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# Manufacturing: The Qualitative Study of a Transition to a Green Facility

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# MANUFACTURING:
# THE QUALITATIVE STUDY OF A TRANSITION TO A GREEN FACILITY

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MANUFACTURING:
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I dedicate this thesis to my wife Chassidy and my kids Brileigh and Grayson for giving me the motivation to continue to better myself and reach a higher degree of education. Without them not only would I have been complacent in my level of education, but I would have never had the commitment to achieve this goal.

To both my grandpa David Lee Jones and dad Barry Lee Staves who helped shape my career path and my dedication to family. They are both inspirations on so many levels to how I raise my kids and I hope to have my kids look up to me as I have looked up to them. To my grandma Natalie Jones and mom Kelly Ann Robbins who told me there is always a way to achieve your goals if you have the dedication and have helped me every step of the way. As well as the rest of my family who have shaped how I have grown.

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This qualitative study focused on answering three core questions: How have facilities reduce pollutions in regards to the quality of air, water, land, light and noise? Which Types of pollution reduction projects are more or less successful to implement? What types of pollution are facilities focusing on and why? The results of the 15 companies surveyed show a variety of projects that facilities have used to reduce pollution, it also shows that cost is a major factor in the unsuccessful projects, and that facilities are actively focused on reducing Air, Land, and Water pollution. While the data shows a variety of projects that companies focused on it shows that cost plays a major factor in determining if a project succeeds, it also shows that some pollutions such as light may not be fully understood. The study was successful at creating a list of roughly 50 ways that various companies have targeted pollution reduction.

# INTRODUCTION

## Background / Overview

Climate change is defined as a long-term change in the earth's climate, especially a change due to an increase in average atmospheric temperature. (Unabridged Dictionary, 2019). According to the 2019 United Nation NDC Global Outlook Report (Doyle, 2019) countries are recognizing climate change is real and are beginning to develop or revise plans to reduce greenhouse gasses a cause of climate change. In fact, the report states that 112 nations have signaled their intent to revise plans, 53 are working on long term strategies, and even 90 developing nations are preparing climate adaption plans. Most importantly in relation to this study, is that the report shows that since 2015 climate action has been widening across society to involve the private sector, investors, civil society, and stakeholders. Due to the rapid deployment of strategies, manufacturing facilities are having to implement changes to adapt and account for climate change, in other words they are "going green". This thesis will take a qualitative view of how these manufacturing facilities are adapting to climate change.

## Statement of Research Problem

Climate change has increasingly become a more common issue among the public resulting in tougher federal, state, and city regulations, different consumer perspectives, and political repercussion. Companies are taking notice and becoming more focused on

going green and properly managing their effect on the environment. While there are many studies on the effects of climate change, there are not comprehensive studies of how manufacturing facilities implementing these changes have been affected or a list of options facilities can implement to meet these goals.

## Need or Significance

With the growing importance of climate change, and the increased awareness that facilities need to manage their impact, there is need to provide guidance on the resources available to implement and what to expect during implementation. There is also a need to capture the mistakes that facilities have made along the way so that others can have a more consistent transition.

## Purpose Statement

The purpose of this thesis is to understand how facilities transform from typical styles of manufacturing into green facilities, focusing on manufacturers in Kentucky and Indiana. At this point a green facility will be defined as a facility that strives to reduce any form of pollution. Defined as, an addition of any substance or form of energy to the environment at a rate faster than it can be dispersed or stored in a harmless form, including carbon emissions, light, sound, air, water, or various forms of energy.

## Research Questions

The overall research will try and answer the following guiding questions.

1) How have facilities reduced pollution or "gone green" in regards to the quality of air, water, land, light, or noise?
2) Which types of pollution reduction projects are more or less successful to implement?
3) What types of pollution are facilities focusing on and why?

## Assumptions

The following study assumes that those that respond are honest in their responses. That facilities are aware of their impact on the environment and understand what climate change and pollution are. That answers to questionnaires were given in good faith and that answers given by survey subjects were accurate and representative of their true perceptions.

## Limitations

This study is limited to 15-25 respondents who all reside in Kentucky and Indiana most of which will be limited through my own networking as well as linked-in or the

AMS departments emails. Climate change and pollution are a global problem, and this study does not detail the affect that it has on global facilities. In addition, climate change is a rapidly evolving problem, the affects that it has on facilities at the time of this study may not be the same as the affects within a few years.

Participation was voluntary and confidential.

**Definition of Terms**

For the Purpose of the study the following definitions and explanation of acronyms are needed:

*Climate change* - A long-term change in the earth's climate, especially a change due to an increase in average atmospheric temperature. (Unabridged Dictionary, 2019)

*Pollution* – Addition of any substance or form of energy to the environment at a rate faster than it can be dispersed or stored in a harmless form. This can include air, water, land, sound, dust, radiation, thermal, and light (Unabridged Dictionary, 2019)

*Green Facility* – (Facility) Buildings, services, equipment, etc. that are provided for a particular purpose that (Green) support the protection of the environment as a political principle. (Oxford, 2021)

*GHG* – Green House Gasses or GHG is defined by the Environmental Protection agency as gases that trap heat in the atmosphere. The gases can include but are not limited to carbon dioxide, methane, nitrous oxide, and fluorinated gases. These are typically represented as CO2 equivalents. (United States Environmental Protection Agency, 2021)

# REVIEW OF LITERATURE

## Pollution and Causes

Pollution is the introduction of harmful materials called pollutants into the environment. These can be natural or created by human activity. Pollution is a global problem that can be found in urban, rural, and even remote areas such as the artic. There are three majorly recognized types of pollution air, water, and land pollution. However, there are many more rapidly growing areas of pollution such as light and noise pollution. (Boudreau, McDaniel, Sprout, & Turgeon, 2011)

Pollution can be created by natural processes such as volcanic ash however they are also caused by human activity(Boudreau, McDaniel, Sprout, & Turgeon, 2011). As technology improves the environment was a second thought to human convenience. For example: Humans wanted to travel quicker so we built cars that burned fossil fuels and pumped toxins into the air. Humans wanted to see better at night, so the light bulb came about neglecting the effect it had on nocturnal animals and requiring energy from fire burned materials. Humans needed to eat more food requiring deforestation to make room for farmland and using pesticides to produce better quality food sources. Humans wanted easier ways to clean up after events or eat on the go and thus one-use plastics were created such as plastic cups and plates. Thus, Human convenience played a major role in how pollution came to be created. (Boudreau, McDaniel, Sprout, & Turgeon, 2011)

In addition, due to population and standard of living increases across various nations energy is being consumed now more than ever before. In turn leading to increases

in transportation, heating, electricity, and tangible goods and services creating an increase level in pollution (Sung-Hoon, Doo-Man, & Won-Shik, 2013).

Even though human convenience causes pollution it is important to recognize that human convenience isn't a bad thing. Vehicles and aircraft allow people to travel the world, pesticides allowed humans to grow in population without starving or fighting over food, coal power allowed people to stay warm during freezing winters and allowed many of our goods and services that humans use on a daily basis to produce at quantities that wouldn't be possible otherwise. Yet there are very important reasons to reduce and eliminate pollution, hopefully in a way that maintains our human conveniences.

**Land Pollution**

Land pollution where human waste is placed upon the land in one way or another. Landfills, where solid waste is usually deposited, is a widely used practice around the world due to its cheap nature and is a form of land pollution. However, landfills can have detrimental effects. (Njoku, Edokpayi, & Odiyo, 2019) states that landfill operation is usually associated with contamination of surface and groundwater by leachate from the landfill, pungent odor, loud disturbing noises, bioaerosol emissions, and volatile organic compounds. In his study he concluded that the health risk associate with living close to landfills are at high health risk compared to those that live far away and recommended landfill sites be located far from residential areas. (Njoku, Edokpayi, & Odiyo, 2019)

The health factors associated with living near the landfill included increased air pollution of $CH_4$ that causes loss of coordination, nausea, vomiting. Increase in nitrogen dioxide and sulfur dioxide that can cause nose and throat irritations, bronchoconstriction, respiratory infections and can trigger asthma attacks. Njoku et al. (2019) goes on to state that the sulfur dioxide has harmful effects on plant growth and productivity. Landfills can also have concentrations of heavy metals that can damage the nervous system, causing memory disturbances, sleep disorders, anger, fatigue, head tremors, blurred vision, and slurred speech along with kidney damage and various cancers. (Njoku, Edokpayi, & Odiyo, 2019)

**Air Pollution**

Air pollution as an example has been linked to many different disorders from before birth to the late stages of life (Elizabeth, 2019). In children air pollution has been linked to impaired fetal growth in utero and smaller head circumference at birth, decreased verbal and nonverbal intelligence, memory restriction, and poor performance on visual reaction time, pursuit aiming a variety of other things by ages 8 to 11. In addition, studies demonstrate that babies had developed mental delay, lower IQs, and more anxiety, depression, inattention, and reduce brain white matter when compared to those in environments with less air pollution. In older adults air pollution has been shown to increase the risk for pulmonary illnesses, stroke, myocardial infarction, and various cancers. In elderly it was demonstrated that for every 10-point increase on the EPA air quality score there was a .02-point decline on global cognitive score the equivalent to a 2-

year increase in age. Those with greater exposure to air pollution resulted in an 81% - 92% higher risk of global cognitive decline and all-cause dementia. (Elizabeth, 2019)

In addition to the effects air pollution has on the human body, it also has a disastrous effect on the environment. The Intergovernmental Panel on Climate Change noted in 2001 that emission trends would lead to an average global temperature rise between 1.4 and 5.8 degrees Celsius (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013). To help stabilize the concentrations of GHG in the atmosphere the Kyoto protocol agreement was reached, establishing legally binding targets for reduction of GHGs.

**Water Pollution**

Water pollution caused by things such as wastewater, stormwater, non-point source pollution, metals, pesticides, and nanomaterials have been linked to reproductive issues in fish and having adverse effects on other freshwater organisms (Harmon, 2009). Water pollutants particularly that of nano-plastics have been found to be enter the human body entering various organs such as the liver, spleen, kidneys, heart and have even been able to pass through the blood-brain barrier and enter the brain leaving plastics and the chemical effects of these plastics direct access to the brain. Dependent on the type of plastics that have entered the body can cause various chemical effects affecting reproductive health, cancer rate, and can cause other mutations. BPA plastics for example have been found to be able to bind to estrogen receptors that can cause hormones in the body and can cause breast and testicular cancer, affect metabolism, decrease sperm count (Hrissi & Ioannis, 2019).

## Light Pollution

Light pollution is one of the most rapidly increasing types of environmental degradation, growing exponentially over the natural nocturnal lighting levels (Falchi, Cinzano, Elvidge, Keith, & Haim, 2011). In fact, more than 60% of world population lives under light polluted skies, and 99% of the population of both USA and Europe live in these conditions. Light pollution has been found to decrease pineal melatonin production. This causes alteration to the circadian clock which leads to performance, alertness, sleep and metabolic disorders. (Falchi, Cinzano, Elvidge, Keith, & Haim, 2011).

It isn't just humans that are affected by light pollution animals that have evolved around night are also being affected. There is an entire book written around the affects that light pollution has had on various animals and plants, Ecological Consequences of Artificial Night Lighting, that discuss increased risk of being killed by predators, decreases in food consumptions, even possible connections to survival and reproduction rates (Rich & Longcore, 2006).

## Noise Pollution

Noise pollution affects nearly 100 million people in the United States or roughly 50% of the population (Hammer, Swinburn, & Neitzel, 2014). Noise pollution is the

elevation of natural ambient noise levels due to sound generating human activities (Slabbekoorn, 2019). Noise pollution can cause many different health problems such as sleep disturbance, noise-induced hearing loss, cardiovascular disease, endocrine effects, and increased incidence of diabetes. In addition, it was found that children in noisy environments have poor school performance, resulting in lower reading comprehension and concentration deficits.

Noise pollution can also affect wildlife, (Fakan & McCormick, 2019) shows that noise from motorboats affected the embryogenesis of the coral reef damselfish. When noise was present the embryos had a 10% faster heartbeat, while it didn't affect their survival rate it did cause them to hatch about 5% larger as well as have eyes 9% larger. Another study showed that noise was a contributing factor in bird population density and in order to conserve native local species that reducing noise levels must be taken into consideration (Fontana, Burger, & Magnusson, 2011).

**Manufacturing's Contribution to Pollution**

Manufacturing is a major contributor to this problem as they increase production in order to keep up with the growing demand, (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013) states that manufacturing is dominant in its environmental impacts in categories such as toxic chemicals, waste generation energy consumption and carbon emissions. In fact, data from the EPA collected in 2018 shows that Industry accounts for 22% of greenhouse gas emissions, when the entire supply chain is taken into

account this number increases significantly (EPA, 2018). In fact, electricity at 27%, transportation at 28% and agriculture at 10% are all separate entities but the argument could be made that a food manufacturer for example can assume percentages from each separate entity. In addition, as of 2004, the industrial sector of the United States economy produced the larges $CO_2$ equivalent emissions, with the manufacturing industry accounting for approximately 80% of the category.

The manufacturing industry generates much more waste than the mining, oil and gas, agricultural, hazardous, MSW, coal ash, and medical industries (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013). In 2003, the manufacturing industry consumed approximately 23% of total energy in the United States only the transportation industry consumed more energy. Considering that as of 2006, the United States, generated 71.4% of its energy from fossil fuels, you can see how big of an impact manufacturing is having on the environment. (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013)

In a study researching pollution from pharmaceutical manufacturing facilities into natural sources of water found traces of active pharmaceutical ingredients at detectable levels. In fact, in Sweden there was more ciprofloxacin found in one day than is consumed in five days or enough to treat 44,000 inhabitants (Larsoson, 2014). Manufacturing also contributes to light pollution by lighting up their building, parking lots and other outdoor areas (Falchi, Cinzano, Elvidge, Keith, & Haim, 2011). In essence manufacturing industries contribute to every type of pollution in some form. However, there has been growing concern on both a global political and consumer level to reduce the current levels of pollution.

## Defining Green Manufacturing

Green Manufacturing is one potential framework that aims to improve manufacturing performance so that there is less industrial pollution, less material and energy consumption, less wastage and etc. (Sangwan & Mittal, 2015).

Green Manufacturing is known by multiple terms such as clean manufacturing, environmentally conscious manufacturing, environmentally benign manufacturing, even environmentally responsible manufacturing among others (Sangwan & Mittal, 2015). These terms have appeared in literature since the early 1990s, and while similar in nature not all are interchangeable (Sangwan & Mittal, 2015). For this reason, the duration of the thesis will use Dornfeld et al.'s definition as detailed below.

Dornfeld et al. (2013) define green manufacturing as a process or system which has a minimal, nonexistent, or negative impact on the environment. There are other variations of manufacturing that can contribute to green manufacturing that do not encompass it as a whole. It is important to note that while these manufacturing practices, such as lean and socially conscious manufacturing, may attribute to green manufacturing they do not have the same end goals. (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013) provide a good Venn diagram that paints the differences in these. Essentially connecting each type of manufacturing to their goal, Lean – Economic, Green – Environmental, Socially Conscious – Social, and Sustainable manufacturing that takes pieces of each.


*Figure 1:*Manufacturing in relation to the three pillars of sustainability (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013)

**The Push for a Green Economy**

Rusink (2007) states that shareholders are more frequently asking their organizations to be more responsible with products and process due to regulations, stewardship, public image and competitive advantages. Customers, suppliers, and the public are also increasingly demanding that organization minimize the negative impact of products and operations on the environment (Klassen & Whybark, 1999).

For example, the U.S. Congress has enacted the Clean Air Act, Resource Conservation and Recovery Act, Pollution Prevention Act. In addition, the US EPA requires a Toxic Release Inventory, reporting on their annual release of chemicals, to be filed by manufacturing facilities. The Department of Energy has established a voluntary greenhouse gas registry program, the Department of Commerce has organized a green manufacturing day", according to (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013) and most recently President Biden signed executive actions to tackle the "climate crisis at home and abroad" (White House: Breifing Room, 2021).

Dornfeild et al. (2013) mention that the United States congress have a goal to reduce CO2 by 83% by 2050 and envision some form of cap-and-trade program. They go on to state that if products being produced rely on a global market, that it is inevitable that the producer will face green manufacturing at some point. (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013) lay out an example of a car manufacturer in Kentucky and California, pointing out, that after conversion of energy to GHG (greenhouse gas), that the exact same process would produce more GHG in Kentucky than that in California. This is due to the fact that California's energy grid is based on a mix of renewable energy whereas Kentucky relies on coal powered plants. This can become more and more important for manufacturers looking to lower their GHG and state governments looking to attract manufacturers as the federal government pushed for a cleaner and greener environment. In addition, location based on emissions can lead to economic incentives.

It is reported that manufacturers spend approximately $170 billion per year in waste treatment and disposal cost. Add that to the proposition being proposed to charge

for GHG emissions and applying green initiatives quickly become a cost-efficient solution. This also can give competitive advantages as societies become more aware of environmental issues customers are anticipated to begin selecting products that are more environmentally conscious. Marketing being environmentally friendly can lead to an increasing market share and generating more revenue. (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013)

In addition, the majority of manufacturers now days are part of a larger supply chain. Often times it is members of this supply chain, or internal stakeholders, that is pushing other manufacturers to go green. Onsrud and Simon (2013) mention that while manufacturers only have so much control over the working conditions of their suppliers, they do have a choice in where they source their components from. Take a large-scale manufacturer such as Toyota, who decides it is in their companies' best interest to go green. This means all tiered suppliers then get pushed to go green as well, as they contribute to the overall Toyota supply chain and Toyotas overall green footprint.

External stakeholders, including customers non-government organizations media and communities, also play a role in pushing manufacturers to go green. Onsrud and Simon (2013) state that consumer interest in issues of sustainability, such as human health, depletion of resources, pollution, waste creation, and climate change have grown over the years. One activist Greta Thunberg has organized protest given speeches to the United Nations and has been a large influence on non-government organizations as well a member of communities to push involvement in the impact everyone plays on the environment. In a pointed speech speaking to world leaders back in 2019, Greta stated that the world leaders are "failing us, but young people are starting to understand your

betrayal…The world is waking up, and change is coming whether you like it or not." (Thunberg, 2019). To put into perspective the impact of this one person 4 million people worldwide participated in strikes organized in response to Greta's various speeches, 1.1 million students in New York alone were excused from school where they had planned to walk out in support of reducing societies impact on the planet (Stanglin, Hauck, & Wilson, 2019).

For the reasons above it is important for manufacturers to understand the potential desires of the consumers and the broader frameworks emerging, by taking action, becoming educated on priority issues, and acknowledging what a company can improve. Manufacturers must be aware of the concerns of their stakeholders in order to mitigate their future risk and help build and acceptable future. (Onsrud & Simon, 2013)

**Manufacturing's Response to the Green Push**

Sezen and Cankaya (2013)'s study of 53 companies in Turkey indicated that green manufacturing had a positive impact on environmental and social performance. Proving that making a sustainable adjustment to the manufacturing process can improve a company's perspective of shareholders and consumers. At the same time that the management of the environment is being driven, organizations are also challenged to implement changes that improve competitiveness (Klassen & Whybark, 1999).

(2001) presents things that manufacturing as a whole are doing. Many manufacturing facilities are implementing "reduction, reuse, recycle, and remanufacture"

and attempting to develop their process around them. Facilities are also frequently implementing continuous improvement and total quality management striving for zero defects which in turn leads to less emissions. In addition, they have implemented design for environment and life cycle analysis to help mitigate the effects of the product over its lifetime. Designing the product using degradable material or materials that aren't as detrimental to the environment during production. In addition, reusing materials from old product via disassembly and reuse are also being trialed. (Sarkis, 2001)

Environmental theorist have explicated the need to convert the linear systems of manufacturing to circular systems. The concept of "cradle to cradle" extends the responsibilities of manufacturers to all phases of a product's life cycle, with the idea being that products and byproducts are harmlessly reintegrated into the natural ecosystem or act as food (raw material) for the next industrial process. (Onsrud & Simon, 2013)

Xerox provides an excellent example of how going green and implementing the circular life cycle can impact a company. Xerox has implemented an end-of-life takeback and reprocessing program that led to savings of over $80 million in Europe in 1997 while turning disposal cost into revenue streams and hiring an additional 400 people, according to (Maslennikova & Foley, 2000). An example of the circular life cycle is detailed in the image below.

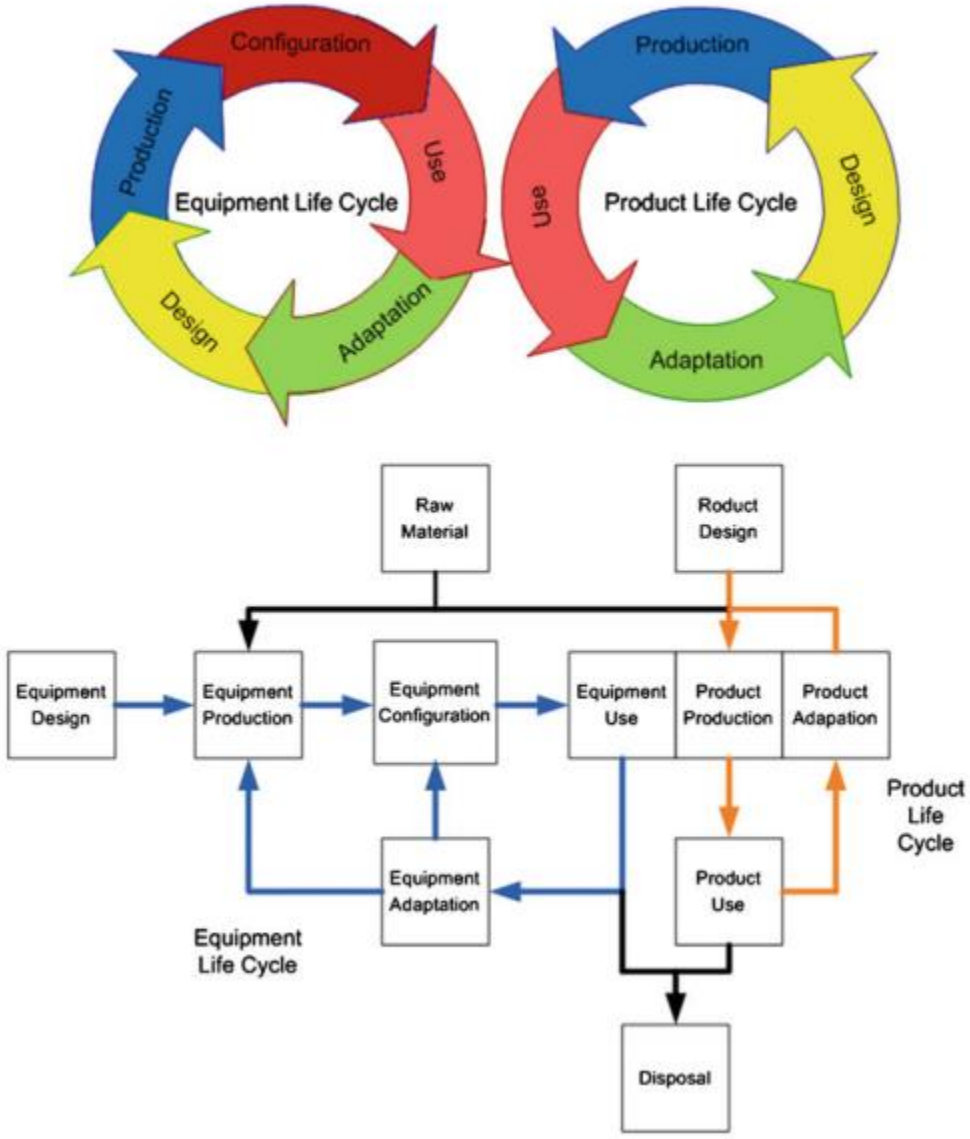


*Figure 2:*Synchronized life cycles of products and production equipment (Vijayaraghavan, Yuan, Diaz, Fleschutz, & Helu, 2013)

There is also a methodology that has been created to select the best cost option with the most impact. Congbo et al. (2010) created a formula to express the total benefits of a green technology portfolio. The formula equates the total benefits of one green technology portfolio, using the direct benefits of the technology, the synergy effect coefficient of technology, and a 0-1 variable. Throughout their study they dive into how to populate the equation and create the best selection of available technologies to create

the best green portfolio while maintaining cost integrity. In fact, (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013) states that results of a survey of 1000 U.S. manufacturers, have shown that 90% have an environmental strategy and 80% have environmental-friendly operations mechanisms.

Dornfeld et al. (2013) state that there are three areas to look at when developing strategies for green manufacturing: Pollution prevention, end-of-pipe control, and environmental restoration. Pollution prevention is applied before and during the emission generating process through preventative measures. An example would be replacing obsolete motors, inefficient equipment, or changing raw materials to more environmentally friendly ones. End-of-pipe control would be control strategies after the emissions and waste are generated, but before they are released into the environment. An example of this would be an RTO (Regenerative Thermal Oxidizer) which burns air emissions to destruction, releasing clean air, or a HEPA (high efficiency particulate air) filter catching particulate matter before released into the atmosphere. Environmental Restoration is employed to remediate environmental damage after the emission/waste have ben generated and released into the environment. An example of this would be oil spill clean ups, or reseeding forest that have been cut down for lumber/paper.

However, as more environmental programs develop most facilities don't want to try theories, instead they seek to implement proven technologies and programs. While programs have developed such as ISO 14000 certification, certifications alone do not guarantee a successful environmentally benign system. Benchmarking and information sharing is a necessity that must occur and is an issue that needs to be addressed. (Sarkis, 2001)

## Barriers to Green Manufacturing

Interestingly, a study done by Despeisse, Oates and Ball (2013) implied that despite the increasing pressure placed on manufacturers to implement sustainable manufacturing practices, there is a gap in knowledge on how to achieve the desired aims at operational levels. A second study states that the understanding of relationships among environmental management, implantation of technologies, and performance out comes remains limited (Klassen & Whybark, 1999). In other words, manufacturing facilities are being told to become green, more and more every day. Yet, when they start the journey, they're doing it blindly. Aiming for the first thing they think will create a green environment around them.

There are other barriers industries have to establishing green manufacturing. Dornfeld et al. (2013) list three categories of these barriers: economic, technological, and managerial. Economics barriers include high capital cost with long payback, often times the capital cost exceeded the gain. Though it is also mentioned that this barrier is gradually diminishing as cost for emissions and waste disposal increases.

Technologically, manufacturers are often having to rely on processes technologies and materials that produce effects that have a negative impact on their environment. The technology is not there to avoid these effects yet, and often while being developed often time manufacturers want the technology proven before relying on it to produce their products. (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013)

Managerially speaking, the industry lacks capable scientifically based decision support tools for effective implementation of green manufacturing strategies (Dornfeld, Yuan, Diaz, Zhang, & Vijayaraghavan, 2013). In other words, management has trouble visualizing the effects of bad green practices. They have trouble grasping the situation which in turn leads management to rejecting capital request, or not seeing the justification in an additional process to reduce pollutants. Specific benchmarking analytical tools can be used to help alleviate this barrier. Dornfeld et al. (2013) state that the environmental impact of manufacturing must be assessed both comprehensively and specifically for robust decision support in industrial applications and that it needs further research on environmental impact assessment methods and manufacturing process modeling and characterization.

Thus, the need for this study, to improve on a lack of research around actual implementations. Specifically, what manufacturing facilities have done to reduce their pollution of all types. What technologies were implemented, what was successful, what was a failure, how did they get the required support or justification. A documented list of specific technologies or programs such as recycling programs, efficiency improvements, and environmental waste reduction activities needs and should be documented. This documentation could help to improve the global quality of life in humans and for the environment. It could help address what Onsrud and Simon (2013) state is insufficient progress, hindered by a lack of partnerships, dialog, commitments and aid and the need for changes and action at all scales. In addition, it would address what Onsrud and Simon (2013) note is that despite the necessary motivation, manufacturers need actual steps on which to take action.

# CHAPTER 3 – METHODOLOGY

## Research Design

This qualitative study is poised to answer the core questions listed in the introduction of this thesis, because the core questions that are being asked require different perspectives and there is not a clear definable yes/no or positive/null, a qualitative approach has been chosen.

Using open ended questions via online surveys were used to help get a broader range of replies rather than simple yes/no responses. These surveys are found in appendix A. After responses were received, they were analyzed and grouped in order to be properly analyzed to create simplified analysis, graphs and, lists of activities that facilities have done. Extensive replies that were received have been shared in detail when found that it answers the core question well.

## Participants and Data Sets

The targeted participants in this study were intended to be facility managers, supervisors, environmental specialist, or other decision makers working directly in the facilities. The reason being that these participants would have been because they are usually the ones with firsthand knowledge of what has actually been done to achieve the goals set by corporate managers, shareholders, or other sources. They are be the ones going on the floor and telling what truly made a difference and what was a waste of time.

They are the ones implementing ideas generated by others and have the most understanding of how these things were done, and where to find the options that are available.

**Survey Questions**

The survey questions were created and sent out via Google Forms. The form created a web interface for the questions consisting of two separate pages, located in appendix A. The first displayed the IRB approval, shown in appendix B, as well as a consent agreement that required the user to exit the survey if they didn't agree or would allow them to proceed to the second page if consent was given. The second page of the survey listed the questions detailed below.

1) Name
2) Organization
3) Can you provide examples of how your facility has reduce pollution or "gone green" or been more sustainable in regards to the quality of air, water, land, light, and noise?
    3a. What was relatively the most successful "green" implementation; Why?
    3b. Is your facility actively pursuing future "green" initiatives, if so can you provide examples?
    3c. Can you provide examples of any initiatives that were unsuccessful or that your facility decided not to implement; Why?
4) Which areas of pollution is a target for your facility: Air, Water, Land, Light, Noise, Other?

## Data Collection, Instruments, and Procedure

The survey was intended to follow the steps detailed in Creswell and Creswell (2018). Asking one central question followed by no more than five to seven sub-questions. The intent is to get the participant to inquire a more detailed answer that a simple one allowing more flow of information through the survey. This survey also use open-ended questions that are intended to encourage each participant to answer uniquely. It was created in a way that would guide them to what was considered to be pollution but allowed them to answer in a broader sense.

The distribution of the survey was done via email and Linked-in. The intent being that managers of facilities (not corporate managers) would respond to the survey and that the participants would be those who work at facilities located in Kentucky and Indiana.

The surveys will blanket a large group as linked-in is open to anyone who signs up for an account. This is not a bad thing as most users do not actively participate in surveys. Because of this the target set of this study was between 15-20 manufacturing facility managers, of which we received 15 as detailed in the next section.

## Survey Details

The survey period lasted from March 15th 2021 to May 1st 2021. It included a total participation of 13 individuals representing 15 organizations. There are fewer

participants than there are organizations, as some individuals filled out the survey in reference to multiple organizations. Each individual gave consent for the information they provided to be used in regards to this thesis.

The organizations represented in the findings include the following: Tobacco Manufacturing – 20%, Food Manufacturing – 20%, Tiered Automotive Manufacturers – 6.67%, Aluminum Manufacturing – 6.67%, Plastics Manufacturing – 6.67%, Retail Manufacturing – 6.67%, Laundry Manufacturing – 6.67%, Heat Exchange Manufacturing – 6.67%, Alcohol Manufacturing – 6.67%, Paper Manufacturing – 6.67%, and University – 6.67%. These categories are presented in Figure 3: Organizational Category of Respondents.

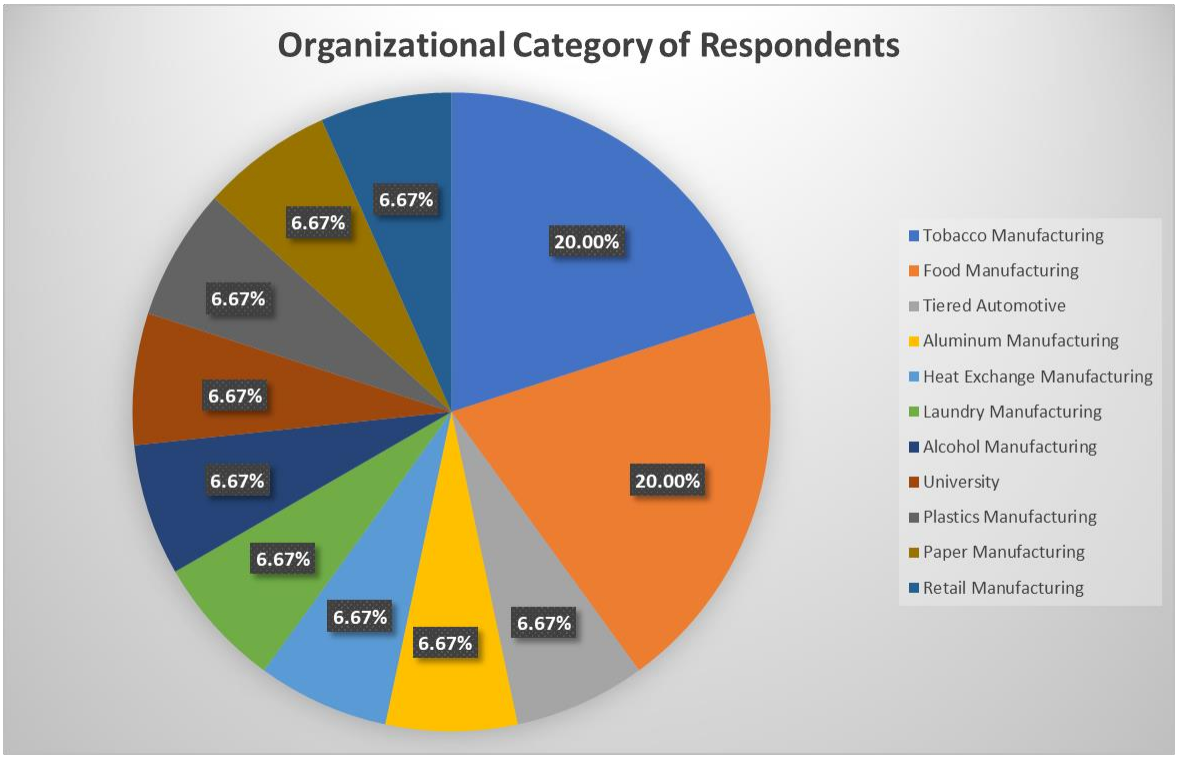


*Figure 3: Organizational Category of Respondents*

## Data Analysis

Surveys were analyzed a broken down into categories. This allowed for a cleaner statistical analysis of each question and provided results that could be detailed for better references. In addition, an uncategorized list was created to show the detail of projects done, unless a project was worded the same, they were all included on the list shown in Figure 9: Complete List of Projects Mentioned by Participants.

The first and second questions of the survey shown in appendix A and detailed in the section above titled Survey Questions were designed to capture the manufacturer information to show the variety of organizations that participated and to ensure that there were no repeated participants that may have submitted two surveys by mistake. This analysis was already provided in the section above titled survey details.

The third questions show what participants have done in their facility that they believe to help their organization transition to a green state. While the third and fifth questions help us evaluate what participants viewed as successful implementations as well as what was viewed as a bad implementation, this allowed us to see if there was an correlation in what different organizations considered successful and if there were any correlations on what was considered unsuccessful. The fourth question helped us understand if facilities were actively pursuing the green state or not. While the final question helped to determine what each of the facilities actually considered to be

pollution and if all major pollution categories were considered necessary by organizations to be in the green state.

## Threat to Validity

There are various threats to the validity of this study including but not limited to:

The possibility of dishonest survey participants.

Survey participants that could be incompetent or participants that had an unequal knowledge base.

There is a possibility that there were misinterpretations of responses to the surveys.

The possibility of survey participants misinterpreting the survey questions.

There could have also been a variety of a participant's level of education, experience, or understanding.

# CHAPTER 4 – RESULTS OR FINDINGS

**How have Facilities reduced pollution or "gone green" in regards to the quality of air, water, land, light, and noise?**

The data collected points towards a variety of methods facilities are using to go green. As detailed in Figure 4: Organization Utilization of Pollution Reduction Techniques.

Facilities have invested in transitioning away from landfill with initiatives such as "Waste to energy" facilities, used wood pallets being redirected to compost facilities or other recycling initiatives, reduced plastics on raw materials, food waste to farms for animal feed, and general waste repurposing. One has even begin planning trees as a method of offsetting pollution.

Organizations have focused on energy reduction as a form of green implementation by replacing lighting with LED lights, upgraded HVAC units and controls, and extensive compressed air leak repairs. Depending on the type of supplied energy this could categorically go into different categories, air for coal/natural gas-powered plants, water for hydroelectric, or even land for nuclear, it is also possible that some of these facilities get energy from renewable energies.

Air quality had been improved from facilities implementing Low NOx (nitrogen oxide) boilers, efficient HVAC units, and "smart way" vehicle fleet replacement. Water quality has been improved using water filtration systems that allow recycling of facility

water, stormwater runoff infiltration ditches, and upgrades to wastewater treatment plants.

Noise pollution was affected by two facilities one that installed mufflers on roof stacks and another that installed sound barriers. Light pollution while mentioned as an activity was only in the form of using LED lighting and while improving other pollution categories depending on the brightness of light may not affect light pollution.

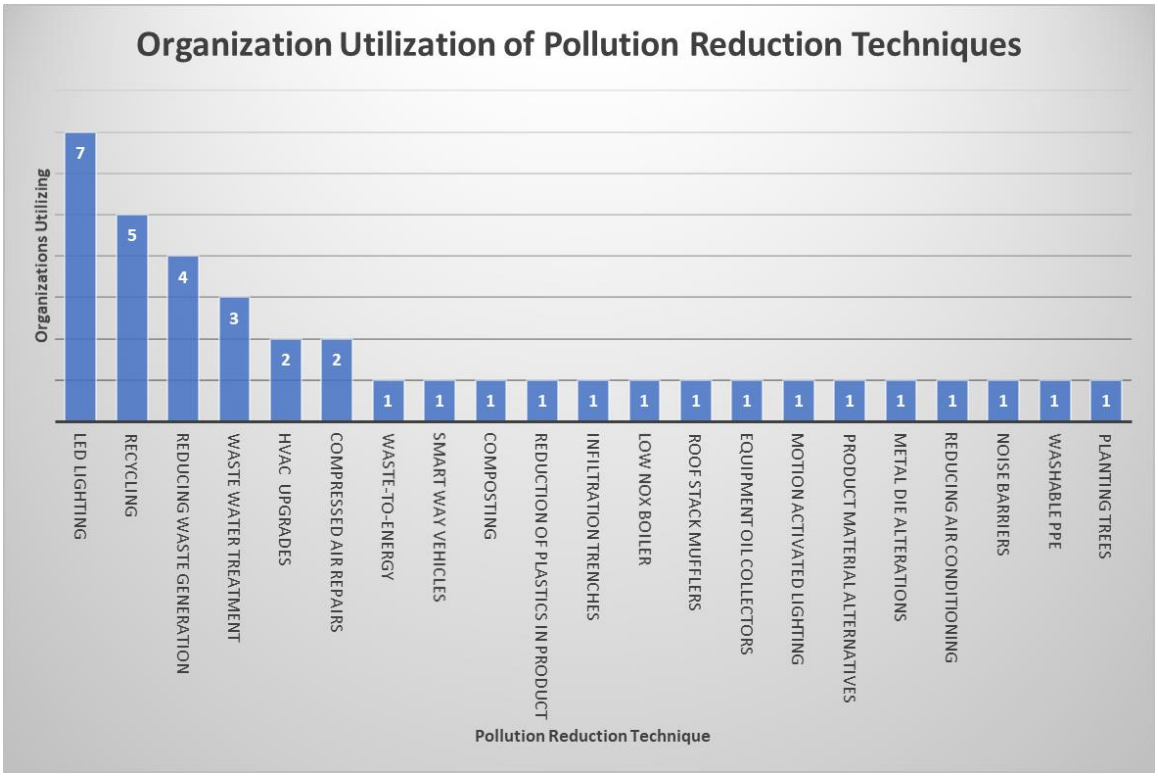


*Figure 4: Organization Utilization of Pollution Reduction Techniques*

**Which types of pollution reduction projects are more or less successful to implement?**

*Most Successful:*

Participants were asked what their most successful "green" implementation was as well as what their least successful was. The most successful projects came back as a wide variety of answers including: Raw material plastic reduction, recycling (cost improvements and landfill reduction), eliminating waste streams, HVAC controls upgrades (reducing energy and water consumption), two companies stated compressed air utilization (allowed them to shut down two 100 hp air compressors reducing energy consumption), food waste to animal feed (reducing 70% of material waste to landfill), water filtration (reduced 40% of water consumption), two companies stated LED lighting (reduced cost), metal recycling (reducing landfill usage), permeable pavement (reduced needed potable water used in landscaping), and washable PPE (reducing hazardous waste). These items are listed in Figure 5: Most Successful Implementation.

| Most Successful Implementation (Why; If Stated) |
|---|
| Reduction of Plastics in Product (Reduction of GHG) |
| Recycling (Cost Improvement and Landfill Reduction) |
| Reduce/Elimination of Waste streams |
| HVAC  Upgrades (Saves Electricity/Water Usage) |
| Compressed Air Repairs (Reduced Run Time/Energy Consumption) |
| Waste-to-Pig Farm (Eliminated 70% of Material Waste) |
| Water filtration (Water Consumption Reduced by 40%) |
| LED lighting (Reduced Cost) |
| Metal Recycling (Landfill Reduction) |
| Compressed air reduction (Cost Savings) |
| LED Lighting (Cost Return on Investment) |
| Permeable Pavement (Reduced Needed Potable Water for Landscaping) |
| Washable PPE (Hazardous Waste Reduction) |
| Equipment Replacement (Reduced Waste Disposal by 30% and Annual Cost by 25%) |

*Figure 5: Most Successful Implementation*

*Least Successful:*

The projects that were least successful came back as a wide variety of projects but with a more unified underling cause that caused them to be unsuccessful including: DC warehouse relocation (high cost), Hazardous waste initiative to grant disposal exemption that would enable recycling (high financial cost), Plastic banding recycling that required shredding equipment (high cost), individual pollutant controls (marginal improvements or are too expensive), changing HVAC temperature by 1 or 2 degrees (employee discomfort), energy reduction (large capital investment or too much downtime), biodegradable cups (high cost of cups), Power monitoring equipment (not implemented with no reason given), Increase waste bailing (cost of equipment), Cardboard recycling

(incorrect equipment), two others gave cost as a reason for failure without providing examples, only one gave no identifiable projects that were unsuccessful. These items are listed in Figure 6: Least Successful Implementation.

| Least Successful Implementation (Why; If Stated) |
|---|
| DC Warehouse Relocation and Hazardous Waste Reduction Initiative (Cost) |
| Plastic Banding Recycling (Cost) |
| (Cost) |
| Infiltration Trench (Difficult to Measure) |
| HVAC Temperature Adjustment (Employee Discomfort) |
| Energy Reduction (Cost) |
| Biodegradable Cups (Cost) |
| (Cost) |
| Power Monitors (Not Implemented) |
| Scrap Reuse (Safety Concerns) |
| Increased Waste Bailing (Cost to Implement) |
| Cardboard Recycling (Incorrect Equipment) |
| No Unsuccesful Implementations |

*Figure 6: Least Successful Implementation*

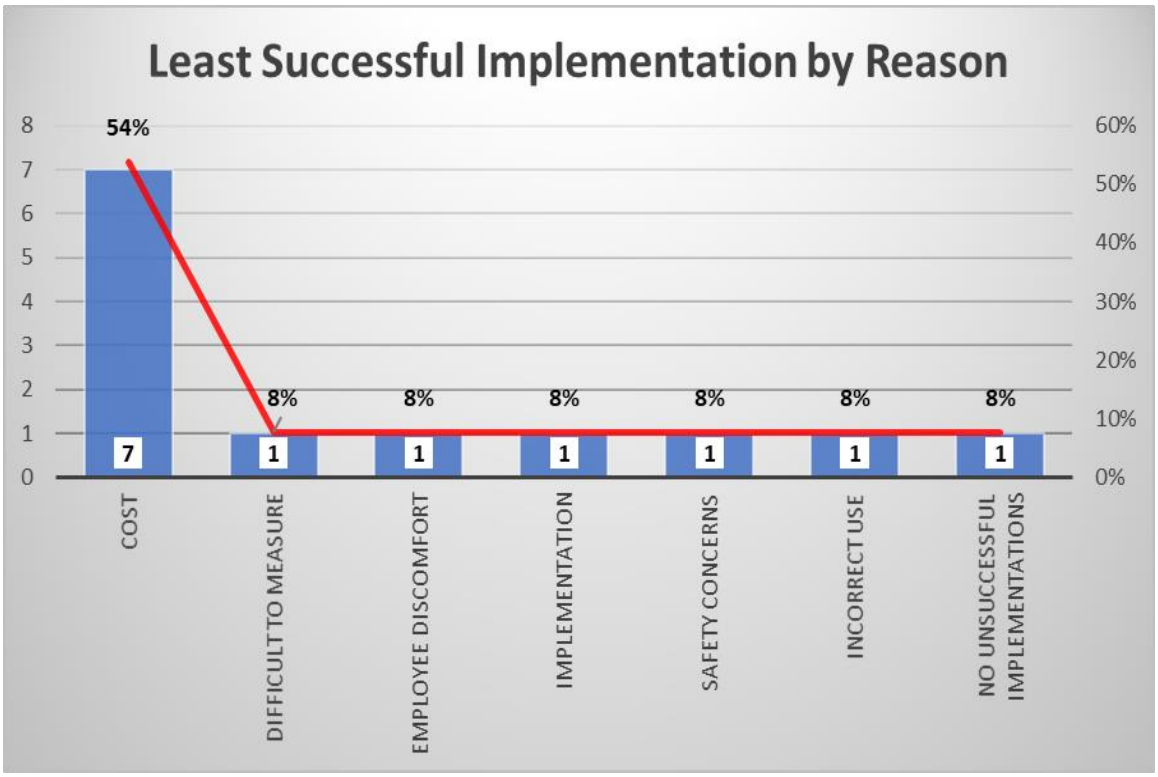


*Figure 7: Least Successful Implementation by Reason*

As shown in Figure 7: Least Successful Implementation by Reason cost is the primary reason that survey participants listed as the reason for least successful implementation. Cost was the reason associated with 54% of participants least successful projects, while difficult to measure, employee discomfort, implementation, safety concerns, incorrect use, and no unsuccessful implementations all were mentioned once giving an 8% association for each.

**Are facilities actively pursuing future "green" initiatives?**

Every single facility surveyed is actively pursuing "green" initiatives. While two did not give specifics those that did included: Solar panels, Sustainable packaging, Landfill incineration, Recycling, Searching for cleaner energy providers, Landfill reduction, Air compressor utilization, Water and wastewater reduction, Vend-misers, Reducing plastic scrap, Reusable containers, LED lighting, Chiller upgrades, Pursuing zero waste to landfill, and Recycling damaged pallets. Included were three companies that either already had money allocated to a future project that was not decided yet or were pursuing baseline measurements to show improvements on future projects.

**Which areas of pollution is a target for facilities?**

Those surveyed were asked which areas of pollution were being targeted presented with the following options to select from: Air, Water, Land, Light, Noise, and Other (with the option to type out what was considered other). Two facilities selected other; one was redistributed to land as the surveyed typed out "Landfill reduction" which clearly falls into land. The other facility typed out turning off conveyors when not being used, because this falls into an energy conservation and there was no way to know where this facility received their electricity from it could not be accurately put into one of the other categories and as such was left as other.

Of the facilities surveyed, they ranged on what they were targeting for pollution targets with 53% targeting Air, 47% targeting Water and Land, 40% targeting light, and 33% targeting noise, and 7% targeting other. These are demonstrated in Figure 8: Pollution Targets by % of Participants Pursuing Them.

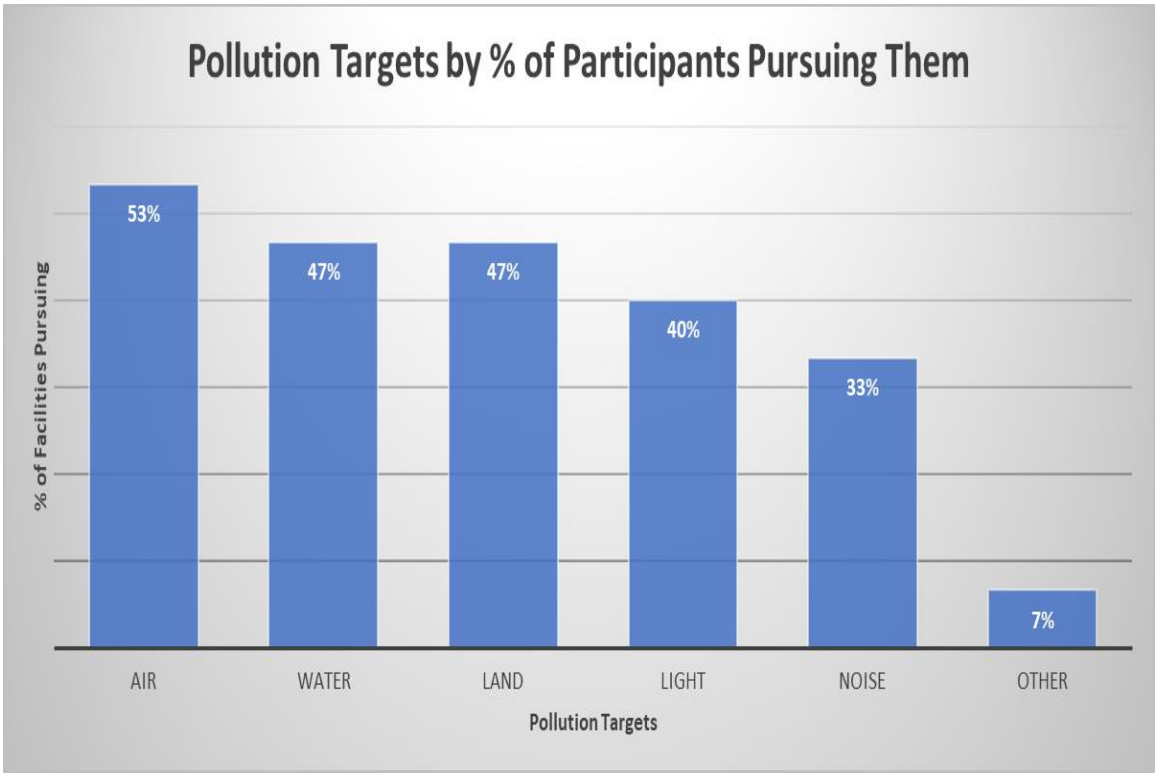


*Figure 8: Pollution Targets by % of Participants Pursuing Them*

**Complete List of Projects Mentioned by Participants**

Throughout the study we have asked what participants have done. What they failed at, succeeded at, what they are planning for the future. Shown in below, is a comprehensive

list of what participants have mentioned as projects. The intent of this is that these projects mentioned, may trigger those who read this study to attempt to implement versions of these into their facilities.

| Complete List of Projects Mentioned by Participants |
|---|
| LED Lighting |
| Recycling |
| Reducing Waste Generation |
| Waste Water Treatment |
| HVAC  Upgrades |
| Compressed Air Repairs |
| Waste-to-Energy |
| Smart way Vehicles |
| Composting |
| Reduction of Plastics in Product |
| Infiltration Trenches |
| Low Nox Boiler |
| Roof Stack Mufflers |
| Equipment Oil Collectors |
| Motion Activated Lighting |
| Product Material Alternatives |
| Metal Die Alterations |
| Reducing Air Conditioning |
| Noise Barriers |
| Washable PPE |
| Planting Trees |
| Waste-to-Pig Farm |
| Water filtration |
| Metal Recycling |
| Compressed air reduction |
| Permeable Pavement |
| Equipment Replacement |
| DC Warehouse Relocation |
| Hazardous Waste Reduction Initiative |
| Plastic Banding Recycling |
| HVAC Temperature Adjustment |
| Energy Reduction |
| Biodegradable Cups |
| Power Monitors |
| Scrap Reuse |
| Increased Waste Bailing |
| Cardboard Recycling |
| Solar |
| Sustainable packaging |
| Cleaner Energy Providers |
| Landfill Reduction |
| Air Compressor Utilization |
| Reduce Water and Wastewater Consumption |
| Vend-misors |
| Process Waste Tracking |
| Reusable Containers |
| Chiller Upgrades |
| Zero Waste to Landfill |
| Recycling Damaged Pallets |
| Landfill Incineration |

*Figure 9: Complete List of Projects Mentioned by Participants*

# CHAPTER 5 – CONCLUSIONS

In conclusion, based off of the data provided facilities are actively pursuing green initiatives. While it seems the most frequently used method is replacing lights with LEDs, many other projects seem to be unique to the individual facility. This could mean that either every green transition project is unique to the facility or that there is no clear route that facilities know to take. Providing a list of projects that other facilities have done may help in this endeavor, including the list of projects listed in this survey. In addition, it seems that a majority of projects that do fail, do so because of cost. It also becomes apparent that while the majority of pollutant types are recognized and decently understood, that light pollution is one that may not be clearly defined as most of those surveyed that listed light pollution as a target pollution reduction listed LED lights as one of their projects. This, however, does not necessarily have any effect on light pollution and depending on the brightness of the LED could actually pollute more.

## Future Work and Recommendations

Overall, I hope that in the future this thesis can be used for facilities trying to "go green" by sharing ideas of what other facilities have tried, what has failed as well as why they failed and potentially keep other facilities from doing the same. More research does need to be done as this was a small sample size. I visualize there could eventually be a Wiki-style data base that organizations could go to in order to generate ideas that could

be used in there facility. Since going green tends to help the communities as a whole I don't see this violating any trade secrets or violating any company copyrights instead it would be a place that could help organizations ease into policies that shareholders are forcing upon organizations.

Future research could also show how companies that have high success in projects, incentivize those projects with high cost. My recommendation would be to add a cost associated with pollution, similar things are done in lean manufacturing in reference to floor space where a dollar amount is added to every square-foot saved, I assume that once pollution emissions are measured companies could apply the same logic to those emissions as they do to floor space savings.

Another possible work would be on how many organizations actively categorize light pollution as part of their green initiatives this small sample size makes it seem like companies don't view this as an issue or don't understand what light pollution is. This is something that should be highlighted more often to bring understanding that light pollution is using more light than needed causing light to travel beyond where intended, causing the night sky to brighten as detailed in the research portion of this Thesis. This does not mean that these companies are not trying to reduce light pollution as they may have projects that are not detailed or may be using motion activated LEDs.

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# APPENDIX: A

## Survey Questions

Implied Consent Document

**IMPLIED CONSENT DOCUMENT**

**Project Title:** Manufacturing: The Qualitative Study of a Transition to a Green Facility
**Investigator:** Brandon Staves, AMS, Email: Brandon.staves912@topper.wku.edu

You are being asked to participate in a project conducted through Western Kentucky University. The University requires that you give your agreement to participate in this project.

**You must be 18 years old or older to participate in this research study.**

A basic explanation of the project is written below. Please read this explanation and email the researcher any questions you may have. If you then decide to participate in the project, please continue to the survey. You should keep a copy of this form for your records.

1. **Nature and Purpose of the Project:** The nature of the project is to understand what your facility has done in order to reduce pollution including what has been successful, what has failed, future projects, and which pollutant types have been targeted/considered.

2. **Explanation of Procedures:** You will be asked a series of questions related to initiatives implemented by you facility to reduce pollution this should take no more that 15-20 minutes depending on the detail of answers given.

3. **Discomfort and Risks:** You will be asked to reveal your name and organization, however this information is only to ensure there is no repeated surveys. This information will not be shared.

4. **Benefits:** By answering in detail, the questions presented, other facilities can learn of different "green" initiatives taken by other companies that could be implemented in their own. In addition, others can learn from mistakes made by initiatives that didn't work out, allowing for a smoother transition when pursuing "green" initiatives.

5. **Confidentiality:** No information regarding name or organization will be shared or detailed in any way. This information is only to be used to guarantee that surveys are not taken multiple times by the same people. Records will be viewed, stored, and maintained in private, secure files only accessible by the P.I. and advising faculty for three years following the study, after which time they will be destroyed.

6. **Refusal/Withdrawal:** Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time with no penalty.

*You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.*

***Your continued cooperation with the following research implies your consent.***

THE DATED APPROVAL ON THIS CONSENT FORM INDICATES THAT
THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY
THE WESTERN KENTUCKY UNIVERSITY INSTITUTIONAL REVIEW BOARD
Robin Fyles, Human Protections Administrator
TELEPHONE: (270) 745-3360

WKU IRB# 21-177
Approved: 3/15/2021
End Date: 5/01/2021
EXPEDITED
Original: 2/07/2021

In completing this survey you are accepting that this data can be used in a research project. The information gathered will only contribute to the research project and will not be distributed. If you do not consent than please exit the survey now, by exiting the data will not be collected. *

- (●) I GIVE CONSENT

Next Clear form

## Facilitating a Green Transition

Name *

Your answer

Organization *

Your answer

Can you provide examples of how your facility has reduced pollution or "gone green" or been more sustainable in regards to the quality of air, water, land, light, and noise? *

Your answer

What was the most successful "green" implementation? Why? *

Your answer

Is your facility actively pursuing future "green" initiatives, if so can you provide examples? *

Your answer

Can you provide examples of any initiatives that were unsuccessful or that your facility decided not to implement? Why? *

Your answer

Which areas of pollution is a target for your facility: *

- [ ] Air
- [ ] Water
- [ ] Land
- [ ] Light
- [ ] Noise
- [ ] Other:

Back Submit Clear form

# APPENDIX B

## Implied Consent Document

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