic crop farmers with food-safe, nutrient-rich, affordable fertilizers that mitigate human, animal and environmental health problems associated with conventional poultry manure management strategies.
Executive Summary

Venture Overview

OrganicMatters manufactures certified organic fertilizer out of poultry waste from the egg industry. By drying and pelleting poultry manure, we create a high-value organic fertilizer that can be used by a wide range of crop growers, landscapers, and gardeners. Our third-party partnerships with egg producers provide more sustainable manure management and thus lowers these farmers’ current production and environmental risks.

Problem

The US egg industry produces approximately 45,000 tons of poultry manure every day. Laying hen manure is a natural source of nutrients like nitrogen, phosphorus, and potassium, and has been used as a fertilizer and soil amendment for generations. Conventional manure management strategy is to transport raw manure directly from poultry farms and apply the material to nearby cropland. However, in areas where large-scale poultry farming has become very concentrated, land application of manure has led to over-fertilization and water degradation by nutrient overloading. In these areas, land-application of manure has become restricted, and the manure is stored in heaps or pits. The chemical nature of poultry manure makes it susceptible to environmental degradation, and the nutrients can escape through off-gassing (volatilization) or leaching (water run-off).

As with all fertilizers, there is a seasonality of demand for poultry manure. Fertilizers are typically in high demand before and during the early crop-growing season, and experience lower demand the rest of the year. Poultry manure experiences extremely low demand during non-growing season, and the odor problems associated with the storage of manure can lead to continuous complaints from neighbors. Additionally, manure that is applied during the wet months of the year is extremely susceptible to nutrient leaching and runoff. As with over-fertilized regions, poultry manure that is generated during low-demand season must be stored. The longer the manure sits in storage, the more nutrients it loses, thereby lowering its value.

Because of this, manure is an inconsistent revenue stream for poultry farmers. These farmers can receive $10-30 per ton for poultry manure during the growing season, but have trouble giving the material away during the winter, even for free. Due to nutrient volatilization and leaching, poultry manure that has been stored for months is not as valuable as fresh manure.

Despite this unfortunate fate for poultry manure, there are crop growers that wish to use it. Whenever possible, poultry manure typically is sent to fertilize corn fields that produce animal feed. However, the USDA qualifies poultry manure as a certified-organic fertilizer – even if the manure comes from conventional poultry farms. However, due to food-safety risks from pathogens like E. coli and Salmonella, raw poultry manure cannot be used in instances where it comes in direct contact with crops grown for human consumption. As a result, many organic
crop growers are forced to choose between affordable options like mulches and compost that are nutrient-poor, or expensive fertilizer blends that have higher nutrient content.

Solution

At OrganicMatters, we see the perfect opportunity to provide organic crop growers with a cost-effective, nutrient-dense fertilizer that can mitigate the environmental problems due to poultry manure’s seasonal demand. By drying and pelleting poultry manure, we mitigate many of the environmental problems associated with conventional manure management, and create an odorless, food-safe, organic fertilizer that can be utilized by a wider range of crop growers.

First, we arrange long term contracts with clusters of regionally-localized egg-laying farms and provide manure drying technology to each operation. As part of the agreement, we guarantee to pay the egg producer a consistent rate for each dried ton of product. By offering on-site manure drying and pickup, our process removes odor and fly problems that egg producers normally deal with. The manure is chopped into pellets and then dried creating a shelf-stable, pathogen-free, odorless fertilizer. The final product will be then transported to our centralized packaging facility packaged into 1-ton super sacks for wholesale distribution.

Drying and pelleting poultry manure reduces environmental impact of manure and increase its selling value. Drying the manure and processing the dried material into fertilizer pellets reduces the weight of manure and preserves nitrogen content, which results in a high value final product (over $200 per ton of poultry manure pellets). However, due to the specialized equipment required, drying and pelleting has a high capital investment, and can cost an egg producer between $1.5 – 5 million.

Similar to the third-party partner method commonly utilized by anaerobic digester systems and dairy farms in the United States, OrganicMatters partners with large-scale egg producers to provide revenue for these operations’ manure and shift the capital costs of equipment. OrganicMatters provides the opportunity to scale on-site manure drying and pelleting systems industry-wide. Our market due diligence uncovered five egg-producing operations on the West Coast that have recently begun to dry and process (pellet or compost) their waste, but these facilities service only a fraction of the 45 large-scale West Coast operations. Several market barriers hinder wider adoption of drying across the industry. Fit-for-purpose equipment designed to treat poultry manure at smaller, large-scale operations (100k-500K hens) is not readily available and custom-built units are rare and expensive. Smaller, large-scale egg farms currently have a need for manure dryers, yet the technology available is often too large and costly for their operation. Rotary drum biomass dryers comprise the clear majority of manure drying systems available on the market, but are expensive and extremely energy intensive and operationally inefficient. Additionally, egg farmers often lack technical expertise or desire to manufacture consistent fertilizer and bring it to market. We utilize newer, modular, more technologically advanced biomass drying technology and provide third-party partnership to
shift the capital expenses of these dryers off of the egg producer and provide technical expertise for this technology.

**Fertilizer Market Analysis**

Pelleted poultry manure is a high nutrient organic fertilizer that can be used in many agricultural sectors. Although a subset within the conventional US food market, U.S. certified organic food sales have experienced double-digit growth nearly every year since the 1990s and are still on the rise. Certified organic crop growers are required to follow strict procedures, including the use of certified organic fertilizers. In 2014, U.S. market sales of certified organic fertilizers were over $390 MM, with close to 60% of sales occurring in California, Oregon, and Washington. Certified organic crop farmers have severely limited choices of fertilizer and are not always satisfied with current options available on the market.

**Impact**

Our manure drying system can reduce air and water quality degradation posed by conventional manure management. Drying the manure significantly reduces the material's ammonia and greenhouse gas emissions, and poultry manure pellets release nutrients into soils at a slower rate than raw manure, which minimizes nitrogen and phosphorus water pollution. Our vision is to integrate the OrganicMatters product into conventional chemical fertilizer applications. If our product is used cooperatively with synthetic fertilizers in conventional crop farming, it would further offset greenhouse gas emissions associated with the production of chemical nitrogen.

**Management Team**

**Jacob R. Levine, Co-Founder and Chief Executive Officer:** Jacob is a Master’s candidate at the Bren School of Environmental Science & Management focusing in Eco-Entrepreneurship and Pollution Prevention and Remediation. Jacob has 3 years of analytical experience within the financial and energy sectors performing quantitative analysis, market due diligence and regulatory analysis. He attended The George Washington University where he obtained a dual bachelor's degrees in Statistics and Economics in 2014.

**Lauren Catlin, Co-Founder and Chief Impact Officer:** Lauren is a Master’s candidate at the Bren School of Environmental Science & Management focusing in Eco-Entrepreneurship and Pollution Prevention and Remediation. Lauren has two years of laboratory, field biology and forestry experience. She graduated summa cum laude from Fort Lewis College in 2014 with a degree in Biology.
Part 1
Environmental Problem and Policy Analysis

The application and storage of laying hen manure pose environmental problems, namely air and water quality degradation. Manure management regulations have limited the areas to which manure can be applied, incurring extra costs to poultry operations. Regulations and transportation costs associated with manure application have contributed to the US transition towards chemical fertilizers, which contribute significantly to global greenhouse gas emissions.
Background

Market pressures and changes in technology have resulted in a transition from small farms to industrial Confined Animal Feeding Operations (CAFOs) in the United States. A CAFO is defined by the USEPA as “an animal feeding operation that confines 1,000 animal units or more at any one time”. Since the 1950s, the number of farms selling eggs in the US has decreased, while their size has increased. Between 1997 and 2012, the average number of hens on large egg farms has grown from 399,000 to 695,000 birds. In 2012, 49.3 percent of egg-laying hens in the US were located in five states: Iowa, Ohio, Indiana, California, and Texas.

The 360 million hens in the USDA inventory generate roughly 45,000 tons of manure every day. Poultry manure has traditionally been used as a fertilizer and soil amendment for generations. The age-old manure management strategy has been to transport raw manure directly from poultry farms and apply the material - either by broadcasting, tilling, or injecting - to neighboring cropland. However, in areas where large-scale poultry farming has become very concentrated and there is not sufficient acreage of nearby cropland, land application of manure has led to over-fertilization of the available acres. Widespread manure distribution is limited by the transportation costs, so most of the material is spread on cropland less than 100 miles from the sourcing poultry farm.

Poultry manure is inefficient to transport due to its water content. Fresh egg-layer manure is 65% water. At 2% nitrogen content, a typical 40-ton semi-truck full of egg-layer manure can carry and deliver 0.8 tons nitrogen. The same semi-truck carrying urea anhydrous ammonia, a chemical fertilizer with 30% nitrogen content, can deliver 12 tons of nitrogen. This huge discrepancy in nutrient delivery contributes to the regional restrictions of poultry litter application, as well as the wide-spread adoption of chemical fertilizers.

The geographic location of an egg farm determines the fate of the manure, because of the high transportation costs associated with raw manure. For example, a poultry farm in Iowa surrounded by ample crop acreage will be in high demand. Poultry farms in areas with fewer crop acres and near urban areas (where manure application leads to odor nuisance complaints) will have more problems associated with applying the manure to nearby cropland.
Figure 1. Density map depicting concentration of egg-laying CAFOs in counties throughout the United States. Yellow areas depict no density, orange is moderate to high density, and red is extreme density (Food & Water Watch, USDA).

Laying Hen Manure as a Fertilizer
Poultry manure is the most nutrient-dense livestock manure. The nutrient value differs between egg-laying hen operations and broiler operations due to the composition of the animals’ feed. Broilers are housed in large structures and live on the floor with a variety of bedding materials like rice hulls and/or straw, which becomes mixed with the manure. Egg-laying hens are typically housed in a stacked orientation, either in cages or an open aviary system.\(^{10}\) The manure can be collected on belts that run below each layer of cages. Fresh egg-layer manure usually consists of 2% nitrogen (40lb nitrogen/ton manure), while fresh broiler manure consists of roughly 3% nitrogen (64lb nitrogen/ton manure).\(^{11}\)

Environmental Problems Associated with Poultry Manure
When exposed to the environment, the nutrient composition in poultry manure can degrade rapidly. The leaching of nitrogen, phosphorus, and other nutrients from nutrient runoff can lead to surface water eutrophication, and the volatilization of gases from poultry manure can result in air quality problems.\(^{12}\)

Agricultural runoff is the primary source of nitrogen and phosphorus contamination of surface and groundwater in the United States.\(^{13}\) Water quality degradation can occur
when manure is still in the poultry housing structure, as it is transported from poultry house to place of application, and during/after land application. Most water quality issues associated with poultry manure occur after land application. Improper timing of application, excessive amounts of manure applied, and lack of manure incorporation into soils can contribute to nutrient leaching and runoff from poultry manure.\textsuperscript{14,15} Excess nutrients are susceptible to being washed away by rain and can result in the eutrophication of surface waters. The Chesapeake Bay Watershed has been the most prevalent example of this phenomena with the decline of shellfish populations in response to excessive nutrient loading.\textsuperscript{16}

Numerous studies have found that improper poultry litter applications have contributed to increased nitrate levels in drinking water.\textsuperscript{17,18} 31 states have confirmed nitrate groundwater contamination.\textsuperscript{18} The increased nitrate levels in many of these areas vastly exceed the U.S. EPA Maximum Contamination Limits (MCLs) for drinking water, which can persist for decades eventually causing Methaemoglobinemia, colloquially known as Blue Baby Syndrome.\textsuperscript{19,20} The nitrate reduces the ability of infants’ red blood cells to carry oxygen leading to respiratory issues, vomiting and diarrhea. Vulnerability of nitrate contamination is particularly present in lower income, rural areas with large amounts of agricultural developments due to high rates of nitrogen deposition due to manure.\textsuperscript{21}

Raw poultry manure is extremely susceptible to ammonia volatilization. The uric acid in poultry manure is easily degraded by microbes that convert the acid into ammonia, which is a volatile compound.\textsuperscript{22} If mixed well into soil, the ammonia can be mineralized and nitrified by soil microbes into other “plant-friendly” forms of nitrogen: ammonium (NH\textsubscript{4}\textsuperscript{+}) and nitrate (NO\textsubscript{3}\textsuperscript{-}).\textsuperscript{23} If exposed to open air, however, poultry manure loses much of its nitrogen to ammonia volatilization. Ammonia is an air pollutant and can move great distances from its source. Ammonia generated by a poultry farm can migrate to remote areas, where it has the potential to damage sensitive ecosystems. Ammonia can deposit on remote vegetation and fertilize plants through the leaves. This may select for nonnative species over native plants and lead to ecological disruptions.\textsuperscript{24} Additionally, excessive ammonia concentrations can be dangerous for humans and hens in the production facilities.\textsuperscript{25} The United Egg Producers recommend ammonia levels below 10ppm for ideal chicken health, and research has shown that egg-laying hens experience adverse health effects at ammonia concentrations exceeding 25ppm.\textsuperscript{26} Raw manure also fosters the breeding of flies, which pose a huge threat to egg producers as flies can carry diseases into the poultry facilities. In addition, manure buildup and mismanagement can lead to inspector visits leading to shut down of the facility until the situation is remedied.\textsuperscript{27}

There are greenhouse gas (GHG) emissions associated with poultry manure. Aside from carbon dioxide (CO\textsubscript{2}), methane (CH\textsubscript{4}) and nitrous oxide (N\textsubscript{2}O) are the most common
greenhouse gases found in our atmosphere. Methane and nitrous oxide both possess global warming potentials much greater than carbon dioxide, making them potent GHGs. Methane and nitrous oxide are released during manure storage, though the quantity of GHGs emitted by the poultry industry is a mere fraction of the quantity emitted by the dairy sector. The most significant GHG emissions from manure management in the CA egg industry is the release of nitrous oxide. California estimated that 47 tons of nitrous oxide were emitted (14,020 CO₂ equivalent) in 2014. GHG emissions occur beyond storage of manure. Methane and nitrous oxide are released during land application, but is only observable when manure broadcasted (not incorporated or injected into the soil).

Chemical Fertilizer Use and the Environment
Chemical fertilizers have long since replaced manure as the most widespread fertilizer in the US. Chemical fertilizer use has increased in the United States since the 1980s, mostly driven by increases in corn production. In 2011, the US agricultural sector consumed 22 million tons of commercial fertilizer. Nitrogen fertilizers are the most common variety used (over potash and phosphate) due to higher yield responses for a majority of crops. Nitrogen used in chemical fertilizers is synthetically produced via the Haber-Bosch process and generates substantial greenhouse gas emissions.

Chemical nitrogen is generated synthetically via the Haber-Bosch process, which involves a catalyst, typically iron-based, to react atmospheric nitrogen with hydrogen from natural gas to form ammonia. This process is extremely energy-intensive and contributes significantly to global greenhouse gas emissions. A commercial fertilizer plant that utilizes Best Available Technology (BAT) with catalytic abatement technology produces 3.6 tons CO₂ equivalent per ton of nitrogen. A commercial fertilizer plant that does not utilize BAT produces 7.8 tons CO₂ equivalent per ton of nitrogen.

As with poultry manure, the over-application of chemical fertilizers contributes to air and water quality degradation through ammonia volatilization and nutrient runoff. The quick-release nature of chemical fertilizers makes them very susceptible for nutrient leaching. Additionally, chemical fertilizers were consistently being over-applied in the 1990s, which overloaded soils above the nutrient-uptake rate of most crops. In 1996, farmers were over-fertilizing crops about 17% more than the recommended rate per acre.

Manure Management and Environmental Policies
Historically, manure management has been regulated by the Clean Water Act. Manure, excess fertilizer, and soil erosion from agriculture are some of the largest contributors to nitrogen and phosphorus water pollution in the US. The US EPA revised Clean Water Act
regulations in 2003 to address surface water eutrophication problems associated with CAFOs.\textsuperscript{38} CAFOs are required by the State or US EPA to obtain point-source discharge permits.\textsuperscript{39} These National Pollutant Discharge Elimination System (NPDES) permits specify the effluent limit guidelines for the CAFO that generates manure and also the land that will receive the manure.\textsuperscript{40} CAFOs are required to have a nutrient management plan for the land that is receiving the CAFO’s manure that outlines the application rate for manure nutrients. The nutrient management plans are based on specific crop needs and contain information regarding how much manure can be applied to a specified acreage.\textsuperscript{41}

Because nutrient management plans limit how much manure can be spread on manure recipient acres compared to past application rates, CAFOs have two options: (1) They can send the manure to a wider land base to adequately dilute the manure. This has sparked interest in improving the efficiency of transporting manure.\textsuperscript{42} (2) Alternatively, CAFOs may try to encourage nitrogen losses from the manure by leaving it susceptible to ammonia volatilization so that, over time, the manure loses enough nitrogen to meet the nutrient management plan’s limit for a certain acreage.\textsuperscript{43} Egg-laying CAFOs are limited to 6 months of manure storage time. Excessive storage or leakage problems can lead to fines for the egg-laying facility.\textsuperscript{44}

Ammonia emissions, though not strictly regulated at the moment, are an area of concern for CAFOs. Environmental groups supporting the Clean Air Act have placed more pressure on regulatory agencies to regulate the air emissions from CAFOs.\textsuperscript{45} Ammonia emissions from large poultry farms are under increasing scrutiny.\textsuperscript{46} The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) requires that ammonia emissions that exceed a “reportable quantity” in a 24 hour period be reported to the National Response Center.\textsuperscript{47} For egg-laying CAFOs, if a facility emits more than 150kg of ammonia, the emissions need to be reported immediately.
Part 1 References

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Part 2
Business Model Environment
Fertilizer Market, Egg and Manure Market, and Competitive Analysis
Fertilizer Market Context

Industry Definition
“This industry primarily manufactures fertilizer products. These products contain a different mixture of the three vital nutrients essential for plant growth: nitrogen, phosphorus and potassium. The products are distributed via wholesale arrangements with third parties or, in the case of vertically integrated operations, by the manufacturer.”

Total Available Market: USA Fertilizer
In 2015, the USA fertilizer industry reported more than $23.3 B in revenue. The US fertilizer customer base is enormous, with an estimated 2.1 million farms in 2012. The same year reported 389.7 acres in the US dedicated to growing crops (914.5 million acres for all agriculture).

![Figure 2. Target available, serviceable available, and serviceable obtainable markets for OrganicMatters](image)

Serviceable Available Market: USA Organic Fertilizer
Although most of the US fertilizer market consists of chemical fertilizers, there is a rapidly growing subset of fertilizer buyers that is only interested in organic fertilizers: organic crop growers. Because organic foods must be produced in a manner that does not use chemical pesticides or fertilizers, growers of these foods need to use fertilizers that do not contain synthetic inputs. The organic fertilizer market consists of natural-organic, animal-waste, and sewage-origin fertilizers.

The US organic fertilizer market reached $407.8MM in 2014. This estimate includes USDA certified organic and exempt products, including lime and soil conditioners.

Organic food sales have experienced double-digit growth nearly every year since the 1990s, and the trend shows more growth. As sales increase, so does certified organic acreage.
Organic fruit and vegetable acreage grew 39 percent from 2011-2014, and acreage for certified organic field crops grew 9 percent in the same time span. The USDA estimated $3.5 B in organic produce sales in 2015, and 2.4 million certified organic produce acres for the same year.

![Figure 3. Percent organic food sales growth in the United States between 2000 and 2014. Only three years (2009-2011) experienced growth less than 10%.](image)

**Serviceable Obtainable Market (SOM): West-Coast Organic Fertilizer**

The West Coast dominates organic sales in the US. In 2014, California organic sales were $2.2B, Washington $525MM, and Oregon $237MM. In 2015, of the 2.4 million acres of organic cropland in the US, the West Coast held 20% of organic acreage in production. California experienced 18% growth in organic produce acreage between 2011-2015.

To meet these impressive organic sales, the West Coast also consumes the majority of organic fertilizer in the US. 70% or organic fertilizer sales happen in the West Coast, and more growth is likely. Fertilizer sales for this region grew from $154MM to $234MM between 2008 and 2014, a 51% increase. The organic fertilizer market for this region was estimated to be $234M M in 2014. (Broken down by state: CA: $196.9MM, WA $24MM, and OR: $6 M).
Transportation costs significantly contribute to the final selling price. Because fertilizer manufacturers often sell to customers that are located within a certain geographic distance, we have landed on the West Coast as our target market. The booming organic industry in this region overlaps ideally with a number of egg-laying facilities (Figure 5 and 6).

**Egg and Manure Market Contexts**

**Egg Industry Context**

OrganicMatters utilizes a waste byproduct, which creates a unique business model environment. Our product feedstock is poultry waste from the egg industry. In order to understand the true market potential of this avoided waste product, an understanding of the market forces which drive the industry are crucial for success in this mature commodity market. Commodities, by definition, are practically indistinguishable from each other, which requires firms operating in the space to be “price takers” of the market, and therefore have low profit margins.

**Ideal Market Overlap**

As previously stated, our target market to sell fertilizer is the West Coast. We find ideal market overlap between the demand for our final fertilizer product and supply of our feedstock.
Moreover, it was uncovered during customer discovery research that high quality organic fertilizers are in short supply. Ninety-five percent of West Coast egg-laying operations are controlled by 45 operations with collectively own 27 million hens (3,400 tons of manure per day).14 As stated previously, these large operations overlap ideally with the booming organic crop acreage in CA, OR, and WA (Figure 5 and 6). We believe that these large egg operations will provide ample feedstock supply to launch our business.

![Figure 5. Number of West Coast egg-laying farms with over 100,000 chickens by county (2014)](image)

**Laying Hen Production Cycles**

Enriched cage egg farmers stock the laying hens in stacked cages for 52 to 85 week cycles. Below the cages are manure conveyor belts to constantly remove manure from each cage level, as seen Figure 6. Typically, the manure is stockpiled in a permanent structure after it is removed from the layer house before being transported and applied on nearby (<100 miles) cropland.
Figure 6. Schematic depicting stacked cages and manure belts.\textsuperscript{15}

There are rules regarding the location, size and other aspects of the storage facility which vary state and even on the county level.\textsuperscript{16,17,18} The ideal conventional management strategy was to haul and spread manure to neighboring farms as depending on the accumulation rate of manure and as needed by the poultry farmer and the nutrient management plan (NMP) of the receiving cropland.

**Hen Housing Trends**

As a fertilizer manufacturer that relies on manure for feedstock, OrganicMatters needs consistent manure collection. The possibility and ease of collecting manure depends on the style of hen house in which eggs are produced. The designs of hen houses within the egg industry have been in a period of transition over the past 15 years. Due to increased pressure from consumers and the government, the entire livestock industry has had to change its husbandry practices. In November of 2008, California passed Proposition 2, which prohibits the confinement of animals in any manner that does not allow them to turn around freely, lie down, stand up, and fully extend their limbs. An accessory bill was passed into law in 2010 which banned the sale of any out-of-state eggs produced in "extreme-confinement" from being sold in California.\textsuperscript{19} To comply with the new regulation, egg farmers chose from the few options available. Most switched from conventional battery cage systems to furnished or enriched cages (Figure 7 and 8). Some have switched to cage-free aviary systems (Figure 9) or simply removed partitions from battery cages to satisfy stocking density requirements.
Despite these changes, it is still possible for all three of these types of housing systems to have manure belts running beneath the hens, which ensures the quickest and easiest method of manure removal. These manure belts are extremely convenient for on-site drying systems, as they can feed manure straight into a biomass dryer, rather than monthly (or yearly) scraping and piling of manure that is typical for non-belt systems.
Existing Manure Management Strategies and the Market for Manure

Albeit inconsistent, manure is a revenue stream for poultry and egg producers. Most manure is left untreated and hauled to nearby fields as a fertilizer. This manure cannot be used on food crops for human consumption. To meet the demand for food-safety, some egg producers compost or dry and pellet their manure.

Haul and Spread
Hauling and spreading manure on neighboring fields is the predominant manure management strategy across the country. Farmers who pursue haul and spread management view manure as a liability and a byproduct of their business, not an asset. Due to this fact, the poultry farmer pursues the easiest, technologically and logistically simple management strategy. The manure is either hauled by the individual poultry farmer or by a third-party manure management business. Interviews with manure managers in the industry stated that hauling and spreading has the cheapest upfront cost, requiring solely a truck, a small crew and a wheel loader shown in Figure 10. The value of raw manure depends on the farm, but most raw poultry manure can be sold for $0-35 per ton during high-demand season. Due to the high transportation costs and low sale price of raw manure, transportation distances are limited to 100 miles or less.

This method is facing difficulties as increasingly stringent environmental regulations have been implemented to deal with the air and water quality problems. As the regulatory constraints placed on poultry farmers continues to restrict land application rates of manure, the transportation costs associated with this disposal method increase. Volumes of manure that
exceed an egg-laying CAFO’s nutrient management plan must be stored or sent further away, which reduces the value of the manure.

**Compost**
As a result of more stringent land application restrictions, some poultry farmers have turned to composting. Composting laying hen manure is an effective strategy to deal with the manure and turn it into an asset. A compost facility has larger upfront costs than a hauling and spreading operation due to the land required, compost equipment, air quality and land-use permits, fertilizer license, etc. In addition, composting has higher operating costs as the system requires more labor, has higher machinery maintenance costs, and requires expertise to manage the sensitive process in order to ensure a consistent final product.

A well-managed compost operation can demand $75-90 dollars per ton wholesale to farmers. Composted poultry manure is often sold as a soil amendment and not a fertilizer because its nutrients cannot be guaranteed batch to batch. Soil amendments improve physical conditions of a soil whereas fertilizers add nutrients. In addition, as explained in early sections, the longer manure sits naturally, the less nutrients are contained in the finished compost thereby reducing its value. Well managed compost that complies with USDA organic standards can be applied to organic crops, however high-dollar specialty row crops (leafy greens, heirloom tomatoes and beets, Persian cucumbers, etc.) have been hesitant to use manure compost due to the risk of the liability from pathogen contamination.

Although compost is a step in the right direction to increase the lifecycle of this waste product, it does not maximize the potential value. Moreover, in certain locations, it is increasingly hard to receive permits to start a large-scale compost facility in general due the particulate matter and ammonia emissions from the piles.

**Drying and Pelleting**
Maximizing the value from manure within the poultry industry is a relatively new process. As land application of raw manure becomes more restricted, two processes are increasingly adopted as sustainable management strategies: composting and pelleting. The goal the processes is to: dry and heat the material enough to reduce ammonia emissions and remove pathogens, and preserve nutrients to increase the value of the finished product. This strategy has been shown to increase the shelf life and customer base of manure products, as manure pellets can be used on certified organic food crops, if processed appropriately.

Drying and pelleting initially costs more than all manure management strategies, but produces a high value final product. It reduces the weight in a matter of days, fully halts ammonia emissions, which preserves nitrogen nutrients within the material. There are a variety of market barriers hindering wider adoption of this practice across the industry. Poultry farmers face high capital investments to purchase, permit and install the drying and pelleting facility.
Additionally, these farmers often lack the expertise to manufacture consistent fertilizer and bring it to market.

Fit-for-purpose equipment designed to treat poultry manure at smaller, large-scale operations (100k-750K hens) is not readily available and custom-built units are rare and expensive.\textsuperscript{32,33,34,35,36} Rotary drum dryers comprise the clear majority of manure drying systems available on the market.\textsuperscript{37,38,39,40} These dryers have high capital costs ($1.5MM-$5MM), are extremely energy intensive (approximately 2,000 Btu per pound of water removed) and operationally inefficient. Poultry farmers face high capital investments to purchase, permit and install the drying and pelleting facility. These farmers often lack the expertise to manufacture consistent fertilizer and bring it to market.

**Competitor Analysis**

Our market due diligence uncovered five egg-producing operations on the West Coast that have recently begun to dry and process (either compost or pellet) their waste, but these facilities service only a fraction of the 45 large-scale West Coast operations. Several market barriers hinder wider adoption of drying across the industry. The operations include: Hickman’s Family Farms, True Organic, Organic Farms/Nature Tech Fertilizers, Weber Family Farms and Stuzman Organic Products. The information gathered was obtained through industry expert interviews and provides a partial picture of their operations.

**Hickman’s Family Farms**

Hickman’s Family Farm is a conglomerate of 6 laying hen farms, each with over 500,000 birds: 3 in Arizona, 2 in California, 1 in Colorado.\textsuperscript{41} To manufacture fertilizers, they use manure belts to move manure out of the houses and spread it in thin layers on concrete pads to compost and sun-dry. Following the drying process, they pellet the manure. Their final product is a 4-2-2 and OMRI certified organic product. They distribute their product wholesale in 1-ton super sacks and truckloads. In addition, they sell a portion of their product to retail in 20 and 40 pound bags. Their total production capacity is unknown.

**True Organic Inc.**

True Organic claims to be the largest manufacturer of organic fertilizers on the West Coast. Through interviews with farmers who sell their manure to True Organic, we were able to determine their process. True Organic partners with the some of the larger operations in California and guarantees to purchase semi-composted manure. They bring the moist manure to their central processing plant where they heat it using industrial rotary drum dryers and blend the material into a host of products with varying nutrient capabilities. They not only handle laying hens, but also receive manure from broilers and turkeys. They are also OMRI certified.
Organic Farms Fertilizers
Organic Farms Fertilizer is a foster farms subsidiary. According to the installer of their systems, California Mill Equipment, Organic Farms forms partnerships with their contract growers to buy manure from them at a low price. They transport the manure at 20% moisture to their centralized processing plant. At this facility they utilize a 15-year-old conventional rotary drum dryer to dehydrate the manure, however they do not guarantee pathogen removal and are therefore not certified organic. They primarily sell their product to golf courses, landscaping and sports turf. They also sell their product through wholesale and retail channels.

Weber Family Farms
Mike Weber, one of our external advisers, owns and operates an egg farm with over 360,000 hens and is in the process of expanding to over 600,000. He invested in a custom build drying and pelleting operation on his own farm to convert the liabilities associated with manure into assets. He invested approximately $2.5 million in order to guarantee pathogen reduction to ensure the product can be used on food crops. His product is certified organic and he currently sells directly to certified organic growers and fertilizer brokers. His operation currently produces 4,700 tons of pelleted product, which he sells for $200/ton. Although Mr. Weber has successfully implemented drying and pelleting technology on his own farm, interview research indicated that many egg producers are preoccupied with egg business and do not wish to complicate their existing model by starting a fertilizer manufacturing business, as well as being unwilling to provide the capital investment for the necessary machinery (n=7).

Stutzman Organic Products
Stutzman Organic Products is the only pelleting operation in Oregon State. The company handles both broiler and laying hen manure from 20 and 3 farms, respectively. They offer two distinct products, keep the manures separate throughout their processes, produce a pelleted product from egg layers and a composted product out of broilers. They do not own any of the birds that they service and set up contracts to purchase the manure from the poultry operations. To source their feedstock, they perform scheduled barn clean outs. They transport the semi-composted layer hen manure to their offsite drying and pelleting plant, where they produce a certified organic pellet. They utilize a conventional rotary drum dryer for their laying hen manure.

Other Organic Fertilizers
Organic growers are prohibited from using fertilizers made from synthetic inputs. Besides poultry manure, organic fertilizer options include compost blends, bone/feather meal, bat guano, and fish emulsion blends (Figure 12). Bone and feather meal, fish meal, and green waste composts are sourced from industry by-products. Some organic crop producers use “green manure”, which involves planting a layer of legumes and tilling the plant matter between crop cycles.
Class A biosolids – biosolids that have undergone adequate de-watering and heating - recovered from wastewater treatment plants can also be used as organic fertilizer. The approximate selling prices of these fertilizers (along with manures) are listed in Table 1.

Table 1. Organic fertilizers and nitrogen content, selling price, and release rate.\textsuperscript{53}

<table>
<thead>
<tr>
<th>Source of N</th>
<th>%N</th>
<th>Example Freight on Board ($/Ton)</th>
<th>Release Rate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh dairy manure</td>
<td>0.5</td>
<td>8</td>
<td>medium</td>
<td>0.5-0.1-0.5, has weed seeds, consistency varies</td>
</tr>
<tr>
<td>Fresh cage layer manure</td>
<td>1.5</td>
<td>15</td>
<td>rapid</td>
<td>1.5-1-0.5, may be hard to handle, can burn</td>
</tr>
<tr>
<td>Poultry manure compost</td>
<td>4</td>
<td>251</td>
<td>slow</td>
<td>3-4-3 analysis varies, may be pelletized</td>
</tr>
<tr>
<td>Finished ‘field’ compost</td>
<td>1.2</td>
<td>25</td>
<td>slow</td>
<td>1-1-1 analysis varies, aids soil ‘health’</td>
</tr>
<tr>
<td>Legume hay</td>
<td>2.5</td>
<td>you grow</td>
<td>medium</td>
<td>strong stand with tops provides most N</td>
</tr>
<tr>
<td>Grass hay</td>
<td>1.2</td>
<td>you grow</td>
<td>medium</td>
<td>releases N when young; old growth ties N up</td>
</tr>
<tr>
<td>Alfalfa meal</td>
<td>2.7</td>
<td>348</td>
<td>medium</td>
<td>3-0.5-3, feed grade by the ton</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>6</td>
<td>314</td>
<td>medium</td>
<td>6-1-2, feed grade by the ton</td>
</tr>
<tr>
<td>Blood meal</td>
<td>12</td>
<td>1146</td>
<td>rapid</td>
<td>13-2-0, mad cow risk similar to eating meat</td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>6</td>
<td>738</td>
<td>slow</td>
<td>6-2-2 analysis, 85% water insoluble N</td>
</tr>
<tr>
<td>Crab meal</td>
<td>5</td>
<td>628</td>
<td>medium</td>
<td>5-2-0.5 analysis, 15% Ca</td>
</tr>
<tr>
<td>Fish meal</td>
<td>9</td>
<td>1157</td>
<td>rapid</td>
<td>9-3-0, smelly, dusty, may contain high salts</td>
</tr>
<tr>
<td>Feather meal</td>
<td>10</td>
<td>968</td>
<td>very slow</td>
<td>contains protein slow to break down</td>
</tr>
<tr>
<td>Chilean nitrate</td>
<td>16</td>
<td>500</td>
<td>rapid</td>
<td>organic standards limit usage</td>
</tr>
<tr>
<td>‘Pro-Gro’5-3-4</td>
<td>5</td>
<td>340</td>
<td>medium</td>
<td>balanced organic fertilizer blend</td>
</tr>
<tr>
<td>‘Pro-Booster’10-0-0</td>
<td>10</td>
<td>375</td>
<td>medium</td>
<td>vegetable and plant meals plus 1/3 Chilean</td>
</tr>
</tbody>
</table>

OrganicMatters poultry manure pellets offer medium-high nitrogen content (4-5%) at a competitive price compared to other organic fertilizer options. OrganicMatters pellets are similar in nutrient content and price to some organic fertilizer blends. These blends, like “Pro-Gro” 5-3-4 (Table 1), consist of a combination of organic materials. ‘Pro-Gro’ 5-3-4, a Vermont-based organic fertilizer blend, consists of vegetable protein meals, animal protein meals (blood meal, crab meal, dried whey, feather meal, and fish meal), bone char, pasteurized poultry litter.
sulfate of potash, greensand, phosphate rock, and nitrate of soda.\textsuperscript{54} With just one ingredient, OrganicMatters pellets ensure supply-chain transparency so customers are fully aware of the source of their fertilizer. In the food and agriculture industry, customers are becoming increasingly concerned about where their food comes from, how it is made, and what is in it.\textsuperscript{55} With extremely limited ingredients, OrganicMatters fertilizers can be accurately labeled and the source of our feedstock (the location of our partner egg farms) can be traced. Our product offers organic crop growers a transparent and traceable input for their crop growing needs.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure11.png}
\caption{OrganicMatters competitive analysis petal diagram.}
\end{figure}
Part 2 References

3 Ibid.
6 Ibid.
12 Ibid.
13 Ibid.
24 Mark Pierce (Pierce Litter Service) interviewed by Lauren Catlin of OrganicMatters in Santa Barbara, California 10/10/16
25 Ibid.
Part 3

Proposed Business Model

OrganicMatters manufactures dry pellet fertilizer out of poultry waste from the egg industry and offers the opportunity to scale industry-wide. We form third-party partnerships with egg producers to dry manure on-site and bring poultry manure pellets into the mainstream organic fertilizer market. Our mission is to provide certified organic crop farmers with food-safe, nutrient-rich, affordable fertilizers that mitigate human, animal and environmental health problems associated with conventional poultry manure management strategies.
Customer Segments

Organic Crop Growers
OrganicMatters’ product meets the demand of agricultural customers, large and small, across a wide range of crops and applications. Poultry manure, when dried and pelleted appropriately, is a very balanced, high nutrient fertilizer that can satisfy both conventional agriculture and the rapidly expanding organic sector.\textsuperscript{1,2,3,4,5,6,7} Industry and customer interviews validated that the nutrient load of pelleted poultry manure fertilizer can feasibly meet the requirements of high-dollar specialty crop producers, cannabis growers, landscapers, nurseries and environmentally-conscious gardeners (n=25).

Organic produce growers are limited in their choice of fertilizer. Through customer discovery research, it was uncovered that untreated poultry manure is the lowest cost form of nitrogen fertilizer that an organic farmer can buy, however it is not readily available to these farmers. Additionally, crop growers seeking food-safe fertilizer products cannot use untreated manure as it presents pathogen risks. As previously stated, poultry manure is high in moisture making it cost prohibitive to transport long distances, so it is usually spread on cropland within 100 miles of the poultry farm. This means that most poultry manure is being applied to land that is closest to the poultry farms, not necessarily land that is nutrient-deficit.

Home Gardeners
OrganicMatters pellets are not limited to agricultural use. Our product can meet the needs of environmentally-conscious home gardeners. The pellets are easily applied to soil by hand, and can be distributed to home and garden stores in 20-40lb bags.

Conventional Fertilizer Users
Although our goal is to integrate our product into conventional agricultural practices, we recognize that organic growers are earlier on in their adoption pathway and are more likely to use innovative products. Additionally, conventional fertilizer users might not be willing to pay a price premium for the benefits offered by our product. We hope that, after successful adoption by organic growers, conventional growers will recognize the benefits like the slow-release mechanism, micronutrient content, and water-retention offered by our pellets.

Value Proposition to Crop Growers
OrganicMatters creates organic fertilizer that is more affordable than other organic options without sacrificing nutrient content. Our product provides additional soil benefits, which in turn can reduce operational expenses faced by organic crop growers. Our
pelleted fertilizers can be easily applied to any field with traditional dry fertilizer application machinery or by hand at organic farms. Pelleted products release nutrients at slower rates than alternatives (granules or liquid) allowing for more efficient uptake by the crops, reducing waste and nutrient runoff. Unlike most competitive products, poultry manure provides additional micronutrients (calcium, zinc and magnesium), thereby lowering additional expenses on concentrated micronutrient products. Unlike most conventional and organic fertilizers, poultry manure has high concentrations of organic matter, which builds healthy soil structure, increasing water retention and decreasing soil erosion.

**Key Partners: Egg Producers**

To source our feedstock, OrganicMatters forms partnerships with a cluster of regionally-localized egg-laying farms to provide our drying technology for free at each site. We will transfer all liability for the manure to our company and agree to pay the farmer a consistent rate per ton of dried product. In addition, OrganicMatters will manage and maintain the dryer to ensure maximum efficiency from the system. Drying manure quickly after excretion maximizes nutrient concentrations, mitigates environmental impacts, and reduces transportation costs. The dried manure, will then be automatically conveyed into a storage hopper where it will remain until a full truckload can be removed and transported to our offsite, centralized processing facility. At the processing facility it will be pelleted, packaged and shipped to our customers (Figure 13).

**Why should an egg farmer work with us?**

As previously mentioned, interviews with poultry and egg producers indicated that these producers are often content producing chickens and eggs and do not wish to complicate their existing model by starting a fertilizer manufacturing business (n=7). In addition, they may not have the time or skill set necessary to produce consistent fertilizers and bring them to market. This has led to the industry’s inability to effectively capture the full value of the waste stream.

As previously stated, existing drying technologies are not suited for smaller, large scale operations (100K-750K hen) and are capital intensive. An entire drying and pelleting system can cost between $1.5 and $5 MM. From our investigations into existing technologies, the capital requirements to purchase and install dryers make them economically unrealistic for most conventional operations with less than 1 MM hens. Furthermore, the current systems are extremely energy intensive, which make them costly to operate. We plan on utilizing newer drying technology that is close to 50% more energy efficient than commonly-used biomass dryers (please see “Dryer Technology Discussion” below).
Figure 12. The OrganicMatters Business Process

Our Value Proposition to Egg Producers
OrganicMatters provides several key benefits to egg farmers including:

- A consistent revenue stream
- Eliminating Upfront Capital Expenditure for Dryers
- Hands off Manure Management
- Transforming manure liabilities into assets

Currently, most egg farmers only receive revenue for their manure during the crop growing season. We add value to their operations by providing a consistent revenue stream for each dried ton of waste that we collect. We provide our manufactured dryer service at no cost to the farmer, thereby completely eliminating the capital investment. OrganicMatters adds value to egg producers by providing a manure management system that substantially reduces problems associated with traditional manure storage. Consistent manure management can help poultry producers comply with county and state water and nutrient regulations. In addition, drying and removing manure from the poultry houses can reduce bird mortality and ultimately have a positive effect on the producer’s bottom line. Finally, as mentioned earlier, drying manure benefits egg producers by mitigating odor and fly problems, which can improve relationships with neighbors.¹⁹

Channels and Distribution
OrganicMatters can sell our finalized pellet product direct to our customers or indirectly through wholesale brokers. Most crop farmers buy fertilizers and other agricultural products from certified Pest Control Advisers (PCAs) or agricultural product distributors. PCAs are typically employed by one of the large fertilizer manufactures or growers, or are self-employed consultants who work closely with agricultural product distributors.²⁰ We also have written quotes from our potential pilot that demonstrate that PCAs sell pelleted poultry manure for up to $450/ton.²¹ We have only considered selling to organic
crop growers, and have an understanding of this market segment’s distribution channel. Every distributor has its own volumetric requirements when deciding to sell your product. If you cannot supply sufficient product quantities, then they will not sell your product. They are only concerned with whether or not it is compliant with food safety and organic certification standards. We have considered selling our product in two volumes:

1. 1-ton super sacks - $350 indirect/ $450 direct
2. 40 lb bags - $5-7.5 / bag at retail

Currently, we are focusing on bulk channels (1-ton super sacks). To sell our product to retail lawn and garden or consumers, more research into the channels and distribution is needed.

Demand Creation

Get

The agricultural community is special case where traditional methods of marketing and advertising are not as important or influential as word-of-mouth. Through customer discovery research, OrganicMatters learned that, when it comes to using new products or services, “growers want to hear it from other growers”. This is one reason why we are in the process of arranging a partnership with our external adviser, Mike Weber (Weber Family Farms). Mr. Weber has installed drying and pelleting equipment based on conventional technology at his own egg-production facility, but has had difficulty distributing his pellets due to lack of credibility as a fertilizer. Mr. Weber has agreed to provide a portion of his pellets for us to use on pilot projects. We are finalizing a pilot project with Tenalu Farms, a mid-size, 12,000 acres, conventional and organic citrus, avocado and olive farm in California’s Central Valley. Tenalu is owned by Julia Inestroza and has been in her family since 1917. She is very well known throughout the community and known for being progressive and an environmental steward among her peers. With our pilot farms, we hope to show proof of concept and gain crucial word-of-mouth connections to expand to other organic growers in the region.

Although networking within the growing community is a huge part of demand creation, we seek further exposure at various agricultural conferences, startup villages and startup weekends.

We were invited to present at the Waste to Worth 2017, an international conference on livestock and poultry environmental quality in Durham North Carolina April 18-21. In addition, we will be applying to the Food Ag Innovation Showcase at UC Davis, held in May.
OrganicMatters has also applied to five competitions: UC Berkeley's Haas School of Business - Big Ideas Contest and Global Social Ventures Competition, UCSB New Venture Competition, University of Oregon New Venture Championship, and the Rice University Business Plan Competition. Although not directly connected to the agricultural community, these competitions offer more exposure, networking and funding opportunities for OrganicMatters.

**Keep**
In order to keep customers, OrganicMatters will provide a consistent product. By partnering with multiple egg producers, we reduce third party risk. To ensure consistent product composition (NPK content, micronutrient content) and complete pathogen removal, we plan to perform regular nutrient testing.

**Grow**
Once we have shown proof of concept on one cluster of farms, customer acquisition costs are likely to decline as our brand awareness and strength grows. The growth of the OrganicMatters brand will rely heavily on communication and networking within the agricultural community.

**Analogous Business Models**
The OrganicMatters business model is highly analogous to the anaerobic digestion models that have been widely adopted by the dairy industry. If planned for and installed properly, anaerobic digesters can reduce costs and increase revenues on farms by producing energy and fertilizer from animal waste. However, anaerobic digester systems pose risks to farmers, including construction risk, technology risk, margin risk, management risks and counterparty risk. 24 (anaerobic-digester-business-model-financing-options). Because of these risks and the high capital costs associated with anaerobic digester systems, farmers are reluctant to finance these systems. Third-party ownership of digester systems finance and manage the anaerobic digesters and reduce the risks associated with these systems.

Applying the typical third-party anaerobic digestion ownership model to the OrganicMatters process, we would require the following:

1. A lease or arrangement for land to place the drying facility.
2. A manure supply agreement between the poultry farm and OrganicMatters.
3. Performance guarantees from OrganicMatters and manufacturer of our dryer for the period of time the dryer will operate.
In addition, we would prefer to have a revenue agreement with a fertilizer distributor or various organic crop growers for fertilizer contracts. We believe that this is highly likely scenario as our customer discovery research showed that high quality organic fertilizer is scarce and that mid-sized PCAs enter into buying agreements.

Financial Model and Projections

The OrganicMatters financial model is analogous to an anaerobic digestion third party ownership business model. In addition, it functions like any manufacturing business, with respect to its capacity to gain production efficiencies through economies of scale and scope. The initial capital expenditure may be substantial at first glance, but once we reach a certain production capacity, we have a relatively low cost of goods sold.

<table>
<thead>
<tr>
<th>Table 2. OrganicMatters 5-year Cash Flow Projection (Numbers in 1000s).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OrganicMatters Cash Flow Projections</strong></td>
</tr>
<tr>
<td><strong>2017</strong></td>
</tr>
<tr>
<td><strong>Revenues</strong></td>
</tr>
<tr>
<td>Fertilizer Production (in Tons)</td>
</tr>
<tr>
<td>Sales Price (per Ton)</td>
</tr>
<tr>
<td><strong>Annual Revenue</strong></td>
</tr>
<tr>
<td><strong>Costs</strong></td>
</tr>
<tr>
<td>Capital Expenditure</td>
</tr>
<tr>
<td>Operational Leases Payments</td>
</tr>
<tr>
<td>Production Costs (at $126/ton)</td>
</tr>
<tr>
<td><strong>Annual Costs</strong></td>
</tr>
<tr>
<td><strong>Annual Net Cash Flow</strong></td>
</tr>
<tr>
<td><strong>Cumulative Net Cash Flow</strong></td>
</tr>
</tbody>
</table>

Revenue Model

Given that our initial target customer segment are certified organic crop growers, we plan to generate all our revenue through the sale of our pelleted fertilizer in 1-ton super sacks. Through customer and industry expert interviews, coupled with written quotes provided to us by brokers and farmers, know that the market value of 1-ton super sacks varies depending on which part of the supply chain a business operates. If OrganicMatters were to sell indirect through a broker, we can expect to receive $350 per ton of product. If we were to sell direct to farmers, our product is worth as much as $450 per ton. We are confident that we can finalize a partnership agreement with our external adviser over the next several months and purchase our first system at the end of the fiscal 2017 year. We will purchase our initial dryer in cash to provide proof of concept for our business model. Our goal is to begin production at 25% operational capacity and ramp over 6 months to 100% operational on the first farm. During the first 6 months of operation we are confident that we can partner with Mike Weber’s 2 additional cooperative partners to install dryers at their egg production facilities. We then plan to partner with 2-3 farms annually thereafter until we have cornered the west coast market. By the end of year 5, it is our goal to partner with 18 farms across California, Oregon and Washington.
We will form capital lease agreements for dryers 2-18 to reduce the upfront capital required to purchase the systems. 100% of the final product will be sold to a fertilizer broker at $350/ton.\textsuperscript{25} We anticipate breaking even the first quarter of 2019.

**Costs of Production**

The OrganicMatters production process requires one raw materials input: poultry manure. Through a manure supply agreement, we guarantee to the pay the farmer $25 per ton of dried manure that we collect. Although we pay the farmer the same price for less mass, we are providing a consistent and guaranteed rate for the manure without the costs associated with disposal and management.

We aim to be operational at 25% capacity by July 2018 and ramp to 100% by the end of the fiscal year 2019. Total operating expenses are $1.69MM/year when fully operational ($113/dried ton) in current dollars. We assume a 2% annual escalation for inflation and maintenance expenses. Our dryers and pelleter require 1,000 Btu per pound of water removed. We assume the natural gas price remains constant at $3.91/MMBtu ($15.11/dried ton), which is 20% higher than the Henry Hub spot price on February 1, 2017. We require four laborers (one per farm) who are paid standard industry rates ($12.68/hr, $44.80/dried ton).\textsuperscript{26} We will hire a third-party class-8 truck hauling service to move the dried material to our packing plant ($100/hr., $29.02/dried ton). The packaging plant 3 kW/hr of electricity at a price of ($.0169/KWh, $0.04/dried ton).\textsuperscript{27,28} Maintenance was conservatively assumed to be 5% of the capital expenditure. One-ton super sacks were assumed to be $8.28/bag.\textsuperscript{29} One laborer was assumed to operate the packaging facility.

<table>
<thead>
<tr>
<th>Table 3. OrganicMatters per unit operating expenses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operating Expenditures ($/Dry Ton)</strong></td>
</tr>
<tr>
<td><strong>On-Site Drying and Pelleting</strong></td>
</tr>
<tr>
<td>Labor</td>
</tr>
<tr>
<td>Manure Payments</td>
</tr>
<tr>
<td>Natural Gas</td>
</tr>
<tr>
<td><strong>Trucking</strong></td>
</tr>
<tr>
<td>Hauling Service</td>
</tr>
<tr>
<td><strong>Packaging Facility</strong></td>
</tr>
<tr>
<td>1 Ton Super Sacks</td>
</tr>
<tr>
<td>Labor</td>
</tr>
<tr>
<td>Electricity</td>
</tr>
<tr>
<td><strong>Total OpEx</strong></td>
</tr>
</tbody>
</table>

**Fixed Costs**

The fixed costs for OrganicMatters are broken down into the following components:
Facilities Leasing
In order to build out our off-site processing facility to process the dried manure into the final bagged pellets, we will need to secure zoned agricultural land has space to house storage hoppers, pelleting and bagging machinery. The rate to lease land was assumed to be $0.35/ft$^2$. To handle the volume of product we desire, it was estimated that we would need a 15,000ft$^2$ facility.\(^\text{30}\)

Sales and Wages (Non-production)
We anticipate additional expenses for non-production employees. This category includes solely company management, which includes the Chief Executive Officer, Chief Impact Officer and Chief Technology Officer. Assuming an average cost of $100,000 per employee (including salary, benefits and tax obligations) at the onset of operation, we estimate overall non-production staff to be $200K. The roles of the employees are Chief Executive Officer and Chief Impact Officer.

Depreciation, Amortization and Maintenance
Consistent with industry practice, annual maintenance costs of all machinery were assumed to be 5% of capital expenditure.\(^\text{31,32}\) Depreciation and amortization were excluded from the our analysis.

Marketing & Sales/ General & Administrative
More research is needed to estimate our marketing and sales cost estimates.

Upfront Capital Expenditures
OrganicMatters seeks an initial capital investment of $2 MM. This money will be used to purchase our first drying and pelleting system and hire the required laborers to operate the machinery.\(^\text{33,34,35,36}\) Every subsequent dryer will be leased. More information regarding exact line item costs pertaining to the pellet plant can be found in the appendix.

Drying Technology Discussion
The OrganicMatters executive team is in the process of building a team to assist us with concept research and development into a new drying technology. Through a combination of industry expert and customer interviews, and literature review, we have decided that in order to effectively enter into this market with our proposed business model, we must revolutionize the drying process.

Conventional technologies can be an effective solution and are currently service a small fraction of egg laying operations. Although there are a handful of operations that prove profitable, several market barriers hinder wider adoption of drying across the industry. Fit-for-purpose equipment designed to treat poultry manure at smaller, large-scale operations (100k-500K hens) is not readily available and custom-built units are rare and expensive.\(^\text{37,38,39,40,41}\)
Big Dutchman manufactures a serpentine drying system that utilizes a fan system to blow air from the poultry houses across the manure belts. Belt dryers like Big Dutchman take approximately 3 days to complete a drying cycle of manure. Our adviser, Mike Weber invested $1MM in this system, yet it does not fully remove pathogens. Mike was then forced to invest an additional $1MM to integrate an additional step in the process to ensure pathogen removal.

Omnis Thermal sells dryers for $500K that also have an efficiency of 2000 Btu/lb of water removed. This system is fit-for-purpose and can handle the waste of about 500,000 hens. This information, coupled with our literature review of other biomass dryers in other industries, has lead us to believe that poultry manure dryers have room for innovation and efficiency. Gryphon environmental, LLC., has developed a biomass dryer and pelleteer that uses 1000 Btu/lb of water removed – approximately half of the energy used by rotary drum dryers (Figure 13).

Inside the dryer is a continuous belt system to move biomass through the machine. These dryers inject compressed, heated air into a vacuum to physically remove and evaporate water out of biomass. These dryers are designed as a closed-loop air system to recirculate the hot air throughout the system. Not only do these dryers result in fewer GHG emissions than other biomass dryers, but Gryphon dryers can reduce drying capital and operating costs by 30-40%. With this knowledge, OrganicMatters seeks to form a partnership with this innovative biomass drying manufacturer to implement manure-specific dryers on our partner egg farms.
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15. Andrew Konigsberg and Jon Korn (Eco-Entrepreneurship Advisory Council) interviewed by Jacob R. Levine of OrganicMatters in Santa Barbara, CA 2/5/17
16. Dan Smith (Omnis Thermal Technologies) interviewed by Jacob R Levine of OrganicMatters in Santa Barbara, CA 10/25/16
17. Nick Reckinger (FEECO) interviewed by Lauren Catlin of OrganicMatters in Santa Barbara, CA, 10/12/16
18. Geoff Powers (California Mill Equipment) interviewed by Jacob Levine of OrganicMatters in Santa Barbara 10/28/16
19. Mike Weber (Weber Family Farms) interviewed by Jacob R. Levine and Lauren Catlin of OrganicMatters in Petaluma, California, 5/20/16
20. Dave Nerpel (Independent Consultant) interviewed by Jacob R Levine, Lauren Catlin and Minos Athanassiadis in Santa Barbara, CA, 1/18/17
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27. Ron Fuller (CPM Roskamp Champion) interviewed by Jacob R. Levine of OrganicMatters in Santa Barbara, 12/4/16
29 Charlotte Chandler (BAG Corp) interviewed by Jacob R. Levine of OrganicMatters in Santa Barbara, CA, 12/5/16
31 Mike Weber (Weber Family Farms) interviewed by Jacob R. Levine and Lauren Catlin of OrganicMatters in Petaluma, California, 5/20/16
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38 Mike Weber (Weber Family Farms) interviewed by Jacob R. Levine and Lauren Catlin of OrganicMatters in Petaluma, California, 5/20/16
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40 Phillip Maust (Maust California Poultry) interviewed by Jacob R. Levine and Lauren Catlin of OrganicMatters in Chino, CA, 9/26/16
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Part 4
Customer Discovery Research
Research questions and interviews that brought us from the original business model to the current state of development.
The OrganicMatters business model started with the proposed AdieuDoo business that aimed to mitigate the environmental impacts from bovine livestock and dairy producers. Due to the concentration of animal populations, waste from these facilities is a constant problem that operators must manage. The typical lactating cow in a dairy operation can produce up to 150 pounds of manure in a single day.¹ The accumulating waste from this source can lead to issues with the environment, neighboring farms and residential areas. This type of waste is becoming more heavily regulated that can potentially harm the herd and surrounding communities when it builds up. This is an increasingly cumbersome problem that is requiring waste generators to look for solutions to handle this burden. First hand interviews and industry research has confirmed this customer problem and elaborated on inefficient systems within the sector.

Current waste mitigating strategies in dairy operations use a two strategies: manure pits and pile heaps. Manure pits congregate all the waste from the animals in the barn or pen via pumps and plumbing.² This pit system constantly collects and enacts evaporation on the manure. When the farmer has the time or labor to address the pit, they will agitate the pond, creating a slurry to spread through their fields (if fields are nearby). Using hose and tractors to spread the fertilizer is a capital intensive operation that is also weather dependent. If too cold, the fertilizer doesn’t spread easily or efficiently.³ When raining, tractors may get stuck and the excessive nutrients may wash into nearby effluents. Aside from infrastructure costs and clogging pumps, this frequent dispersion of a high nitrogen fertilizer can cause harm to soil pH, enter waterways via runoff and contaminate groundwater used on the farm and in the surrounding communities.

In some districts and counties, small operations create manure share program. These programs allow members to post when they have manure available for accepting individuals to come and collect the waste for free.⁴ There is a substantial time cost to both waste generators and the customer accepting the waste. Moreover, there is a capital cost to the customer to effectively and appropriately transport the material. Although free, this system is not convenient to either party due to the timing of when the material needs to leave the farm and when it is required by the end user.

AdieuDoo attempted to solve the problem of removing the waste for the farmer in a timely manner while simultaneously providing what was thought to be a high nutrient soil amendment to farmers, landscapers and gardeners when required. Figure 14 simply depicts the process. Utilizing a manure pelletizing system mounted on two flatbed trailers,
the service efficiently dries the manure allowing for pressurized pellet formation and packaging.

![Image](image_url)

**Figure 14. AdieuDoo Product and Service Offering**

The pellet retains complex nutrients while removing up to 90% of manure weight. The end product is no longer considered manure and does not need a permit to be relocated like wet feces. This allows for cost effective packaging, easier transportation and use with normal hand spreading or automated machinery. The animal owner no longer labors with waste, can potentially increase their herd/coup and a manageable, natural fertilizer can be offered to the market without mining or chemical synthesis.

As a mobile solution, the system travels to the customer and retains a strategy similar to a food truck; lower overhead than a stationary facility and mobility to meet the market demand. The farmer can continue to focus on milk or meat production while both parties do not have to schedule an inefficient appointment for the manure transaction. AdieuDoo saves time, was thought to offer a high grade product with low input costs. Processing the manure into a compressed dry pellet allows the business to prevent environmental degradation of water and soil quality due to manure management by removing its travel medium, water. If hydrated manure were allowed to concentrate in unregulated areas, disease and potential eutrophication of water bodies can affect more than the herd or flock on the property. Our offering will remove the potential impact of this waste stock and through measurable reductions of pathogens, nitrates, and other chemical concentrations in surface water.

The business’s original goal was to prevent water contamination from waste, and use the waste in a more beneficial manner than disposing of it. The initial idea revolved around turning food waste into energy, but the cost/benefit ratio was not feasible in a very competitive market. As the focus became more targeted to the farm for pre-consumer waste, research allowed more insight into the operations of dairy and animal feedlots.
Waste was continuous and often carried higher nutrient loads than molding vegetables. The guaranteed waste and consistent input characteristics would require purchasing the equipment, mounting it on two diesels trailers and start producing the soil amendment. Smaller farms with smaller dependent waste input have proven this to be a revenue generating system within a year. Due to the individual cases being stationary operations, they cannot hit the amount of inputs needed to profit on the levels that a mobile unit can attain. Moreover, farmers would rather focus on maximizing their current product offering, not enter a new market using their waste.

Focus on Poultry Industry
Research Question: What is the best feedstock?
Industry Expert Interviews: 8

Although the dairy and bovine livestock industry provided large amounts of waste and substantial environmental hazard, progression through customer discovery and industry expert interviews uncovered a host of potential barriers that lead to the pivot towards dealing solely with poultry waste. Our research led us to understand that poultry manure is the most nutrient-dense manure \((n = 6)\). Additionally, we discovered that cow manure is extremely low in value as a fertilizer, and is largely dealt with by anaerobic digesters \((n = 2)\). Cow manure is oversupplied, has very little nutrients, which therefore makes it a poor choice for fertilizer. Poultry manure, on the other hand, can be used by anybody in organic production given pathogen elimination is guaranteed during drying and processing. Dried and pelleted poultry manure pellets can be sold for over $300 per ton. This discovery led to the next business model modification.

Target Organic Crop Growers
Research Question: Is manure generally sought after by small organic and non-organic produce farmers?
Crop-Grower Interviews: 5

OrganicMatters attempted to validate our hypothesis that manure, irrespective of the type is a highly valued and sought after fertilizer for organic and non-organic producers at the Santa Barbara, Goleta and Montecito farmers’ markets. Through our customer discovery research it was validated through 5 interviews that poultry manure is the cheapest form of nitrogen a small organic farmer can get and the preferred type of manure. Although this fertilizer is not limited to the organic market, it was determined through these interviews that organic farmers have a hard time getting this form of manure due to the fact that they are geographically disjointed from the poultry manure sources. The use of manure by small farmers was verified through literature.
review of USDA Economic Research Service (ERS) resources that the smallest quartile of produce farmers make up over 40% of the total demand for manure.\textsuperscript{15}

This was further affirmed through literature research that, due to naturally lower moisture contents of both broiler and layer hen manure, coupled with higher concentrations of nutrients make it more economic to transport longer distances.\textsuperscript{16,17}

We assume that our fertilizer will not be immediately integrating into conventional farming. Our customer discovery research indicated that many conventional farmers base their practices off of what their fathers and/or neighbors do before considering alternatives (n = 5).

**Pivot: Mobile Unit to Stationary, On-Site Manure Drying**

*Research Question: Is the mobile unit viable?*

*Industry Expert Interviews: 10*

OrganicMatters believed that by utilizing a manure drying and pelleting system mounted on two flatbed trailers, we could easily drive to poultry farms, provide manure cleanout services, process it on site and then drive directly to produce growers and sell our product to them. The dried manure pelleting process removes up to 90\% of the weight from the initial wet product, while simultaneously preserving the nutrient capabilities.\textsuperscript{18}

To test our hypothesis and gain more understanding, we conducted a combination of interviews with poultry and fertilizer industry experts including: doctoral poultry science researchers at UC Davis, fertilizer brokers, heads of the major fertilizer and poultry industry trade organizations in California and the U.S., and lastly our primary customers, small and mid-sized produce growers. We followed up on statements made by the interviewees through investigative research into scientific literature and market research.

OrganicMatters learned that the liability to manage manure and all consequences of mismanagement fall on the contract farmer, and that on-site manure management is ideal (n = 3). Manure management strategies are determined by the housing designs and are the largest determining factor contributing to air emissions and bird mortality.\textsuperscript{19,20} There are many different housing structures that all have varying emission and mortality rates due to their management strategies.\textsuperscript{21} Manure management is dependent upon the integrator’s specifications on the poultry flock production cycle.\textsuperscript{22} The most important point we learned was that biosecurity is the single most important problem facing the poultry industry. It seemed as though a mobile unit could be logistically challenging to ensure biosecurity between chicken farms.
More expert industry interviews confirmed that on-site manure management is a better option due to transportation costs and nutrient recovery in the manure (n = 2). One fertilizer broker stated that the “best way to pelletize is to make pellets as close to the source as possible to cut processing time and costs”. He stressed that we should be viewing our business model from the perspective of how we will add value to both the poultry farmer and produce grower. He underscored the importance that drying manure as quickly as possible maximizes the value of the nutrient and dollar value while simultaneously reducing transportation costs. He said that as a mobile business we would be competing with the few farmers who pelletize the material on-site and will likely have lower production costs due to lack of transportation costs and the fact that pelleting typically takes place on larger operations. One important piece of information was that freight can be as much as 30% of total cost of traditional manure management and therefore wouldn’t be well served by a mobile platform.

Other fertilizer distributors reaffirmed these points regarding the cost of freight, barriers to entry as a mobile unit due a higher per unit cost. These fertilizer distributors worried that a mobile business is not scalable and could not benefit from the economies of scale that other manufacturers gain through larger stationary facilities. Moreover, as we were researching contacts to call in the manure-based fertilizer industry we uncovered various poultry pelleting operations, all of which are stationary manufacturing facilities (n = 5).

**Arrange Third-Party Partnerships**

Research Question: Why aren’t more egg producers doing this?

**Industry Expert Interviews: 14**

After learning that pelleted poultry manure can be sold in bulk for over $300 per ton, we were perplexed that not many poultry farms dry and pellet their manure. We located several large-scale operations scattered around the U.S. that do. Perdue has the largest pelleting facility in the country and processes 80,000 tons of manure per year on the Delmarva Peninsula in Delaware. Hickman’s Eggs has 6 farms between Arizona, Colorado and California and process approximately 575,000 tons per year. There are several other companies including True Organic Products Inc., Organic Farms (Foster Farm subsidiary) and our external advisor, Mike Weber.

Industry expert interviews revealed that the capital investment required to implement drying and pelleting technology is extremely daunting for a poultry or egg producer (n = 10). Furthermore, several of these industry experts confirmed that poultry and egg producers are concerned with producing meat and eggs, not fertilizer (n = 4). These barriers to drying and pelleting have prevented market saturation for poultry manure pellets. We recognized the opportunity to arrange third-party partnerships with poultry
and egg producers to provide manure drying services at little or no cost in exchange for a reliable manure feedstock.

**Central Pelleting Facility**

Research Question: How can capital investments related to drying and pelleting be reduced?

**Industry Expert Interviews: 3**

Interviews with drying and pelleting technology manufacturers confirmed that the technology needed to effectively dry and pellet poultry manure requires a capital investment between $1-$6 million. These costs include biomass dryers and pellet mills. The most important step to preserve nutrients in poultry manure is to dry it to 10-12% moisture content \((n = 2)\). Once dried, the risk of ammonia volatilization is mitigated. Manure drying would still have to occur on-site, and multiple biomass dryers would be required to service each of our poultry and egg producing partners. However, after speaking with pellet mill manufacturers, we decided that the pelleting could take place in a strategically-placed central facility with one pellet mill.

**Pivot: Laying Hens Chosen**

Research Question: Can this business model service all poultry and egg producers?

**Industry Expert Interviews: 5**

The broiler and egg industries manage manure in very different ways. OrganicMatters determine that egg-laying poultry operations should be the target feedstock for our business model. This was driven primarily due to the differences in housing types of the chickens and production cycles of the two industries. A large portion of the egg laying operations have manure belt systems, which seemingly can be engineered to integrate with the drying and pelleting system that OrganicMatters desires to implement. Customer discovery and industry expert interviews showed that it is currently feasible and is a growing trend to integrate an industrial dryer into an individual farm’s waste stream.\(^{33}\) Conversely, broiler houses store the litter on the floor of the house, under the feet of the chickens, and the material is cleaned out anywhere between once a year and 10 years.\(^ {34}\) To maintain the nutrient value of the poultry manure, it must be dried as quickly as possible from the time of excretion. If OrganicMatters were to wait, the process would seemingly provide no environmental benefit, bringing the validity of the Eco-Entrepreneurship value proposition into question.

Furthermore, accessibility and face time with customers is keystone to business model development. As a result, because OrganicMatters is currently located in California and the state has one of the largest of egg laying industries in the U.S., it is logistically easier to gain access to industry experts and potential customers and to test our hypotheses.
Part 4 References

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10 Danny Cavaletto (Ag RX) interviewed by Jacob R Levine and Lauren Catlin of OrganicMatters in Goleta, CA 5/10/16
11 Abbott (Hilltop and Canyon Farm) interviewed by Lauren and Jacob R Levine of Organic Matters in Goleta, CA 4/5/16
12 Timothy (Ellwood Farms) interviewed by Lauren Catlin of OrganicMatters in Goleta, CA 5/3/16
13 Shannon Somers (Somers Ranch) interviewed by Jacob Levine and Lauren Catlin in Santa Barbara, CA 4/12/19
14 Hezekiah Allen (California Growers Association) interviewed by Jacob R. Levine of OrganicMatters in Santa Barbara, CA, 5/23/16
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22 Deanne Meyer (Pacific Egg and Poultry Association) interviewed by Jacob R Levine of OrganicMatters in Santa Barbara, CA, 5/3/16
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25 Danny Cavaletto (Ag RX) interviewed by Jacob R Levine and Lauren Catlin of OrganicMatters in Goleta, CA 5/10/16
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27 AgriRecycle page, Hickman’s, True Organics, etc. webpages
29 Bill VanGotum (Hickman’s Family Farm) interviewed by Jacob Levine of OrganicMatters in Santa Barbara, 10/25/2016
33 Site visit to Weber Family Farms
Part 5

Environmental Solution Analysis

Our process of drying and pelleting manure reduces nutrient runoff problems and nitrogen emissions associated with conventional manure management.
Overview

Drying and pelleting manure reduces the potential for air and water quality degradation posed by conventional manure management. Drying the manure prevents the material from losing nutrients through off-gassing, and the compact pellet releases nutrients into the soil at a slower rate than raw manure, which protects the nutrients from being washed away too rapidly. Although energy is required to dry and pellet manure, the added greenhouse gas emissions for our process are less than the emissions related to conventional manure management. We foresee that our product can be used cooperatively with chemical fertilizers in conventional crop farming, which would offset further greenhouse gas emissions and water quality problems.

Air Quality

Manure-drying systems can effectively halt ammonia volatilization, which leads to a significant reduction in ammonia emissions over untreated manure storage. This not only mitigates fine particulate emissions, but also preserves the nutrient content in the manure, so less needs to be applied to the soil.

Ammonia volatilization is mostly a result of microbial degradation of uric acid and proteins.\(^1\) The optimal environment for these microorganisms to degrade uric acid is 40-60% moisture content, and reducing the moisture content of manure to 20-40% can minimize ammonia volatilization and preserve nitrogen content in manure.\(^2\) Further, when moisture content of poultry manure is less than 30%, ammonia formation from uric acid stops.\(^3\) Our system will result in manure with a final moisture content of 12% to stop ammonia volatilization and to eliminate pathogens.\(^4\)

Our process significantly reduces atmospheric ammonia emissions. Because OrganicMatters targets egg operations that already have manure belts implemented, we can compare our system most closely to those facilities. Even in housing systems that use manure belts, much of this manure is stored in a heap after it is belted out of the hen house and continues to release ammonia gas.\(^5\) For every ton of manure that goes through our process, we prevent 13.7 lbs of ammonia from being released into the atmosphere (Table 4).

It is important to incorporate the pellets into the soil to prevent re-moistening the product and inducing the hydrolysis of uric acid by microorganisms.\(^6\) Because of this, we compare our process to other manure management systems that incorporate manure into the soil.
Table 4. Nitrogen losses through ammonia emissions from housing and storage for three manure-management strategies: high-rise egg facilities that store manure in heaps, egg facilities that use manure belts and storage heaps, and egg facilities that partner with OrganicMatters. Units are in lbs of nitrogen per ton of manure.\textsuperscript{7,8}

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<th>System</th>
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*Assumes a 40-day storage period

Water Quality and Nutrient Release

Our manure management strategy mitigates runoff/leaching problems related to normal housing and storage of manure. Because they are dry and odorless, our pellets can be easily stored in bags indoors, which eliminates the need for an exposed manure storage heap. This protects the manure from environmental degradation. Additionally, the manure in a pellet form is subject to less nitrogen runoff than traditionally land-applied manure. Within the first year of application, approximately 30-50% of the nitrogen in poultry manure pellets becomes available.\textsuperscript{9} This leaves 4-5 seasons of residual nitrogen in the soil that plants can continue to utilize. Raw poultry manure leaves approximately 2-3 seasons of residual nitrogen, and chemical fertilizer leaves no residual nitrogen.\textsuperscript{10}

Greenhouse Gas Emissions

Traditional manure storage piles and broadcast manure application release potent greenhouse gases like methane and nitrous oxide. Like ammonia emissions, methane and nitrous oxide emissions are microbial-mediated. Drying and pelleting the manure reduces the moisture content and heats the manure to a high enough temperature to kill microorganisms in the material and prevent the microbial degradation and GHG emissions that occur with conventional manure storage. Because manure is a by-product of egg production, we ignore the emissions associated with aspects of egg production outside of manure management (feed production, transporting hens, heating, etc) in our calculations.

Our process does require energy to remove water and add heat to the manure during drying and pelleting. When comparing our process on a per-ton basis to conventional manure management (no drying, use of storage heaps), we have higher GHG emissions. However, because our process results in a higher nitrogen-content fertilizer, less manure is required to fertilize the same amount of crop, resulting in fewer GHG emissions on a fertilizer per acre basis. Our process (and conventional manure management) results in fewer GHG emissions than chemical nitrogen production (Figure 14).
Overall, the OrganicMatters process offers a sustainable solution to traditional manure management, and poses significantly fewer ammonia emissions than other manure management strategies and chemical nitrogen production. Additionally, producing OrganicMatters pellets is less resource-intensive than other pelleting processes and chemical nitrogen production. By utilizing innovative drying technology, we require approximately 50% less natural gas to dry manure when compared to conventional rotary drum dryers.

**Figure 15.** Greenhouse gas and ammonia emissions associated with the production of various fertilizers to meet the nutritional needs of one acre of corn (140lb nitrogen/acre). Estimations do not include upstream manure emissions (feed inputs, transporting hens, etc) or emissions related to transportation/application.

OrganicMatters pellets have lower environmental impact than other poultry manure pellets, raw poultry manure, composted manure, and chemical nitrogen fertilizers. Based on our review of existing literature, drying and pelleting poultry manure has the potential to mitigate many of the environmental impacts of conventional manure management, namely ammonia and greenhouse gas emissions. In addition, the final poultry manure pellets release nutrients at a slower rate than raw poultry manure and synthetic fertilizers.
Part 5 References

2 Ibid.
4 Mike Weber (Weber Family Farms) interviewed by Jacob Levine and Lauren Catlin of OrganicMatters in Santa Barbara, 5/20/2016
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Part 6

Next Steps
Implementation and Timeline

March-August 2017:
- Contact Gryphon environmental, LLC for more information regarding their biomass dryers and the potential for a patentable, manure-specific machine.
- Recruit a mechanical and environmental engineer to assist with dryer installation and operation.
- Research into available patents and intellectual property protections
- Finalize terms and conditions of partnership agreement with Mike Weber for feedstock and access to cooperative partners to support design and piloting of our production technology. We learned through our process that poultry farmers are more likely to innovate following proof-of-concept on a competitor’s farm. The pilot will hopefully provide a compelling case study to other farmers enabling us to scale our operations.
- Remove Biosecurity Concerns for Egg Producers
  - Biosecurity is a huge concern for egg producers, as the threat of disease (namely avian flu) is very serious. There are typically very strict requirements regarding personnel entering/exiting the egg production facility. It will be a crucial step in business model development to come up with a plan that the transport of manure off-site to be completed in a manner that agrees with the egg producer's biosecurity measures. In addition, farmers may not accept trucks that are on other egg operations due to the potential for cross contamination.
  - Depending on these biosecurity concerns, we may shift away from on-site drying and off-site pelleting and integrate a modular system that dries and pellets. As we are beginning to develop our own technology, we may pivot to more of a franchise model, where we give our technology to a particular farm at no cost, and license an individual product per farm, thereby never needing to address the biosecurity problem.
- File for patents to protect intellectual property.

September 2017-May 2018:
- Install and test production technology on partnering egg farms. The drying technology must ensure greenhouse gas reductions compared to existing technology, and render the material food-safe.
- Finalize pilot project for fertilizer with our Central Valley grower. This will provide field results regarding the efficacy of our product.

June 2018-July 2018:
- Complete on farm pilot project of fertilizer.
- Before the fertilizer can be sold as it must undergo significant testing and certification. We must ensure the fertilizer has consistent nutrients between batches and is certified food-safe and organic.
Fundraising Plan
OrganicMatters has a strategic plan to raise the required capital to launch this business, involving gaining exposure at various conferences, startup weekends, and competitions, and networking at agricultural conventions and events.

New Venture Competitions: In addition to the Big Ideas Contest at UC Berkeley, we are proud to announce that we are semi-finalists in the University of Oregon New Venture Championship. We have already have won a small undisclosed cash prize ($750+) for acceptance as semi-finalists and have the opportunity to compete for additional cash prizes and venture funding from angel investors and venture capitalists. We will be applying to the University of California Santa Barbara New Venture Competition at the end of March 2017 to compete for additional funding and access to angel investors.

Innovation Awards: We were written up in the Pacific Coast Business Times and will be highlighted at the Startup Village at the Central Coast Innovation Awards on March 16, 2017, which will assist us in gaining exposure and access to angel investors.

Startup Weekend: Our Adviser, Minos Athanassiadis invited us to participate in the Startup Weekend Ventura County April 21-23, which features innovation in agribusiness. We will have the opportunity to compete for an additional $10,000. In addition, we will gain exposure to the Executives of major agricultural companies including The Limoneira Company, Bonipak and Reiter Affiliated Companies, who will assist us in refining our business model.

Conferences: We are in the process of applying to pitch at the 2017 Silicon Valley AgTech Conference. If accepted, this opportunity will assist us in gaining exposure with the investment community. We are also applying to the Ag Innovation Showcase at University of California, Davis to present our business model and work with seasoned mentors to refine our model and gain exposure to influential players in the Food & Agribusiness space.

Post-Graduation Funding: The Bren School of Environmental Science & Management at the University of California, Santa Barbara has a stipend up to $5,000 per team member to cover living expenses. In addition, we have the opportunity to apply for up to $10,000 in funding from the UC system, which was recently distributed to assist with minimum viable product development.

Accelerators: We will be applying to the UCSB Technology Management Program’s G2 Summer Accelerator, where we can receive up to $6,000 and assistance with our venture development. The development team at the Bren School is assisting us with our application to the Food System 6 accelerator to assist with fundraising, network expansion and business model development.

Angel Investment: During all of these stages, it is our goal to secure capital from several angel investors. Our board of advisers believe this is feasible given the current stage of development.
Measuring Impact
Mitigating environmental impacts associated with conventional manure management is keystone to the OrganicMatters business model. Throughout the design and testing phase of dryer prototype development we will regularly employ Randomized Control Trials (RCT) to effectively measure our air emissions. We plan to test the nitrogen and carbon concentrations of raw manure and final product to estimate ammonia and greenhouse gas emissions. We optimally would like to hire a third party testing facility to audit our measurements and ensure accuracy, legitimacy and transparency of our emissions. We will then compare our emissions to conventional manure management strategies, alternative drying processes and fertilizers to determine our relative standing. Eventually, when our product is integrated into traditional channels, we will have the opportunity to further offset greenhouse gas emissions from synthetic fertilizer production.
Appendix
## Appendix 1: Business Model Canvas

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<th>Value Propositions</th>
<th>Customer Relationships</th>
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### Key Resources

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<tbody>
<tr>
<td>Industrial space</td>
<td>Indirect</td>
</tr>
<tr>
<td>Drying Equipment</td>
<td>Pest Control Advisers (PCAs)</td>
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<tr>
<td>Pelleting Equipment</td>
<td>Fertilizer brokers</td>
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<td>Permits</td>
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<table>
<thead>
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<th>Cost Structure</th>
<th>Revenue Streams</th>
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<tr>
<td>Labor</td>
<td>Fertilizer pellets</td>
</tr>
<tr>
<td>Energy/fuel</td>
<td>Truckload</td>
</tr>
<tr>
<td>Shipping/transportation</td>
<td>Ton</td>
</tr>
<tr>
<td>Packaging</td>
<td>40-50 lb. bag</td>
</tr>
<tr>
<td>Nutrient testing</td>
<td>Manure Management Service Fee (potentially)</td>
</tr>
</tbody>
</table>

**Wholesale**
- Certified organic specialty crop growers
- Cannabis Industry
- Landscapers
- Golf courses
- Conventional crop growers

**Retail**
- Home gardeners
- Nurseries
# Appendix 2: Financial Model Assumptions

## Financial Assumptions

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Cost of Capital</td>
<td>7.71%</td>
</tr>
<tr>
<td>Inflation Ramp</td>
<td>2%</td>
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<tr>
<td>Federal Income Tax</td>
<td>35%</td>
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## Revenue Assumptions

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price per Ton (Indirect)</td>
<td>300</td>
</tr>
<tr>
<td>1-ton Super Sacks (%)</td>
<td>100%</td>
</tr>
<tr>
<td>1-ton Indirect Sales (%)</td>
<td>100%</td>
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## Energy Assumptions

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Price ($/kWh)</td>
<td>0.1553</td>
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<tr>
<td>Natural Gas Price ($/MMBtu)</td>
<td>3.91</td>
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<tr>
<td>#2 Diesel Price ($/gal)</td>
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## Trucking Assumptions

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Farms Distance to Pellet Mill</td>
<td>100</td>
</tr>
<tr>
<td>Hauling Service Rate ($/hr)</td>
<td>100</td>
</tr>
<tr>
<td>50% Payload Fuel Efficiency (MPG)</td>
<td>6.75</td>
</tr>
<tr>
<td>0% Payload Fuel Efficiency (MPG)</td>
<td>7.55</td>
</tr>
<tr>
<td>Farm 1 Transport Time/Week (Hr)</td>
<td>18</td>
</tr>
<tr>
<td>Farm 2 Transport Time/Week (Hr)</td>
<td>30</td>
</tr>
<tr>
<td>Farm 3 Transport Time/Week (Hr)</td>
<td>42</td>
</tr>
<tr>
<td>Average Speed (MPH)</td>
<td>50</td>
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<tr>
<td>Maintenance Cost ($/10 year)</td>
<td>12,000</td>
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</table>

## Drying Assumptions

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Manure Generation (Wt lb/hen*day)</td>
<td>0.25</td>
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<tr>
<td>Farm 1 ( # of Hens)</td>
<td>200,000</td>
</tr>
<tr>
<td>Farm 2 ( # of Hens)</td>
<td>350,000</td>
</tr>
<tr>
<td>Farm 3 ( # of Hens)</td>
<td>500,000</td>
</tr>
<tr>
<td>Dryers per 500,000 hens</td>
<td>1</td>
</tr>
<tr>
<td>Capital Cost ($)</td>
<td>500,000</td>
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<tr>
<td>Engineering and Installation ($/Dryer)</td>
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<tr>
<td>Land Use Permit ($/Farm)</td>
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<tr>
<td>Drying Capacity (Wet Tons/Hr)</td>
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</tr>
<tr>
<td>Initial Moisture Content (%)</td>
<td>70%</td>
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<tr>
<td>Final Moisture Content (%)</td>
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<tr>
<td>Estimated Efficiency (Btu/lb H2O)</td>
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<tr>
<td>Maintenance (% CapEx)</td>
<td>5%</td>
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<tr>
<td>Farm 1 Hrs of Operation (Hr/Day)</td>
<td>9</td>
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<tr>
<td>Farm 2 Hrs of Operation (Hr/Day)</td>
<td>16</td>
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<tr>
<td>Farm 3 Hrs of Operation (Hr/Day)</td>
<td>23</td>
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## Trucking Assumptions

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farms Distance to Pellet Mill</td>
<td>100</td>
</tr>
<tr>
<td>Hauling Service Rate ($/hr)</td>
<td>100</td>
</tr>
<tr>
<td>50% Payload Fuel Efficiency (MPG)</td>
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<td>0% Payload Fuel Efficiency (MPG)</td>
<td>7.55</td>
</tr>
<tr>
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<td>18</td>
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<tr>
<td>Farm 2 Transport Time/Week (Hr)</td>
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<tr>
<td>Farm 3 Transport Time/Week (Hr)</td>
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<tr>
<td>Average Speed (MPH)</td>
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<tr>
<td>Maintenance Cost ($/10 year)</td>
<td>12,000</td>
</tr>
<tr>
<td>Staffing Assumptions</td>
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<tr>
<td>--------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Truck Driver Wage Rate ($/hr)</td>
<td>14.88</td>
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<tr>
<td>Agricultural Machine Operator ($/hr)</td>
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<tr>
<td>Number of Drivers</td>
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</tr>
<tr>
<td>Staff per Dryer</td>
<td>1</td>
</tr>
<tr>
<td>Staff at Pellet Mill</td>
<td>1</td>
</tr>
<tr>
<td>Employee Compensation</td>
<td>100,000</td>
</tr>
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</table>
Appendix 3: Environmental Calculations

Ammonia Emission Assumptions

Given information

Manure Inputs
- Fresh egg-layer manure = 2% nitrogen content
  - 0.02 X 2000lb = 40lb nitrogen/ton manure
- Poultry manure pellets = 5% nitrogen content
  - 0.05 X 2000lb = 100lb nitrogen/ton pellets

Fertilization Inputs
- 1 acre of corn requires 140lb nitrogen
  - 140/40 = 3.5 tons manure/acre
  - 140/100 = 1.4 tons pellets/acre

In-House Emissions
- High-Rise
  - 15.3lb ammonia/ton manure/day
- Cage and Belt
  - 1.59lb ammonia/ton manure/day

Storage Heap Emissions
- Average loss of 13.7lb ammonia/ton manure after 40 days

Synthetic Nitrogen Emissions
- Ammonia emissions were summed and averaged for the various processes involved with the production of synthetic urea. The total emissions from the production of one ton of urea were 6.2lbs ammonia.

Because OrganicMatters pellets need to be incorporated into soil (buried in furrows), we only calculate emissions up until application. Incorporating fertilizer into soil results in few to none ammonia emissions.

Ammonia Emission Calculations

(Initial lbs nitrogen/ton) - (In-House Emissions + Storage Heap Emissions/ton) = Lbs Nitrogen lost through volatilization per ton manure

For a conservative estimate, we multiplied the lbs nitrogen lost by the initial tonnage required for fertilization (3.5 tons of manure, 1.4 tons of pellets).

1. High Rise
   \[40 - (15.3 + 13.7)] \times 3.5 = 96.85lb ammonia/acre fertilized
2. Cage and Belt
   \[40 - (1.59 + 13.7)] \times 3.5 = 53.82lb ammonia/acre fertilized
3. Cage and Belt Followed by Drying
   \[40 - (1.59 + 0*)] \times 1.4 = 2.32lb ammonia/acre fertilized

*Effective drying systems halt ammonia volatilization.
Greenhouse Gas Emission Assumptions and Calculations

Given Information

1 acre of corn requires 140lb nitrogen

Chemical Nitrogen

Chemical Nitrogen with Best Available Technology (BAT): 3.6lb CO2 eq/lb nitrogen

\[ 3.6 \times 140 = 504 \text{lb CO2 eq/acre fertilized} \]

Chemical Nitrogen without BAT: 5.38lb CO2 eq/lb nitrogen

\[ 5.38 \times 140 = 754 \text{lb CO2 eq/acre fertilized} \]

Manure

75.86lb CO2 eq/ ton manure

40lb nitrogen/ ton manure

1.90lb CO2 eq/lb nitrogen

\[ 140 \times 1.90 = 265 \text{lb CO2 eq/ acre fertilized} \]

Other Pellets

0.66 ton water removed per ton manure

2000btu/ lb water removed, 40lb nitrogen remain

307.75lb CO2 eq/ton manure dried

7.7 lb CO2 eq/lb nitrogen

\[ 140 \times 7.7 = 1077 \text{lb CO2 eq/ acre fertilized} \]

OrganicMatters pellets

0.66 tons water removed per ton manure

1000btu/ lb water removed, 40lb nitrogen remain

153.87lb CO2 eq/ ton manure dried

3.85lb CO2 eq/ lb nitrogen

\[ 140 \times 3.85 = 538.6 \text{lb CO2 eq/ acre fertilized} \]

Compost is assumed to have similar GHG emissions to manure storage. However, we do not directly compare our product to compost, as most composts have about 1% nitrogen content and is used more as a soil amendment, not a true fertilizer.

---

194 Ibid.
195 Ibid.
200 Ibid.
## Appendix 4: Interview Summary

**Table 1.** Interview summary. Interviews were conducted by Jacob Levine and Lauren Catlin between January 2016-March 2017.

<table>
<thead>
<tr>
<th>Interview Type</th>
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<tbody>
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<tr>
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</tr>
<tr>
<td>Other</td>
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<tr>
<td>Engineering (Pelleting and drying systems)</td>
<td>7</td>
</tr>
<tr>
<td>Fertilizer/ Soil Science</td>
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<tr>
<td>Nursery/ Garden</td>
<td>4</td>
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<tr>
<td>Waste Management</td>
<td>3</td>
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<tr>
<td>Policy</td>
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</tr>
<tr>
<td>Manure Expert</td>
<td>5</td>
</tr>
<tr>
<td>Agriculture Retail</td>
<td>4</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>88</strong></td>
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### Key Interviews

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<th>Title</th>
<th>Organization</th>
<th>Quote</th>
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</thead>
<tbody>
<tr>
<td>1 J. Mardis</td>
<td>Senior Director of Environmental Health and Safety</td>
<td>Tyson Foods</td>
<td>“If you can beat transportation cost, you can do a lot of things [with poultry manure].”</td>
</tr>
<tr>
<td>2 N. Brinton</td>
<td>Chief Executive Officer</td>
<td>Charborn</td>
<td>“Typically, waste is unlike other raw materials. Wastes are inconsistent in makeup, shape, size, water content, etc. When you take waste and make a manufactured product, there are challenges with providing a consistent product, which is what the customer wants.”</td>
</tr>
<tr>
<td>3 S. Burgueson</td>
<td>Broker</td>
<td>Unlimited Renewables</td>
<td>“Conventionally raised manure qualifies as organic and can be used by organic farms. Farmers need to figure out how to get rid of it, but there is seasonality to the selling side. Current poultry manure pellet prices are: $300 per ton for a 4% nitrogen pellet (in CA) and $330 per ton for a 5% nitrogen pellet.”</td>
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<tr>
<td>4</td>
<td>M. Weber</td>
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<tr>
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<tr>
<td>5</td>
<td>M. Pierce</td>
<td>Owner</td>
<td>Pierce Litter Service</td>
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<td>6</td>
<td>P. Bredwell</td>
<td>Vice President of Environmental Programs</td>
<td>US Poultry and Egg Association</td>
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<td>7</td>
<td>R. Abbott</td>
<td>Co-Owner</td>
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<td>8</td>
<td>N. Azios</td>
<td>Viticulturist</td>
<td>Agua Dulce Winery</td>
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<td>9</td>
<td>G. Powers</td>
<td>General Manager</td>
<td>California Pellet Mill</td>
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<td>10</td>
<td>H. Allen</td>
<td>Executive Director</td>
<td>California Growers Association</td>
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<tr>
<td>11</td>
<td>J. Inestroza</td>
<td>Owner</td>
<td>Tenalu Farms</td>
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<td>12</td>
<td>D. Andersen</td>
<td>Assistant Professor</td>
<td>Iowa State University</td>
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<td>13</td>
<td>G. Farrar</td>
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<td>Elite Garden Wholesale</td>
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<td>P. Martien</td>
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<td>M. Haddox</td>
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<td>F. Hilliker</td>
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<td>18</td>
<td>David</td>
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<td>19</td>
<td>J. Brooks</td>
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<td>20</td>
<td>Bryce</td>
<td>Owner</td>
<td>Stutzman Ag Products</td>
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<tr>
<td>21</td>
<td>J. Siemens</td>
<td>Owner</td>
<td>Fat Uncle Farms</td>
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<tr>
<td>22</td>
<td>L. Ontiveros</td>
<td>Owner</td>
<td>3 and a Guy Farms</td>
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<tr>
<td>23</td>
<td>J. Bosio</td>
<td>Owner</td>
<td>Terra Bella Ranches LLC</td>
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<td>24</td>
<td>R. Blatchford</td>
<td>Researcher</td>
<td>UC Davis Ag Extension</td>
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<tr>
<td>25</td>
<td>Everett</td>
<td>Owner</td>
<td>2 Peas in a Pod Farm</td>
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<td>26</td>
<td>Timothy</td>
<td>Owner</td>
<td>Ellwood Farms</td>
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<tr>
<td>27</td>
<td>D. Cavaletto</td>
<td>Salesman</td>
<td>Ag Rx</td>
</tr>
<tr>
<td>28</td>
<td>Z. Nichols</td>
<td>Soil Scientist</td>
<td>Cal Poly</td>
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<tr>
<td>29</td>
<td>M. Rothrock</td>
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<td>ARS</td>
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<tr>
<td>30</td>
<td>W. Powers</td>
<td>Associate VP</td>
<td>UC Division of Agriculture and Natural Resources</td>
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</table>
Appendix 5: Technical Environmental Literature Review

Introduction

OrganicMatters aims to rethink animal waste management in the industrial egg industry. By drying and processing poultry manure, our mission to mitigate the environmental and human health problems associated with conventional management strategies can manufacture an organic, shelf-stable, nutrient-rich fertilizer and provide a sustainable alternative to resource-intensive synthetic fertilizers. Currently, manure sellers and buyers are seasonally and geographically disjointed. At OrganicMatters, our goal is to connect large-scale poultry farmers and crop producers who seek consistent sources of organic, pathogen-free fertilizers.

Since our final fertilizer product is derived from poultry waste, understanding the environmental impacts of current management strategies is integral to quantifying the potential benefits of our proposed solution. In the following literature review, we describe the magnitude of the environmental footprint, current industry processes to handle the waste, and the potential mitigation of these impacts by the pellet product. Our report focuses on water and air quality impacts of manure management strategies. In addition, because poultry manure can be a substitute for synthetic fertilizers in some cases, we provide a comparison to articulate the additional benefits gained through offsetting some synthetic demand.

Environmental Footprint of Poultry Waste

Poultry manure is a significant contributor to water and air quality pollution in the United States.\(^1\) There are over 350 million hens used for egg production in US inventory.\(^2\) Because the average egg-laying hen can produce approximately 0.25 lbs of manure every day, the US egg industry generates roughly 44,000 tons of this waste daily.\(^3\)

Poultry manure has an ideal nutrient composition for most agricultural crops and has been used as a fertilizer and soil amendment for centuries.\(^4\,5\) However, raw manure has high transportation costs, which limits the distribution and spreading of the material on cropland to less than 100 miles from the sourced poultry farm.\(^6\) Consequently, as Confined Animal Feeding Operations (CAFOs) for egg production have become larger and concentrated in localized regions around the country, the nearby cropland has become over-fertilized. When not managed properly, nutrients in manure, mainly nitrogen and phosphorus, can run off and lead to surface water quality degradation and groundwater contamination.\(^7\) Excessive nitrogen and phosphorus loading to aquatic ecosystems can lead to toxic algal blooms and mass species die-offs. Numerous studies have found that agricultural runoff contributes to increased nitrate levels in drinking water.\(^8\) In addition, because current management practice stores raw manure for extended periods of time, biochemically mediated degradation of the waste releases ammonia, greenhouse and other gaseous pollutants contributing to air quality
degradation. Ammonia gas is harmful to human and animal respiratory systems and poses an environmental hazard to soils and water bodies as it contributes to acid rain.10

Water Quality Degradation

Nitrogen and Phosphorus Runoff Contribute to Eutrophication
Agricultural runoff is the primary source of nitrogen and phosphorus contamination of surface and groundwater in the United States.11 Nitrogen and phosphorus are two elements found in manure, and their chemical properties allow dissolution into water very easily. Excess nutrient loading of waterways causes an array of negative environmental and human health impacts, which include: toxic algal blooms, hypoxia and nitrate pollution of groundwater.

Seasonal “dead zones” surrounding the Gulf of Mexico and the Chesapeake Bay have been appearing as the result of eutrophication, where manure and fertilizer runoff contribute significantly.12 Increases in crop production and fertilizer use have led to an increase in dead zones and affected surface waters. Eutrophication can lead to toxic algal blooms that consume nitrates and produce neurotoxins, hepatotoxins and dermatoxins which severely impact the brain, liver and skin, respectively.13 These toxins have serious human health implications in areas where lakes and other reservoirs are used for drinking water and recreation activities. In addition, the chemicals produced by the algae cause mass die-offs of fish, mammals and birds in lakes across the country.14 After these blooms end, the organic matter is decomposed by endemic microorganisms which use up the dissolved oxygen creating hypoxia, a conditions that cannot support fish and other animal species. Hypoxia also contribute to huge dead zones in lakes, rivers and coastal marine habitats.

Poultry manure is rich in nutrients that either pass through the animal from the feed stock or are produced by metabolic pathways. Water pollution can occur during housing, transportation, and application stages of manure management. Improper timing of application, improper amount of manure applied, and lack of manure incorporation into soils can contribute to nutrient leaching and runoff.15,16 Typically, manure is applied to cropland via broadcasting, tilling, or soil injection.

Nitrogen is lost from manure via denitrification and/or leaching, which occurs most when soils are wet.17 Nitrification is the conversion from ammonium nitrogen to nitrates and nitrites, which are subject to runoff. Numerous studies have found that improper poultry litter applications have contributed to increased nitrate levels in drinking water.18 The U.S. EPA set a limit on nitrate concentrations in drinking water to 10 mg per liter, and many areas exceed this limit.19 Nitrate can persist for many decades in groundwater and eventually cause methaemoglobinaemia, colloquially known as blue baby syndrome.20 The nitrate reduces the ability of infants’ red blood cells to carry oxygen leading to respiratory issues, vomiting and diarrhea.21 Figure 1 shows that vulnerability of nitrate contamination is particularly present in rural areas with large amounts of agricultural developments due to high rates of nitrogen deposition due to manure.22

Phosphorus is another important nutrient found in poultry manure that can pose environmental harm when over applied. Excess phosphorus levels contribute to
eutrophication and hypoxia in aquatic ecosystems. Current manure management strategies still lead to phosphorus contamination as runoff into surface waters and can result in eutrophication, algal growth, and lower dissolved oxygen levels. Soluble phosphorus concentrations can be higher than 2,000 mg P/kg manure, and the nutrient is readily transported by rain. Cropland in close proximity to poultry operations will receive most of the manure, and therefore will experience high nutrient loading. A 2012 Alabama soil survey shows differences in soil nutrient levels with regard to poultry production. Cullman County, a county with high poultry production, was found to have a surplus of 247 pounds of phosphorous/crop acre. Madison County, with no nearby poultry production, reported a deficit of 6 pounds of phosphorous/crop acre. Because poultry manure has high transportation costs, it is usually not transported further than 100 miles from its source. Though state and federal regulations require CAFOs to follow Nutrient Management Plans to ensure an appropriate amount of manure is being applied to crop acres, over-fertilization still occurs in many areas.

![Groundwater Vulnerability in the United States](http://water.usgs.gov/nawqa/nutrients/pubs/wcp_v39_no12/)

**Figure 1.** Groundwater Vulnerability in the United States. Source: USGS (http://water.usgs.gov/nawqa/nutrients/pubs/wcp_v39_no12/)

**Drying and Pelleting Provide Potential Mitigation**

Drying and pelleting poultry manure mitigates runoff/leaching problems related to normal housing and storage of manure. The likelihood of environmental contamination from dry manure storage is less than that from exposed piles. Pelleted manure can be stored in large super sacks or in smaller bags in an indoor setting.

Reshaping manure into a pellet form provides a slow-release mechanism as a fertilizer. Pellet manure has exhibited multiple environmental benefits, including reduced nitrogen leaching, enhanced nitrogen uptake, and soil health benefits. Pelleting manure can lead to higher crop yields and increased fertilizer use efficiency. Other slow-release fertilizer research has shown that the reduced nitrification from the slow-release mechanism resulted in 18-28% increases in wheat yields and 27.5-50.4% increases in rice yields.

Not all nitrogen in poultry manure pellets is available the first year of application. Approximately 30% of the nitrogen is available within the first season, and the nutrient is released continually through subsequent seasons. Residual nitrogen from poultry pellets
can be detected up to four seasons following the initial application, compared to one to two seasons following application of raw manure, and zero seasons following chemical nitrogen addition.30

Air Quality Degradation

Ammonia Footprint and Impact

The agriculture sector contributes to 85% of all US ammonia emissions.31 In 2002, this meant about 2.4 million tons of ammonia were emitted from agricultural activities.32 Egg-laying hens, broilers, and pullets produced approximately 280,000 tons of ammonia emissions in 1997 (see Table 1).33 Ammonia is lost from manure through volatilization processes. Volatilization can occur during manure storage, transport, and application. Land application of livestock manure is a significant contributor (close to half) of ammonia emissions.34 The poultry industry is estimated to contribute 26.7% of U.S. ammonia emissions.35

<table>
<thead>
<tr>
<th>Table 1. Estimates of annual ammonia emissions from livestock for 1997. (Pierce and Bender, 1999)</th>
</tr>
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<tbody>
<tr>
<td>Category</td>
</tr>
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<td>---------------------------</td>
</tr>
<tr>
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<tr>
<td>hogs</td>
</tr>
<tr>
<td>layers-pullets</td>
</tr>
<tr>
<td>broilers</td>
</tr>
<tr>
<td>turkeys</td>
</tr>
<tr>
<td>sheep</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Ammonia emissions (NH_3) are gaining attention across the agriculture sector, and several environmental groups are pushing for EPA regulation of ammonia.36 Ammonia emissions pose threats to air quality, and the loss of nitrogen through ammonia volatilization prompts the replacement of the valuable nutrient with synthetic, petroleum-based fertilizers.37 Additionally, there is growing concern that current manure management practices promote ammonia concentration in surface waters.38

Fine particulate secondary aerosols are formed when ammonia combines with sulfuric acids and nitric acids in the atmosphere.39 Most aerosol ammonium in the US reacts with sulfate ions, but in California and the Mountain West, where there are low sulfate levels and high ammonia and nitrogen oxide emissions, ammonium nitrate is the favored product.40 These fine particles contribute to decreased visibility and smog. Atmospheric ammonia returns to the surface as ammonium ions or as ammonia gas.41 Ammonia can dissolve in raindrops and fall as ammonium (NH4+) and/or nitrate (NO3-) through wet deposition.42 Additionally, dry deposition can occur, where ammonia can deposit on remote vegetation and fertilize plants through the leaves. Both wet and dry deposition may select for nonnative species over native plants and lead to ecological disruptions.43
Indoor ammonia levels are a concern for poultry operations, as high ammonia levels are linked to numerous poultry health issues. Ammonia levels above 25 ppm can cause respiratory problems for chickens. In an effort to reduce ammonia levels in the chicken houses, poultry farmers are often required to ventilate the structures. In winter months, this interferes with keeping the chicken houses adequately. Ammonia is also extremely odorous and is a common problem for livestock producers when cooperating with the local community.

### Ammonia Volatilization Process

The nitrogen in poultry manure is highly susceptible to ammonia volatilization. An egg-laying hen housed in a conventional cage system produces about 210mg ammonia per 100g stored manure per day (Table 5). Besides CO₂ (from respiration), ammonia is the most emitted pollutant from poultry housing systems.

#### Table 2. Summary of house-level manure storage, and farm-level daily emission rates of ammonia (NH₃), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and particulate matter (PM10 and PM2.5) for the conventional cage (CC), aviary (AV), and enriched colony (EC) housing systems over the 27-month monitoring period.

<table>
<thead>
<tr>
<th>Gas or PM</th>
<th>Source</th>
<th>Conventional cage (CC)</th>
<th>Aviary (AV)</th>
<th>Enriched colony (EC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/hen/d</td>
<td>g/(kg-egg)</td>
<td>% of total</td>
<td>g/ha/d</td>
</tr>
<tr>
<td>NH₃</td>
<td>House</td>
<td>0.08²</td>
<td>1.62</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Manure storage</td>
<td>0.21¹</td>
<td>4.00</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Farm</td>
<td>0.29</td>
<td>5.32</td>
<td>100</td>
</tr>
<tr>
<td>CO₂</td>
<td>House</td>
<td>68.3⁶</td>
<td>1,300</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>Manure storage</td>
<td>8.9</td>
<td>154</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Farm</td>
<td>76.4</td>
<td>1,454</td>
<td>100</td>
</tr>
<tr>
<td>CH₄</td>
<td>House</td>
<td>0.67</td>
<td>1.33</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>Manure storage</td>
<td>0.63</td>
<td>0.57</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Farm</td>
<td>0.10</td>
<td>1.90</td>
<td>100</td>
</tr>
<tr>
<td>N₂O</td>
<td>House</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Manure storage</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Farm</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>PM10</td>
<td>House</td>
<td>0.015⁶</td>
<td>0.299</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Manure storage</td>
<td>0.0157</td>
<td>0.299</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Farm</td>
<td>0.0157</td>
<td>0.299</td>
<td>100</td>
</tr>
<tr>
<td>PM2.5</td>
<td>House</td>
<td>0.009³</td>
<td>0.018</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Manure storage</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Farm</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Means of gaseous or particulate matter emission rates of the housing systems with different superscript letters significantly differ ($P < 0.05$).

Under aerobic conditions, the organic nitrogen in poultry manure is subject to volatilize in the form of ammonia gas. The basic reaction for ammonia volatilization in manure is the conversion of ammonium-N to ammonia gas and hydrogen. Ammonia volatilization is mostly a result of microbial degradation of uric acid and proteins. Microbial enzymes involved in the reaction include uricase, allantoinase, allantoinase or allantoate amidohydrolase, r- and s-ureidoglycolase, and urease. The optimal moisture content for these microorganisms is 40-60%, and reducing the moisture content to 20-40% can minimize ammonia volatilization and preserve nitrogen content in manure. Specifically, when moisture content of poultry manure is less than 30%, ammonia formation from uric acid stops. Alternatively, increasing the moisture content above 60% to create anaerobic conditions will inhibit the microbial degradation of uric acid (Figure 2). Anaerobic manure lagoons (or slurry pits) are uncommon in poultry farming, so most poultry manure is subject to aerobic conditions. Aerobic degradation of uric acid occurs
much faster than anaerobic degradation. Additionally, increases in pH, temperature, and ammonium-N concentrations will increase ammonia volatilization. A 5 °C increase from 25 to 30 °C can increase ammonia volatilization from 35 to 50% after land application.

Ammonia volatilization occurs during all stages of manure management: housing (while manure is still in the chicken house), storage (in an external storage heap or facility), and application. Through ammonia volatilization, 20-34% of available nitrogen can be lost when the manure is still in the poultry or hen house, 20-43% can be lost during storage, and 7-43% can be lost after land application. If broadcasted and not incorporated into the soil, manure loses nitrogen content through cumulative ammonia volatilization over time (Figure 3). In two Northeastern states (Pennsylvania and Vermont), there was 0% ammonia volatilization if manure was injected or immediately applied. Up to 20% volatilization was observed after first-day losses, and 80% volatilization if the manure was unincorporated (applied on bare soil).

Ammonia Volatilization Reduction and Nutrient Preservation
It is possible to control volatilization by reducing the manure surface area exposure to air, reducing manure-air contact time, and/or reducing environment air velocity. This would
involve a closed storage system, like an impermeable cover. Although impermeable covers can reduce ammonia emissions by 80-95% during storage, this does not solve volatilization problems that occur after application to land.\textsuperscript{62} Most volatilization occurs 8-24 hours after application, and incorporating the manure via injection to the soil within the first few hours at the site can prevent most ammonia volatilization.\textsuperscript{63} Immediate injection is not practical, as only a small fraction of cropland is located adjacent to large-scale poultry farms. As stated previously, cropland nearest to large poultry farms has become over-fertilized, and the manure from these farms is subsequently being transported further away.

Manure belts are an effective method reduce in-house ammonia volatilization. For poultry housing systems that utilize a composting manure management strategy, the ammonia emission rate is 386 g NH\textsubscript{3}/hen-storage time, and houses with manure belt systems have an emission rate of 34 g NH\textsubscript{3}/ hen-storage time.\textsuperscript{64} Similarly, for laying hens in a solid-floor storage facility, the ammonia volatilization can be as high as 400g NH\textsubscript{3}/ kg nitrogen in the manure. A manure-belt drying system reduces volatilization to 100g NH\textsubscript{3}/ kg nitrogen.\textsuperscript{65} Although in-house emissions are greatly reduced, significant volatilization still occurs in storage heaps. Drying poultry manure significantly reduces the ammonia emissions that occur with high rise, deep litter, and aviary systems, and eliminates volatilization that occurs during heap storage (Table 3.)

\textbf{Table 3.} Nitrogen losses through ammonia volatilization after various manure treatment strategies. The nitrogen lost to air from storage heap is estimated for a 40-day storage period.\textsuperscript{66,67}

<table>
<thead>
<tr>
<th>Manure Storage Strategy</th>
<th>Nitrogen lost to air (lb/ton)</th>
<th>Nitrogen lost to air from storage heap (lb/ton)</th>
<th>Total lbs N volatilized per ton manure</th>
<th>Tons manure per acre fertilized</th>
<th>lbs N lost per acre fertilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry high rise</td>
<td>20</td>
<td>10</td>
<td>30</td>
<td>3.5</td>
<td>105</td>
</tr>
<tr>
<td>Poultry deep litter</td>
<td>16</td>
<td>12</td>
<td>28</td>
<td>3.5</td>
<td>98</td>
</tr>
<tr>
<td>Poultry cage and belt</td>
<td>4</td>
<td>18</td>
<td>22</td>
<td>3.5</td>
<td>77</td>
</tr>
<tr>
<td>Poultry aviary</td>
<td>12</td>
<td>14</td>
<td>26</td>
<td>3.5</td>
<td>91</td>
</tr>
<tr>
<td>Poultry cage and belt PLUS drying and pelleting</td>
<td>4</td>
<td>NA</td>
<td>4</td>
<td>1.4</td>
<td>5.6</td>
</tr>
</tbody>
</table>

The addition of organic materials to poultry manure has also been found to reduce ammonia emissions. Adding sawdust can reduce ammonia volatilization by up to 48%.\textsuperscript{68} However, this requires adding organic materials constantly as manure is being produced. Adding organic matter during composting can mitigate ammonia volatilization.\textsuperscript{69} Raw manure storage stored as deep litter under the animals has been measured at 50.1 % N loss.\textsuperscript{70}
The addition of soluble phosphate fertilizers is a strategy to prevent ammonia volatilization, but increases phosphate runoff. Adding aluminum sulfate (alum) to poultry manure can reduce ammonia volatilization by 99% and reduce phosphorus runoff. However, alum has not yet been found to be cost-effective for poultry producers.

**Greenhouse Gas Emissions**

Greenhouse gas emissions from poultry production differ between broilers and egg-laying hens, and the housing structure can have an impact on greenhouse gas emissions. For egg-laying hens, a conventional cage housing system generates fewer greenhouse gases than an aviary or enriched colony system. In 2014, California egg production emitted 339 tons of methane (8,476 tons CO$_2$ equivalent), with an estimated livestock population of 13,103,200 hens. 47 tons of nitrous oxide (14,020 tons CO$_2$ equivalent) were estimated for the same year. Values were calculated for broiler production as well, though many fewer broilers are grown than egg-laying hens in California. According to the California Air Resources Board, the population of 9,837,000 broilers in CA produced 196.52 tons of methane in 2014 (4,913 tons CO$_2$ equivalent). Nitrous oxide emissions for the same year were estimated at 17.56 tons (5,232 tons CO$_2$ equivalent).

Nitrous oxide can be produced directly or indirectly through nitrification or denitrification of the nitrogen in the manure. Sixty-five percent of all nitrous oxide emissions from stored manure result from soil microbial nitrification and denitrification. The loss of nitrogen from manure as gaseous emissions depends on how the manure is stored and how it is applied to the land. Indirect emissions result from volatile nitrogen losses primarily in the form of ammonia and nitrous oxide compounds.

These emissions are small when compared to other livestock industries in California, especially dairy. Put in perspective, all the GHG emissions from poultry manure management are equivalent to those of approximately 2,155 houses. Greenhouse gas emissions from dairy cattle in California in 2014 were 18,038,080 tons of CO$_2$ equivalent; 6,794,168 tons from enteric fermentation and 11,243,912 from manure management. Emissions from dairy would be similar to the emissions from 1,727,969 houses.

The frequency at which manure is removed and the dry matter content of manure has an effect on the greenhouse gases emitted by the material. Methane and nitrous oxide production occurs when oxygen is scarce or absent (anaerobic environment) and is reduced when manure is dried.

**Life Cycle Assessment Review**

To finalize our environmental impact analysis of existing management strategies, we reviewed several life cycle assessments (LCA) of both broilers (meat birds) and egg-laying production. Although production cycles are very distinct between the two industries, the environmental problems associated with manure management strategies are comparable. In addition, both types of poultry production were analyzed to provide a better understanding of the efficacy as a fertilizer. Life cycle assessment provides a holistic approach when analyzing the cradle-to-grave impacts of commodities. LCA can identify the stages (processes) of poultry production that contribute to environmental
impacts. A review of LCAs regarding poultry and egg production concluded that manure management contributes significantly to eutrophication and acidification factors, while feed production and house heating contribute mostly to greenhouse gas emissions for these systems.  

To understand the impact of poultry manure on the environment, three LCAs were examined. All three studies reported that manure management was the greatest contributor to eutrophication and acidification. Nitrate leaching was the greatest contribution for eutrophication and ammonia emissions for acidification impact of ammonia deposition on plants. According to an LCA performed for broiler systems in France, one ton of organic broiler meat produced 2.3 tons of carbon dioxide (CO₂) equivalent, 110 lbs sulfur dioxide (SO₂) equivalent, and 59.4 lbs phosphate (PO₄) equivalent. The main contributing factors to greenhouse gas emissions were involved with feed, feed transport, and heating the broiler houses. In the wintertime, heating is a major concern for broiler houses to ensure comfortable living conditions for the chickens. Ammonia emissions from manure buildup force egg and broiler house operators to open ventilation in the houses, thus burning more fuel in the winter to keep the houses warm. If ammonia emissions are reduced in the houses, the carbon footprint from heating will also be reduced. On average, heating the broiler houses contributed 13.5% to total energy consumption of the farms studied, and 12% of global warming contribution of all the processes examined. Ammonia emissions from storing and composting manure from the broiler houses were the largest contributor to acidification factor in the LCA.

Another LCA studied compared the environmental impacts of poultry production in the US over time. Between 1960 and 2010, the largest impacts to emissions for pullet (adolescent chicken) rearing resulted from feed inputs and manure management. These findings were consistent with the previous LCA studies. To produce 1 ton of eggs in 2010, it was reported that 70 kg of SO₂ equivalent (acidification factor), 20 kg of PO₄ equivalent (eutrophication factor), 2080 kg of CO₂ equivalent (GHG factor), and 12 MJ of cumulative energy demand (CED) were generated. Supply chain of feed production contributed the most to the GHG factor and CED, with housing systems contributing the second most to CED. Similar to the previous LCA examined, the largest contributor to the acidification and eutrophication factors was manure management (Table 4). The third LCA examined showed similar results for the contributions of manure management to environmental impacts. Manure was the largest contributor to acidification potential and eutrophication potential for broiler productions, with the notable source being ammonia emissions. Nitrate leaching contributed significantly to eutrophication potential.

Chemical Fertilizer Production

It is our expectation that with enough market penetration, the final product can compete with synthetic fertilizers. Although the 5% nitrogen content of poultry manure pellets is much lower than the 20-40% nitrogen content in chemical fertilizers, the pellets provide slow nutrient release and residual nitrogen properties that chemical fertilizers do not. The organic matter in poultry manure pellets can build soil health and increase water retention, two qualities that are not found in chemical fertilizers.
Since the 1980s, chemical fertilizer use has increased in the United States, mostly driven by increases in corn production. In 2011, the US agricultural sector consumed 22 million tons of chemical fertilizer. The production of chemical/synthetic fertilizers is extremely energy and resource intensive. Chemical nitrogen is generated synthetically via the Haber-Bosch reaction, which involves an iron catalyst to form ammonia from atmospheric nitrogen and hydrogen from natural gas. The process became widely used in 1910 during World War I, and currently consumes 5% of global annual natural gas production, and 2% of global annual energy. Chemical nitrogen demand is forecasted to increase to keep up with growing populations and increases in crop production.

The Haber-Bosch reaction is energy-intensive and is a significant contributor to CO₂ emissions. Producing 1000kg of liquid ammonia via the Haber-Bosch reaction consumes 41,000 MJ of primary energy and releases 1920 kg CO₂ equivalent. Similarly, producing 1 ton of liquid ammonia consumes about 57% of the energy used by one American car in 2000, and releases about 50% of CO₂ emissions from one person in 2002. North America shares 12.9% of world nitrogen consumption. The US consumed 12,840,000 tons of Nitrogen fertilizer in 2011, which equates to roughly 27 billion kg of CO₂ equivalent from emissions. As with manure, nutrients in chemical fertilizer are subject to runoff if applied inefficiently. If too much fertilizer is applied or nutrients are added to crops at different times throughout the season, nutrients can be washed away. Certain crops require nutrients at different months of the year. For example, corn will take up most nitrogen in the spring, but in 2010, 20% of nitrogen application to corn acres occurred in the fall, where nitrogen is exposed to runoff by rain or irrigation.

Nutrient runoff from nitrogen fertilizers is also negatively affecting aquatic ecosystems. The Gulf of Mexico has suffered significant nutrient loading from the Mississippi River, and “dead zones” are increasing rapidly. The increase of nutrients in the Gulf fosters algal blooms, and the decay of excess algal material depletes the dissolved oxygen in the water. The area becomes anoxic, and marine animals vacate or die, which has adverse effects on the ecosystem and fishing industry. It is estimated that 60% of the excess nutrients entering the Gulf of Mexico are sourced from fertilizers.

Aside from water quality issues, chemical fertilizers contribute to the agricultural greenhouse gas inventory. The application of nitrogen fertilizers to crops is a significant source of agricultural nitrous oxide emissions.

Nitrogen management can reduce the loss of nutrients to air or water. Some methods include application of the proper amount, application at a time that corresponds with crop needs, and the injection or incorporation of nitrogen below the soil surface. Using slow-release fertilizers reduces the amount of readily-soluble nitrogen that is susceptible to runoff. Pellets, along with chemically altered and coated fertilizers, are a form of slow-release fertilizer. The size of the pellet determines the time required for its microbial degradation, and larger pellets take longer. Although slow-release fertilizers provide nutrients on an as-need basis for crops, they require more specialized equipment for application.
Conclusion
It is clear that poultry manure contributes to host of water and air quality problems. Raw manure is heavy and costly to transport, which leads to over application on neighboring cropland. Over application has led to leaching of excess nutrients into surface and groundwater causing a range of deleterious effects on the environment. Based on our review of existing literature, drying and pelleting poultry manure has the potential to mitigate many of the environmental impacts of conventional manure management. The drying process removes moisture, which prevents runoff into surface waters and groundwater leaching problems related to normal housing and storage of manure.\textsuperscript{118}

We believe this research demonstrates a substantive environmental and financial opportunity for OrganicMatters. Manure-drying systems can effectively halt ammonia volatilization, mitigating harmful emissions, preserving the nutrient content and allowing it to be stored for long periods of time in an indoor setting resolving the seasonal and geographic over application issue.\textsuperscript{119,120} It has been found that an efficient belt-drying system could reduce ammonia volatilization by almost 90\% when compared to conventional management strategies.\textsuperscript{121} From the fertilizer standpoint, the reshaped manure pellet exhibits multiple environmental and crop production benefits as it greatly reduces nitrogen leaching, increases crop yield and long-term soil health.\textsuperscript{122,123,124}

Although drying and pelleting poultry manure mitigates many of the environmental problems associated with traditional manure management, there are environmental costs that incur with this technology. Drying manure adds significant to electricity expenditure, as does the pellet mill. Additionally, extra packaging materials to store, ship, and sell manure pellets will contribute to fuel use and greenhouse gas emissions. Further analysis is needed to quantify the trade-offs associated with drying and pelleting, which will be completed once the specific machinery is chosen.
Technical Literature Review References

6 Interview with Mark Pierce (Pierce Litter Service) conducted by Lauren Catlin of OrganicMatters on October 26th, 2016.
9 Ibid.
19 Ibid.
23 Ibid.
28 Ibid.
29 Ibid.
30 John Brooks (ARS) interviewed by Lauren Catlin of OrganicMatters in Santa Barbara, 1/19/17.


Interview with Paul Bredwell (US Poultry and Egg Association) conducted by Lauren Catlin of OrganicMatters in Santa Barbara, CA, 10/28/16


Ibid.


Ibid.


Ibid.


Ibid.


Ibid.


Ibid.


Ibid.


Ibid.


Ibid.


Ibid.


Ibid.


Ibid.


Ibid

Appendix 6: Manure Pellet Safety

Pathogens
The use of raw manure on food crops that come in contact with soil (lettuce, strawberries, etc.) is not permitted due to the concerns of pathogenic microorganisms like *E. coli* and *Salmonella* sp. Composting manure removes pathogens from the material by raising the temperature of the manure to thermophilic conditions (130°F).\(^1\) Drying technology heats manure to 131-170°F for three days and can effectively sterilize the material.\(^2\)

Arsenic
Arsenic in conventional poultry manure has been a long-standing concern to the organic community. Arsenic was a common food-additive for poultry feed to enhance weight gain and improve meat coloration.\(^3\) Arsenic acts as a phosphate substitute and results in plant deficiency, and can bioaccumulate in crop tissue.\(^4\) Because arsenic can bind to soil minerals and become relatively immobile, arsenic contamination is greatest when litter is stored in piles and not integrated into the soil.\(^5\) When poultry litter is mixed well with soil, much of the arsenic becomes unavailable to plants. However, concentrations of arsenic can be absorbed by crop tissue. To address this concern, in December of 2015, the FDA withdrew nitarsone (a drug containing arsenic) from animal feed applications.\(^6\)

Pharmaceuticals
Because poultry manure sourced from Concentrated Animal Feeding Operations (CAFOs) can be used on organic soil, there is concern that the manure will have a high antibiotic concentration. Poultry receive antibiotics through feed additives and through treatment for local and systemic infections.\(^7\) Crops can absorb some varieties of antibiotics. Antibiotics present in soil can be taken up by plants. One particular study found that corn, cabbage, and green onions absorbed chlortetracycline, but not tylosin, despite discrepancies in soil sorption properties.\(^8\) Although the human health effects of ingesting antibiotics through plants are not well known yet, there is concern of allergic or toxic reactions, as well as increased threat of microbial antibiotic resistance.\(^9\) Studies show that antibiotics pose toxic effects on aquatic species such as algae and microcrustaceans, but at concentrations 100-1000 times greater than those observed in the environment.\(^10\) The low octanol/water partition coefficient (affinity for fatty substances) indicates that there is low potential for antibiotics to accumulate in animal tissue.\(^11\) Because antibiotic half-lives are decreased with increases in temperature, it is possible that the high temperatures reached through composting or drying technologies can reduce antibiotic concentrations in manure, but more research is needed.\(^12\)

Drying and pelleting manure does eliminate the presence of antibiotic-resistant microorganisms in the material. The temperatures and dry matter content reached by the drying and pelleting process kills all microorganisms.\(^13\) Because of this, poultry manure pellets will not bring antibiotic resistant organisms.\(^14\)

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1 Interview with Bob Engel (Engel and Gray) conducted by Lauren Catlin of OrganicMatters in Santa Maria, November 4, 2016.
Interview with Geoff Powers (California Mill Equipment) conducted by Jacob Levine of OrganicMatters in Santa Barbara, October 28, 2016.


Ibid.


John Brooks (ARS) interviewed by Lauren Catlin of OrganicMatters in Santa Barbara, 1/19/17

Michael Rothrock (USDA) interviewed by Lauren Catlin of OrganicMatters in Santa Barbara, 1/19/17
Appendix 7: Environmental Impacts of Different Poultry Housing Systems

Environmental impacts of manure change in regard to the housing systems where it is produced. Different housing systems remove and store the manure by different methods, which ultimately affect the way that the manure interacts with the environment.

The flow and losses of these nutrients in the manure in broiler and laying hen operations is highly dependent upon feeding practices, housing type and ventilation, and manure collection and management practices. The off gassing of nutrients can be directly measured for specific compounds including: carbon dioxide (CO$\textsubscript{2}$), ammonia (NH$_\text{3}$) and nitrous oxide (N$_\text{2}$O) while the off gassing of specific elements including: carbon (C), nitrogen (N) and sulfur (S) environmental losses can be estimated using mass balance methods.\textsuperscript{1}

Housing system design and manure management practice play a significant role in the environmental footprint of egg production. Three conventional housing types were studied by the Iowa State Agricultural Extension and found that 72% of all ammonia emissions originate from the storage of raw manure.\textsuperscript{2} The three housing types examined were: conventional cage, aviary, and enriched colony. Differences in manure emissions are highly related to the moisture content of each manure source with Enriched Colony having the driest manure, followed by the Aviary and finally the conventional cage.\textsuperscript{3}

Even as industry is pushed towards “cage free” eggs due to public pressure, the manure belts (and our proposed business model) can still service egg-laying houses.

\textsuperscript{2} Ibid.