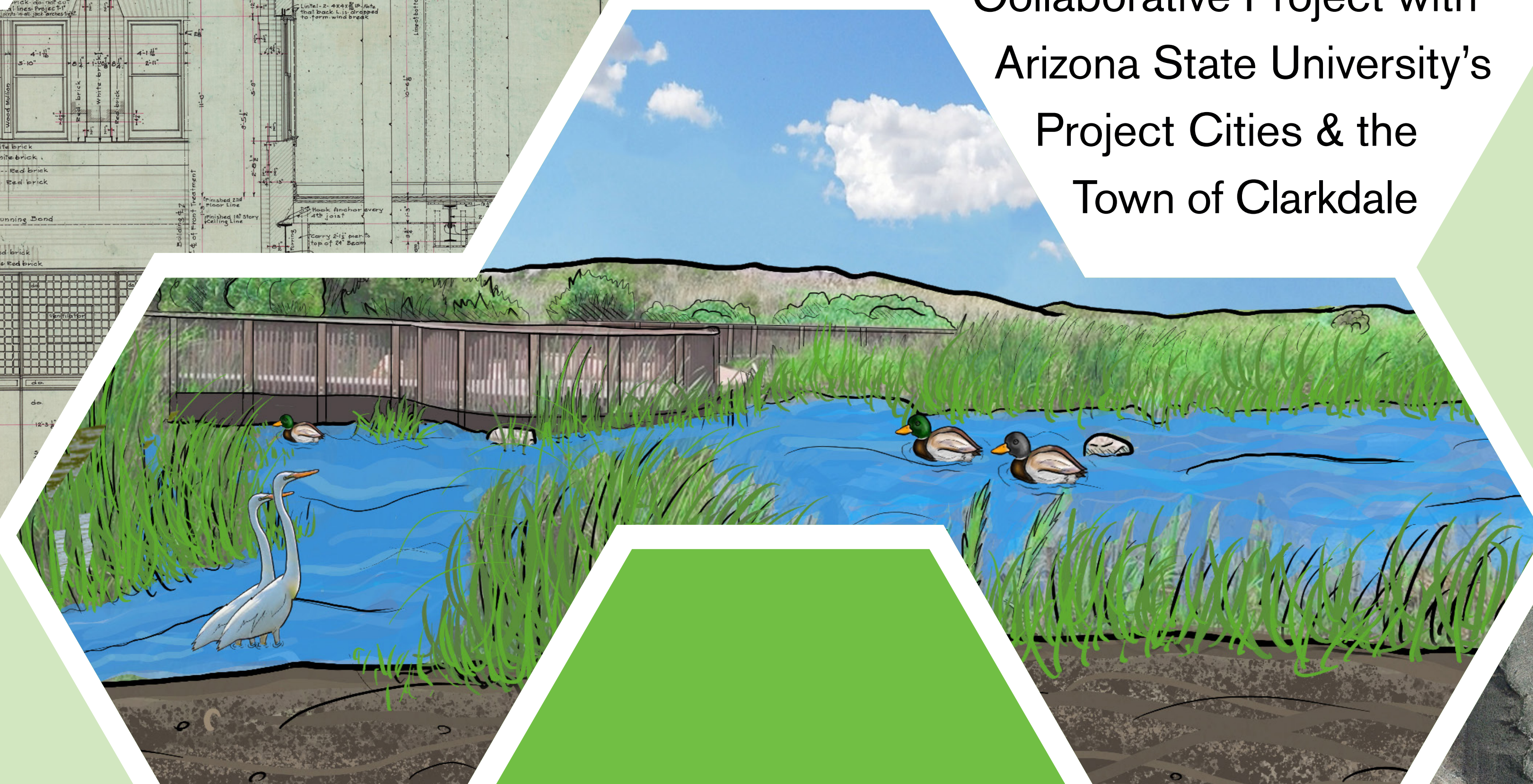
Energy Efficiency & Eco-Tourism: Sustainability in Clarkdale

A Fall 2020 Collaborative Project with Arizona State University's Project Cities & the Town of Clarkdale

Sustainable Cities Network
Arizona State University
Project Cities



PART 1:

Project and community introduction

GET TO KNOW THE PROJECT

ABOUT ASU PROJECT CITIES

ABOUT THE TOWN OF CLARKDALE

EXECUTIVE SUMMARY

KEY STUDENT RECOMMENDATIONS

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Cover images:

Town of Clarkdale,
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ACKNOWLEDGMENTS

Town of Clarkdale

Robyn Prud'homme-Bauer, Mayor

Doug Von Gausig, Mayor (2004-2020)

Debbie Hunseder, Vice Mayor

Bill Regner, Councilmember

Marney Babbitt-Pierce, Councilmember

Lisa O'Neill, Councilmember

Tracie Hlavinka, Town Manager

Ruth Mayday, Community Development Department Director

Maher Hazine, Public Works Director

Mike Gray, Community Development Project Manager

Guss Espolt, Community Development Technician

Arizona State University (ASU)

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On behalf of the Julie Ann Wrigley Global Futures Laboratory, the Global Institute of Sustainability and Innovation, and the School of Sustainability, we extend a heartfelt thank you to the Town of Clarkdale for enthusiastically engaging with students and faculty throughout the semester. These projects provide valuable real-world experience for our students and we hope that their perspectives shine light on opportunities to continuously improve Clarkdale's future livelihood and community well-being.

TABLE OF CONTENTS

To access the original student reports, additional materials, and resources, visit:
links.asu.edu/PCClarkdaleSustainability20F

ABOUT PROJECT CITIES

The ASU Project Cities program uses an innovative, new approach to traditional university-community partnerships. Through a curated relationship over the course of an academic year, selected Community Partners work with Project Cities faculty and students to co-create strategies for better environmental, economic, and social balance in the places we call home. Students from multiple disciplines research difficult challenges chosen by the city and propose innovative sustainable solutions in consultation with city staff. This is a win-win partnership, which also allows students to reinforce classroom learning and practice professional skills in a real-world client-based project. Project Cities is a member of Educational Partnerships for Innovation in Communities Network (EPIC-N), a growing coalition of more than 35 educational institutions partnering with local government agencies across the United States and around the world.

ABOUT SUSTAINABLE CITIES NETWORK

Project Cities is a program of ASU's Sustainable Cities Network. This network was founded in 2008 to support communities in sharing knowledge and coordinating efforts to understand and solve sustainability problems. It is designed to foster partnerships, identify best practices, provide training and information, and connect ASU's research to front-line challenges facing local communities. Network members come from Arizona cities, towns, counties, and Native American communities, and cover a broad range of professional disciplines. Together, these members work to create a more sustainable region and state. In 2012, the network was awarded the Pacific Southwest Region's 2012 Green Government Award by the U.S. EPA for its efforts. For more information, visit *sustainablecities.asu.edu.*

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Sustainability through local action

ABOUT CLARKDALE

The Town of Clarkdale, Arizona is located on the banks of the Verde River in the north central part of Arizona. It is a thriving community and is the gateway to the Sycamore Canyon Wilderness Area in the beautiful Verde Valley. Founded in 1912, Clarkdale is renowned as the first master-planned community in the state of Arizona and was developed with a "Live, work, play" ideology intended to provide its residents with a wholesome living experience. Clarkdale has just over 4,300 residents who thrive in the fresh, clean air of the Verde Valley.

CLARKDALE TEAM

Project Cities Community Liaison

Tracie Hlavinka, Town Manager

Clarkdale Project Leads

Tracie Hlavinka, Town Manager

Ruth Mayday, Community Development Department Director

Maher Hazine, Public Works Director

Mike Gray, Community Development Project Manager

Guss Espolt, Community Development Technician

Celebrating historic charm. Creating a prosperous future.

clarkdale.az.gov

Town of Clarkdale

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Clarkdale, AZ 86324
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September 20, 2021

Dear Town of Clarkdale Residents:

On behalf of the Town Council and the Town of Clarkdale, we would like to express our appreciation to all who have been involved with the ASU Sustainable Cities Project. Over the past two years, the Town has been fortunate to work with nearly 100 students across disciplines to develop strategies for improving the lives of Clarkdale residents. As you know, the Design Principles Guidelines for the Town of Clarkdale's Downtown District and 89A Commercial Corridor was recognized by the Arizona Planning Association Conference in 2020; we have incorporated portions of that document into our General Plan.

This recognition speaks to the quality of work produced by the students that participate in the program, and why our continued partnership is so important to the Town of Clarkdale. Because we are a small town with a small staff, our capacity to research and produce in-depth documents is limited; the ability to work with the students and faculty at ASU provides us with the expertise we need to accomplish our goals for our community, while providing the students with hands-on, documentable experience in the public sector.

The Town of Clarkdale looks forward to our continued collaboration with Sustainable Cities Network and another successful year with the students at ASU.

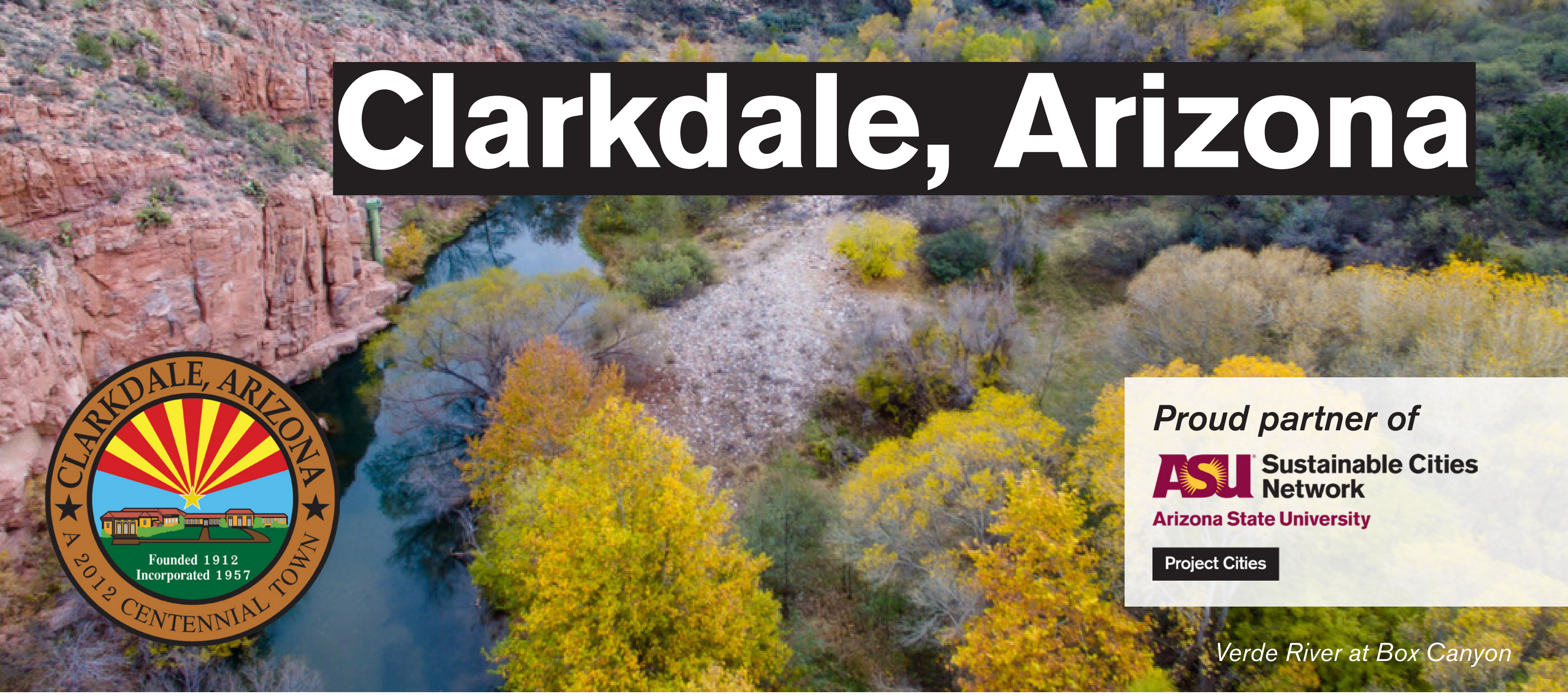
Sincerely,

Robyn C. Prud'homme-Bauer

Robyn Prudhomme-Bauer, Mayor

Rob Sweeney, Interim Town Manager

Clarkdale, Arizona



Proud partner of

ASU Sustainable Cities Network
Arizona State University

Project Cities

Verde River at Box Canyon

Demographics

total population: **4,349**

36% of residents are over the age of 65

median age: **56.27**

78% of residents are homeowners

67.1% of the population has some college education, 31.75% are college graduates

median yearly income: **$45,304**

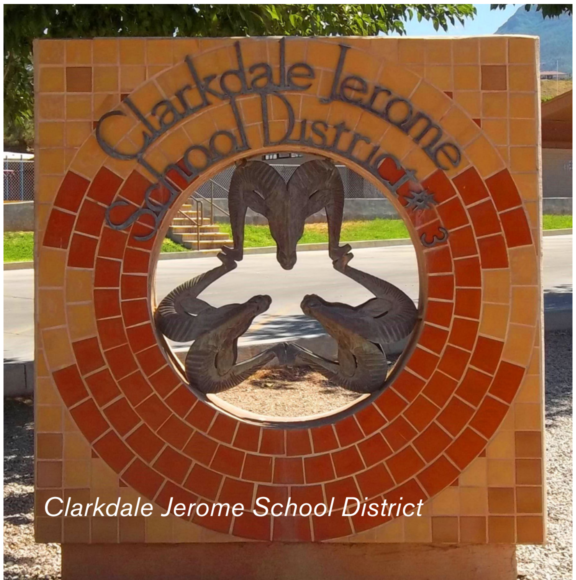
Schools

Clarkdale is home to the Yavapai College Verde Campus and the Small Business Development Center. Yavapai College has one of the leading viticulture and enology schools in the Southwest. High school students in Clarkdale attend Mingus Union High School, and the Clarkdale-Jerome Elementary School boasts an excellent reputation for educating students from Kindergarten through 8th grade.

Sustainability

In Clarkdale's 2013 General Plan, the City identified four main sustainability objectives: **water use, ecological design, sustainable construction** and **mixed use development**. In 2019, Clarkdale announced its partnership with ASU's Project Cities to enliven the Central Business District with a sustainability orientation.

Clarkdale Park



Clarkdale Jerome School District

Tuzigoot National Monument

History

The Town of Clarkdale is located on the banks of the Verde River in the north central part of Arizona. It is a thriving community and is the gateway to the Sycamore Canyon Wilderness Area in the beautiful Verde Valley. Founded in 1912, Clarkdale is renowned as the first master planned community in the State of Arizona. The town was founded as a modern copper-smelting company town for the employees of the mines in Jerome and their families. Ahead of its time, Clarkdale boasted underground utilities, sewers, paved streets, stylish homes and a thriving commercial center.

The main town site was located on a ridge overlooking the industrial smelter complex and was developed with residential homes, including upper and lower-income housing, a commercial area, an administrative center, schools, recreational and cultural facilities, and parks. They intended to include all the parts typically found in a small town within a comprehensive planned design. Today, the original town site of Clarkdale is recognized as a Historic District on the National Register of Historic Places.

The original rail line that served the smelter is now host to a scenic excursion train, the Verde Canyon Railroad, which allows travelers a four-hour round trip to view the protected ecosystem of the Sycamore Canyon Wilderness Area and Verde River firsthand. In addition to the excursion branch, the Arizona Central Railroad (the parent company of the Verde Canyon Railroad) ships materials by rail to Salt River Materials Group, a local cement manufacturer.

Verde Canyon Railroad

Attractions

Hop aboard the Verde Canyon Railroad for the longest-running nature show along the Verde River. Spot bald eagles and enjoy an array of special events onboard throughout the year. Experience the Arizona Copper Art Museum housed in the restored Clarkdale High School with its dazzling array of thousands of gorgeous copper artifacts (some of which you can touch). Float the Verde River with experienced local river outfitters and enjoy unspoiled riparian areas adjacent to the Audubon Important Birding Area in Tavasci Marsh. Dance the night away every weekend to live music. Explore the Tuzigoot National Monument featuring the ruins of an ancient Sinagua Indian pueblo. Savor local terroir at Clarkdale's wineries, the Chateau Tumbleweed tasting room and winery or the Southwest Wine Center in the heart of Yavapai College's Verde Campus in Clarkdale.

Downtown Business District


Downtown Business District

The historic Downtown Business District boasts many treasured historic assets and is the center of Clarkdale's government, cultural and historic core. The Town and downtown-area business owners have invested heavily to keep the town core thriving. As of 2019, there are four vacant properties in the Business District that pose opportunities for redevelopment, including a former grocery store, apartments and the old Grand Theatre. $1.5 million in streetscape improvements in the Downtown Business District were completed in March 2005.

Clarkdale revitalization plan

1. Develop a strategy to **encourage public and private investment**
2. Produce a **report of building conditions** including a revitalization plan for each building, cost estimates on the repairs and possible funding sources
3. Develop a **parking, pedestrian and bicycle connection plan**
4. Identify creative use of existing spaces to **promote foot traffic** in the area

Business Highlights

- Clarkdale has 83 businesses
- Workforce is composed of 45% blue collar; 54% white collar
- 90% of businesses have less than 20 employees
- Annual events, such as Clarktoberfest, the Car Show, wine festivals, and multiple block parties, are anchored in the historic business district


Historic Downtown Mainstreet

Leading industries as of 2019

Public Administration

167 Jobs

Education

110 Jobs

Information

108 Jobs

Transportation & Warehousing

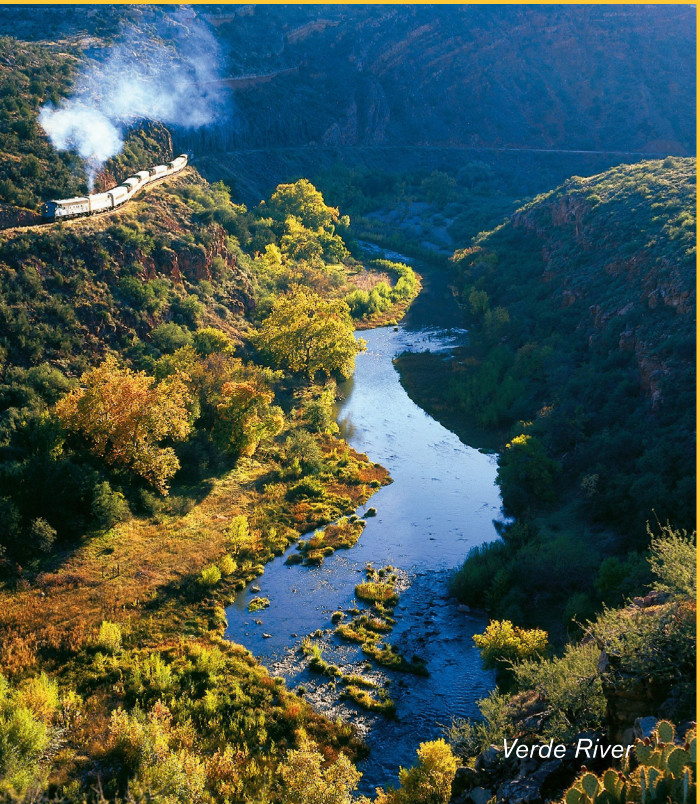
87 Jobs

Kayaking on the Verde River

Local ecology

The Verde River bisects the north portion of Clarkdale at a low elevation of around 3,300 feet. The west side of the town boundary is located along the foothills of Mingus Mountain in the Black Hills Range at a high elevation of approximately 4,600 feet above sea level. On the northeast border of Clarkdale, the National Park service operates the 42-acre Tuzigoot National Monument, an 800-year-old Sinagua pueblo, which is surrounded by hiking trails and hosts a complete museum. Tavasci Marsh borders Tuzigoot National Monument and has been designated as an Important Birding Area by the North American Audubon Society. Arizona State Parks also manages the Tuzigoot River Access Point along the Verde River in Clarkdale. The town is surrounded by the Prescott National Forest to the west and the Coconino National Forest to the east. In addition, trust lands of the Yavapai-Apache Nation are located within the town boundary.

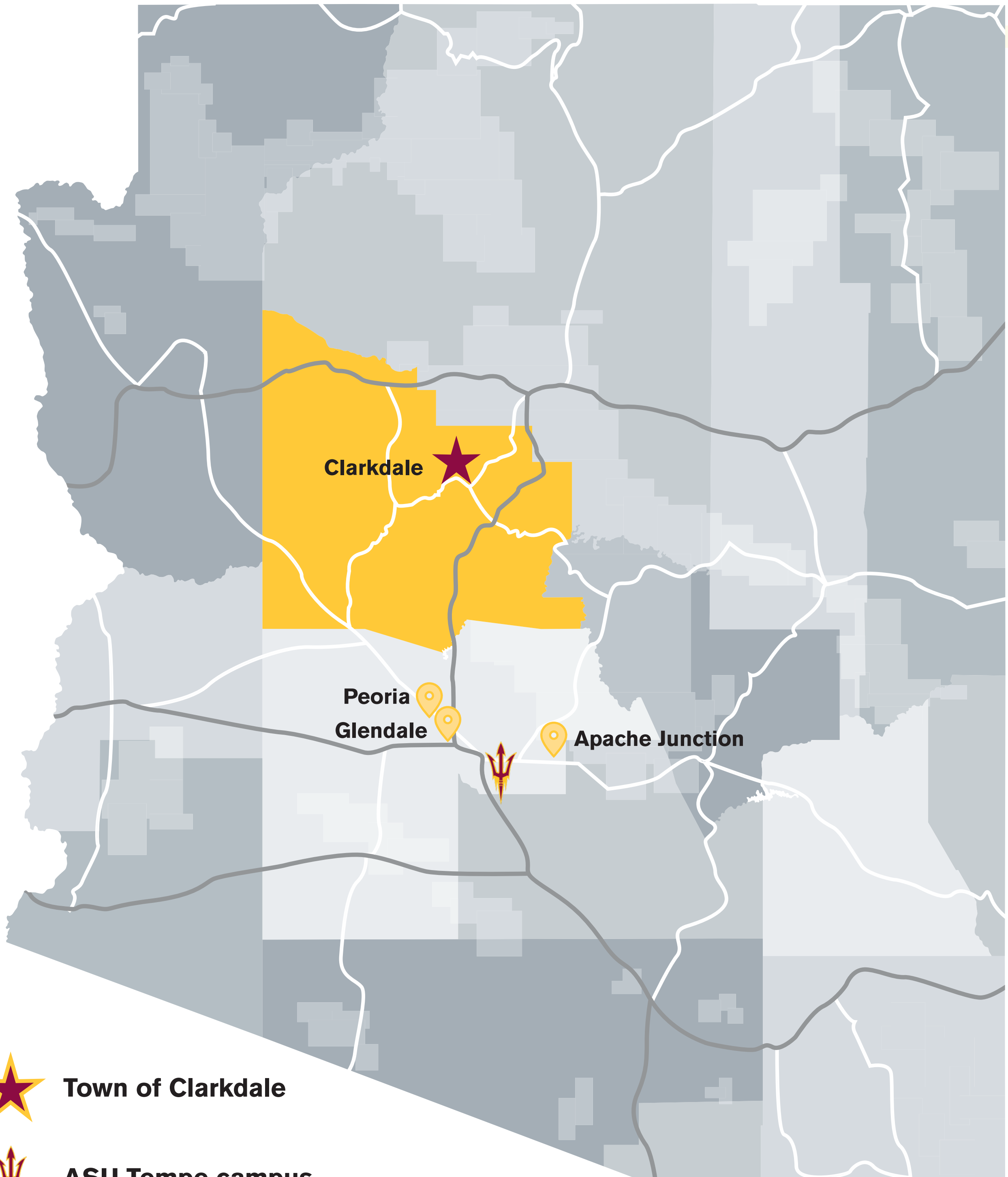
Local wildlife



Verde River

Sycamore Canyon

MAP OF PROJECT CITIES PARTNER COMMUNITIES IN ARIZONA



Town of Clarkdale

ASU Tempe campus

Other Project Cities Partner Communities

The following report summarizes and draws highlights from work and research conducted by students in SOS 498/594 Urban Sustainability Applications, for the Fall 2020 partnership between ASU's Project Cities and the Town of Clarkdale.

To access the original student reports, additional materials, and resources, visit:

links.asu.edu/PCClarkdaleSustainability20F

Sustainable Cities Network
Arizona State University
Project Cities
Sustainability through local action

EXECUTIVE SUMMARY

The Town of Clarkdale is situated in the Verde Valley of central Arizona. A historic mining town, Clarkdale is known for its rich deposits of copper and other minerals, and has long-standing relationships with mining companies such as Freeport-McMoRan. While Clarkdale is dedicated to preserving its history, it also recognizes it is no longer the industrial mining town of its past. Over the years, Clarkdale has prioritized sustainability initiatives and environmental programs driven by local residents and council members alike. Sited in an ecologically rich area, the connection between the local environment and economy is well understood. Dedication to sustainability is demonstrated by recent community documents and plans, such as the 2018-2019 *Economic Development Plan*, 2018 *Sustainable Development Guidelines*, and 2010 *Proposal for the Clarkdale Sustainability Park*.

In the Fall 2020 semester, 9 undergraduate and 2 graduate students in Nalini Chhetri and Anne Reichman's **SOS 498/594: Urban Sustainability Applications** class partnered with the Town of Clarkdale to assist in the continuation of local sustainability efforts. Throughout the semester, students held virtual meetings with instructors as well as town leadership, including former Mayor Doug Von Gausig, Town Manager Tracie Hlavinka, and Public Works Utilities Director Maher Hazine to advise on local context and information, and maintain project milestones. These meetings and presentations covered many topics that helped students conduct their research, such as demographics, town characteristics, budgetary concerns, and future goals. Early in the semester, students split into topical groups based on their specific sustainability research interests.

SOS 594: The community's pride in its history and beautiful natural resources are enmeshed with the town's historic preservation efforts and sustainability goals. Touching on both of these town values, Master of Sustainability Solutions students Huda and Yaritza dove into the topic of maximizing energy efficiency across Clarkdale in both contemporary and historical structures. The duo investigated case studies of exemplary energy-efficient communities from which they compiled best practices and locally-applicable recommendations for Clarkdale's efforts toward more sustainable energy consumption. Additional resource toolkits accompany most recommendations to provide a starting point for further investigation by town leadership. Huda and Yaritza's findings cover an array of potential actions, including partnerships, policy, and physical building updates.

SOS 498: Within Clarkdale's town borders rests a 100-acre parcel of land owned by Freeport-McMoRan, an Arizona mining company with a long history in the community. The empty parcel has been generally underutilized, primarily due to its past role in area mining practices. Students and town leadership believe the land holds untapped potential, and poses an actionable opportunity for Clarkdale to be a leading example of sustainable development in a small- to medium-sized town. The nine undergraduate students partnered with town officials to assist in re-invigorating stalled efforts surrounding the planning, design, and construction of a proposed park, based around the 2010 *Proposal for the Clarkdale Sustainability Park*. Students researched various public and private programs and installations that could play a role in a future sustainability park, and reported on their feasibility to be implemented into the park plan. Some investigated points include the installation of composting facilities, solar panels, and hydroponic gardening. In addition to topical research, students also investigated funding opportunities, case studies on similar projects, and information on the park area itself.

This report represents the inaugural projects of the "Sustainable Clarkdale" portfolio in the Town's partnership with ASU Project Cities. Clarkdale's first project portfolio, "Downtown Revitalization," began in the fall 2019 semester and examined sustainable economic and community growth through practices such as eco-tourism, historic preservation, and mixed-use commercial development. Elements of this foundational project can be found throughout the sustainability portfolio in the facets of the proposed sustainability park and attention to efficiency of historical structures. This connection and continuation is yet another example of Clarkdale's proactive approach to including sustainability across municipal actions.

By prioritizing sustainability practices, Clarkdale demonstrates its dedication to preserving its natural beauty and serving its community. The town has the potential to grow its role as a sustainability leader in the Verde Valley region through interventions such as the sustainability park and energy efficiency efforts. The student research and suggestions featured in the following report seek to assist Clarkdale in maximizing the potential of local sustainability programs, by proposing possible next steps for town staff to consider.

KEY STUDENT RECOMMENDATIONS

Recommendations for general energy efficiency practices	Read more
Adopt the International Green Construction Code (IgCC) which provides guidelines for the design and operation of new construction that supports sustainability, resilience, and high-performance green building outcomes.	pp.40-41, 50, 52
Continue to adhere to the previously adopted policies from the International Energy Conservation Code (IECC), and review any updates available at **https://codes.iccsafe.org/content/IECC2021P1**	pp.40-41, 50, 52
Obtain Leadership in Energy and Environmental Design (LEED) certification, which can be applied to new and existing buildings, or entire communities. Pursuing this certificate can help further increase energy efficiency, while demonstrating the Town's existing sustainability strengths and commitment.	pp.39, 41-42, 50-51
Participate in ASU's Sustainable Energy, Education, and Knowledge-Sharing (SEEK) Project, which can help provide a framework for achieving optimal energy efficiency as well as funding to measure impacts related to energy use, transitions to renewable energy, GHG emissions, and energy expenditures.	pp.42, 50, 52-53
Consider utilizing the proposed timeline on page 52 of this report to help guide initial short-term scheduling and implementation of recommendations.	p.52

Recommendations for contemporary infrastructure efficiency	Read more
Adopt Arizona Public Service (APS) renewable energy goals through solar power. These additional goals can reinforce sustainability leadership while progressing toward optimal energy efficiency.	pp. 43, 50
Reinforce doors and windows by installing highly-insulated, energy efficient components, such as Energy Star windows, to mitigate heating and cooling loss and subsequently save on energy spending.	pp.43, 50
Replace conventional lighting with light-emitting diode (LED) lighting. LEDs can drastically reduce energy consumption while emitting more light and lasting longer than incandescent bulbs. LED lighting in homes and businesses can help reduce energy consumption while saving the Town and its residents money.	pp.44, 50
In addition to general LEED certification, consider pursuing LEED Platinum Energy Certification for residential, commercial, or newly constructed properties. The certification provides guidelines for a wide variety of energy efficiency initiatives. Researching these guidelines in pursuit of certification can also be applicable to historical structures.	pp. 39, 45, 50-53

KEY STUDENT RECOMMENDATIONS

Recommendations for historic infrastructure efficiency	Read more
Install shade structures, such as awnings or balconies, and plant native shade trees to increase environmental comfort, reduce building cooling costs and ambient air temperature (p. 22).	pp.36-37, 46-47, 50-52
Reinforce windows on historic buildings by installing non-invasive storm windows, which can simultaneously curb air leakage and provide additional building insulation, subsequently saving on heating and cooling costs. Storm windows also have a preservation appeal, by protecting the older or original windows without damaging their integrity (p. 23).	pp.48, 50-51
Insulate attics and crawl spaces to reduce air leakage, especially in older buildings. This is an inexpensive, non-intrusive, and reversible way to increase energy efficiency and reduce heating and cooling costs in buildings across the town.	pp.49-51
Replace outdated appliances with Energy-Star appliances, such as dishwashers, washers and dryers, and refrigerators. This is another non-intrusive way to reduce energy consumption that applies to all categories of building discussed in the report, including residential homes, commercial buildings, and historic structures.	pp.49-51
Implement smart meters where applicable to measure a building's electricity usage. The meters link directly with utility providers, allowing for bill utilization, detecting remote switch on, and disconnection during power failures. Smart meter readouts can also help customers save energy and better understand their own energy use.	p.50

KEY STUDENT RECOMMENDATIONS

Sustainability park general strategic recommendations	Read more
Cultivate a sustainability park by considering the implementation of sustainable design, community engagement, education, gardening and agriculture, wetland construction, and plasma gasification.	pp.64-141
Promote tourism, educational opportunities, and community engagement by hosting or encouraging outdoor learning events and partnering with schools or local environmental organizations. It is important to focus on public engagement and the continuity of Clarkdale's community when planning for the implementation of park features.	pp.67, 72-73, 87-90, 99, 101-102, 111, 113-114, 123, 132
Seek outside resources and funding for park sustainability features to ease the financial toll on the town.	pp.79-80, 85-86, 100, 112-113, 122, 127, 131

Recommendations for sustainability park design	Read more
Utilize green infrastructure throughout the park area, such as bioswales, native tree shading, and permeable pavement, to increase ambient cooling, accessibility, and comfort during various seasons.	pp.74-80
Implement best practices to ensure accessibility throughout the park via sensory and auditory features, walkability enhancements, and compliance with the American with Disabilities Act (ADA).	pp.67-73
Make informed decisions when planning park paths and trails by surveying the use of existing paths, planning for mixed use paths, designing different paths with different user needs in mind, and examining facilities distribution around planned paths.	pp.68-70, 73
Ensure that the park compliments the historic nature of the town by incorporating cultural themes into the design.	pp.67, 72-73, 89-90, 124, 127
Introduce electric scooters (e-scooters) and solar powered golf carts to the park to enable micromobility, tourism opportunities, accessibility, and job opportunities for chargers whether they are electric or solar powered.	pp.81-86

KEY STUDENT RECOMMENDATIONS

Recommendations for sustainability park composting	Read more
Initiate community composting by using the three bin method and proliferate collection bins throughout the sustainability park.	pp.91-95, 101
Implement vermicomposting, and consider using the Continuous Flow-Through (CTF) method, to create nutrient rich soil amendments and valuable byproducts while composting more quickly and effectively.	pp.95-98, 101
Host educational classes and facilitate tourism opportunities for the composting centers in an effort to create positive experiences around farming, agribusiness, and gardening.	pp.99, 101

Recommendations for sustainability park hydroponics	Read more
Grow plants in nutrient-rich water by using various hydroponic methods, such as the Kratky method, deep water cultures, and the nutrient film technique.	pp.102-105, 114
Explore the use of treated wastewater where applicable to fuel the hydroponic system.	pp.105-106, 114
Utilize the hydroponics setup as another opportunity for community engagement and education by offering classes around simple, at-home hydroponic growing methods.	pp.111, 113-114
Consider the revenue potential and tourist attraction of a local hydroponic cannabis operation.	pp.110-111, 114
Design or select a greenhouse for the hydroponics operation with sustainability in mind by considering the desired scale and products of the operation, and prioritizing the use of natural lighting, ventilation and solar energy.	pp.107-110, 114
Seek funding for hydroponics efforts through agricultural and federal grants, such as those offered by the USDA Agriculture and Food Research Initiative (AFRI) or the National Farm to School Network, to offset initial and ongoing costs.	pp.112-114

KEY STUDENT RECOMMENDATIONS

Recommendations for sustainability park constructed wetlands	Read more
Construct a wetland within the park to provide wildlife habitat, as well as ecological “co-benefits” such as carbon capture and ecosystem rehabilitation.	pp.115-122
Design the constructed wetland to feature horizontal subsurface flow to reach vegetation, clean the water from pathogens, and prevent eutrophication.	pp.118-119, 122
Select dense native vegetation to install in the wetland that can thrive in the microclimate and support biodiversity by attracting a healthy variety of organisms.	pp.117, 120
Hire professionals to assist with monitoring of the installation’s environmental health.	pp.121-122

Recommendations for sustainability park agrivoltaics	Read more
Construct a solar farm to generate power for the area. Consider building “agrivoltaic” raised community garden beds beneath the panels to maximize efficiency with the added benefit of growing crops.	pp.123-135
Grow crops that are well-suited for the northern Arizona climate, such as native herbs or flowers, depending on the specific zone and season.	pp.134-135
Use the crops from the agrivoltaic garden to supply a local farmers market or to enable local economic opportunities.	pp.129, 134-135
Consider functional and design options for the panels, such as if fixed or tracking panels would best serve the Town's needs, and if the panels could be arranged in an interesting design that also functions as a tourist attraction.	pp.124-127

Recommendations for sustainability park plasma gasification	Read more
Consider building a plasma gasification facility to provide the town with a municipal waste outlet combined with the pre-existing recycling facility and potential composting facility, allowing Clarkdale to become self-sufficient in managing its waste.	pp.136, 138-140
Partner with other municipalities or companies when planning the facility to reduce individual startup costs.	pp.139-140
Conduct an in-depth cost-benefit analysis regarding the potential savings and profitability of a plasma gasification facility for the Town of Clarkdale before planning and construction.	p.140

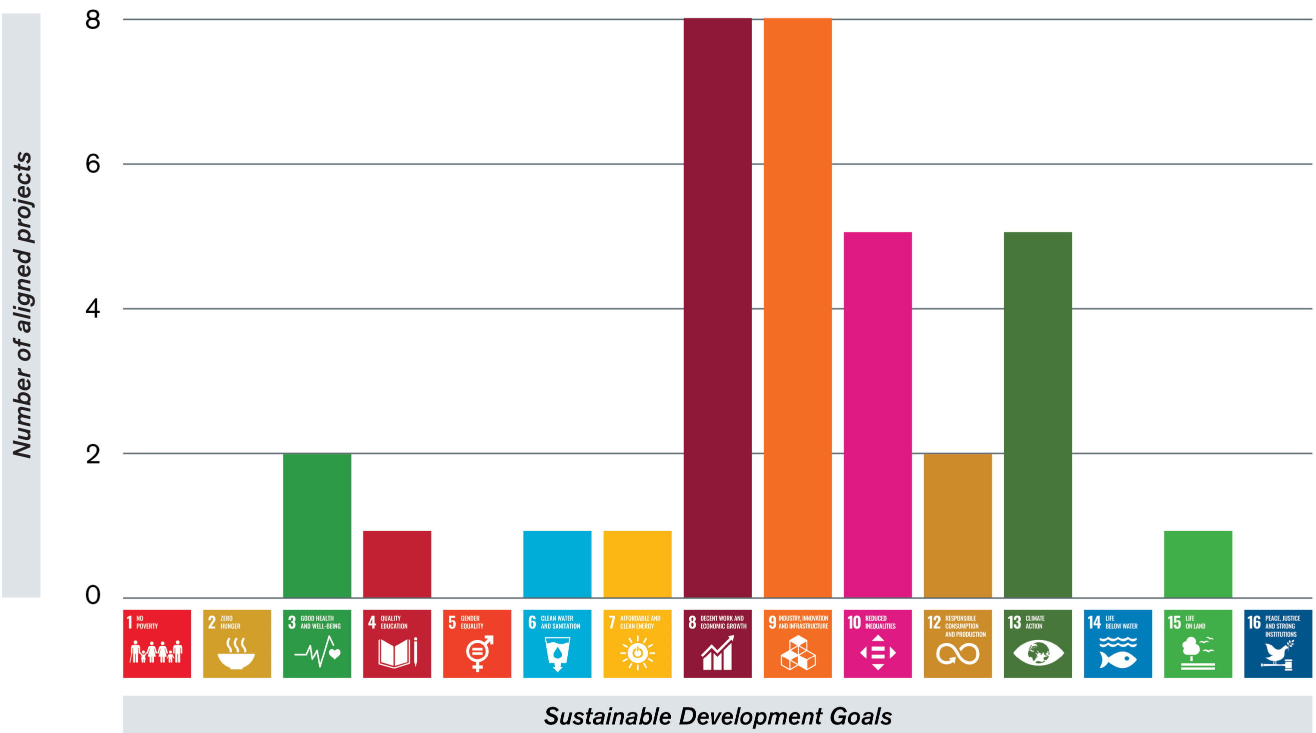
TOWN OF CLARKDALE PROJECTS: ALIGNMENT WITH THE UNITED NATIONS'

SUSTAINABLE DEVELOPMENT GOALS

As the leading international framework for sustainable decision-making, the 17 Sustainable Development Goals (SDGs) lay out a path for partnerships toward global peace and prosperity. The SDGs provide a set of goals and metrics for project impact to be measured, offering an illustration of the benefits experienced by the cities, towns, and students who participate in a Project Cities partnership. For details on the SDGs, visit **sdgs.un.org/goals**.

Every project in the PC program aligns with SDGs 11 and 17.

The figure below illustrates SDG project alignment throughout the Town of Clarkdale's partnership with Project Cities, through the Fall 2020 semester.



TOP THREE GOALS ADDRESSED IN THE FOLLOWING REPORT

The sustainable Clarkdale projects aim to provide strategic recommendations for the Town to grow as a leader in sustainable development practices within small- to medium-sized communities. Economic growth, energy efficiency, and eco-tourism, are at the core of this project's research findings.

Goal 3: Good Health and Well-Being

"Ensure healthy lives and promote well-being for all at all ages."

In addition to preserving natural resources for future generations, eco-tourism opportunities such as the sustainability park provide recreational and educational opportunities for all ages.

Goal 7: Affordable and Clean Energy

"Ensure access to affordable, reliable, sustainable and modern energy for all."

Increasing energy efficiency through solar power, LEED design, and other tactics can help increase energy affordability and decrease the town's overall consumption.

Goal 15: Life on Land

"Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss."

The proposed sustainability park can contribute to the preservation of valuable natural habitats.

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PART 2:

Energy Efficiency and Sustainable Consumption

STRENGTHENING CLARKDALE'S COMMITMENT TO SUSTAINABILITY THROUGH ACTIONABLE ENERGY SAVINGS FOR CONTEMPORARY AND HISTORIC BUILDINGS

SOS 594: URBAN SUSTAINABILITY APPLICATIONS

SCHOOL OF SUSTAINABILITY

FACULTY
NALINI CHHETRI AND
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ACKNOWLEDGMENTS

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Mike Gray

PROJECT GOALS

In this report, graduate students Huda and Yaritza research feasible actions aimed at helping the Town of Clarkdale improve energy efficiency of both contemporary and historic structures. Increased efficiency can help the town consume less energy overall, reducing stress on power supplies, and saving money for Clarkdale and its residents.

BACKGROUND AND TOWN VISION

The Town of Clarkdale is located in northern Arizona and was originally founded in 1912 to house the families of copper-smelting employees working in Jerome mines (Town of Clarkdale, 2020). Now, it is known for being the state's first master-planned community, and is home to a vibrant group of over 4,000 residents that pride themselves on their rich history as seen in the old buildings, the beautiful natural environment including the Verde River, and the town's "live, work, play" mantra (Project Cities, 2020). Today, the town is acknowledged for its National Register of Historic Places as a Historic District, and as such holds many historic attractions such as the Verde Canyon Railroad, the Arizona Copper Art Museum, and the Tuzigoot National Monument (Project Cities, 2020). Tourist attractions in Clarkdale include the Verde River boat rides, the Audubon Important Birding Area, weekend live music performances and dances, the Chateau Tumbleweed tasting room and winery, and the Sycamore Canyon Wilderness Area (Project Cities, 2020).

The neighboring Towns of Jerome and Cottonwood share in the historic appeal which attracts many tourists and adds to the region's economic activity, but in contrast to Clarkdale, benefit from being easily accessible and visible from Route 89A (see Figure 1). Situated between the Towns of Jerome and Cottonwood, the Town of Clarkdale is uniquely positioned to similarly benefit from tourism activity while displaying its unique characteristics to visitors.

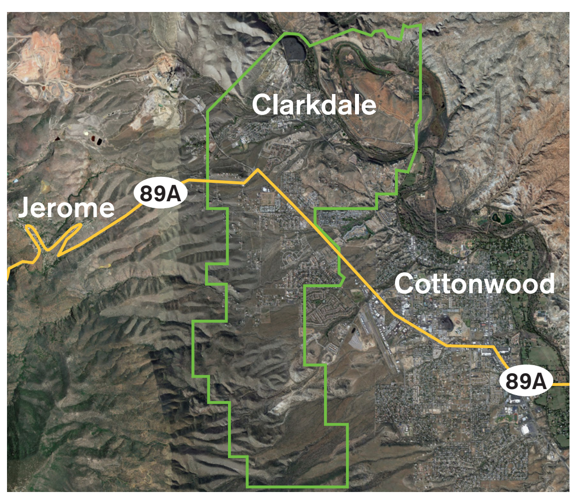

Figure 1 *Area context map of Clarkdale, from Google Earth*

Clarkdale possesses a strong sustainability vision, which the Town intends to actualize through local economic development aimed at increasing tourist and business activity in the region. The residents of Clarkdale pride themselves on their rich and unique history, as displayed in the Town's historic buildings and infrastructure. Community-wide visioning activities and sustainability planning efforts also provide a glimpse into the local value of sustainability practices and initiatives. A review of past Town plans, such as the General Plan and Sustainability Plan, highlight Clarkdale's commitment towards demonstrating community connectedness, history, and small-town aesthetic. This reveals a focus on value creation in the pursuit of economic development. The Town of Clarkdale has a unique story to tell, and in conjunction with increased sustainable development, can position itself to benefit from similar attention and activity enjoyed by the neighboring communities of Jerome and Cottonwood.

To enliven the Central Business District, Clarkdale partnered with Arizona State University's Project Cities program in 2019 to help achieve its main sustainability objectives surrounding "water use, ecological design, sustainable construction, and mixed-use development" (Project Cities, 2020). As part of the revitalization plan, the Town also aims to spur investment and refurbish historical buildings (Project Cities, 2020). Based on Clarkdale's vision and sustainability values, three important Sustainable Development Goals (SDGs) of focus were identified: Affordable and Clean Energy, Decent Work and Economic Growth, and Industry, Innovation and Infrastructure, all of which ensure the maintenance of equitable access to reliable clean energy for Clarkdale residents (Figure 2). It is in this sense that increased energy efficiency is explored to further set the Town of Clarkdale apart from its counterparts through the development of its sustainable tourism appeal, while also standing as a proof of concept to the potential of sustainable development in small towns across the nation.

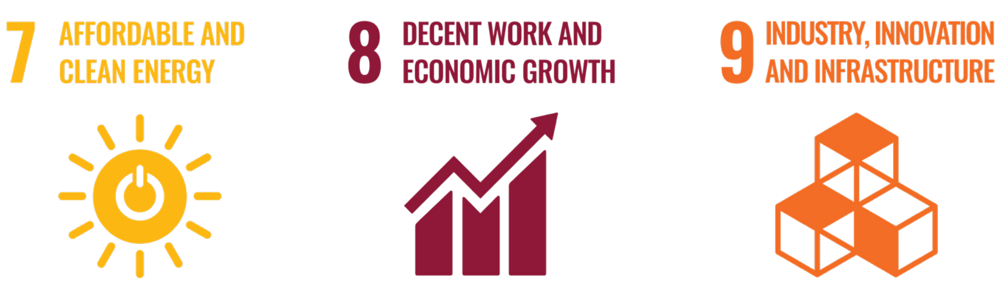

Figure 2 *Identified primary guiding Sustainable Development Goals*

RESEARCH METHODS

Throughout the Fall 2020 semester, graduate students Huda Khalife and Yaritza Hernandez Gil utilized a wide variety of research methods to compile this report. Primarily, students conducted a literature review based on key terms surrounding energy efficiency, as well as an extensive review and personal summary of relevant Project Cities reports, which helped build a base of information on which to develop their project. From the literature, case studies were identified of successful city-wide initiatives to investigate further. Additionally, key subject matter experts were identified and contacted with the help of course facilitators. Included in this group of experts was Professor Chingwen Cheng from the ASU Design School, and former Mayor of Clarkdale Doug Von Gausig. These expert interviews were conducted in an effort to obtain the most accurate, up-to-date information surrounding energy efficiency and related initiatives in a town setting. Throughout the semester, both students worked collaboratively to brainstorm ideas for research focal areas, presentations, and information visualization. It is through these rigorous efforts that this report was compiled in partnership with the Town of Clarkdale to provide suggestions which improve its energy efficiency and sustainability while protecting its historic character.

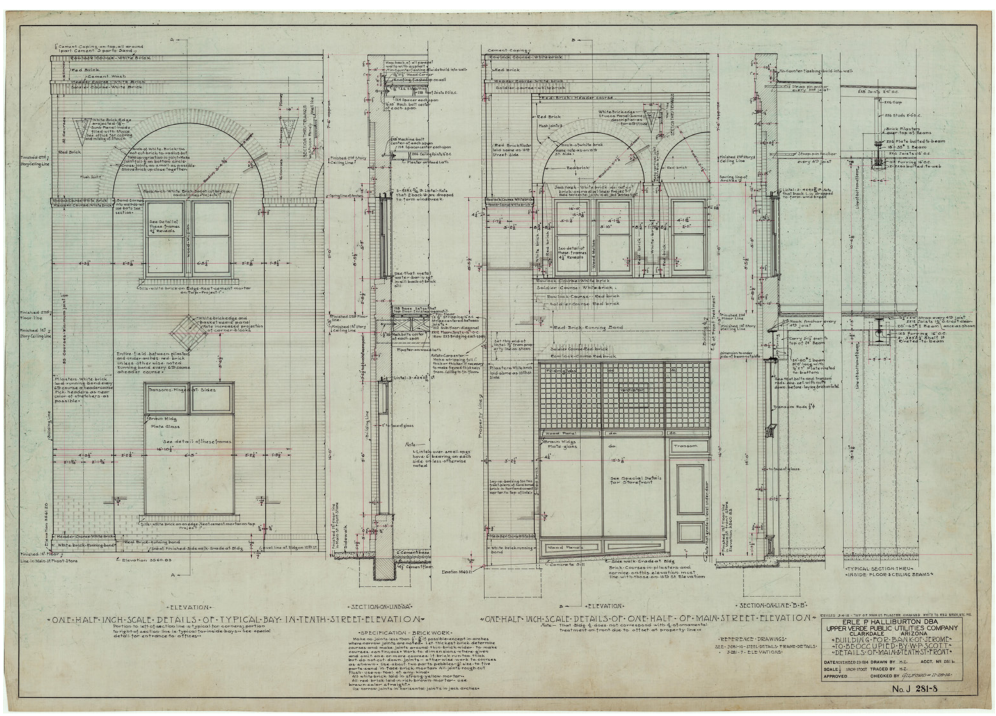

Figure 3 *1914 construction specifications document for the Bank of Jerome at 921 Main Street, Clarkdale, from Town of Clarkdale*

ENERGY AND EMISSIONS IN BUILDINGS

Energy efficiency lies at the core of sustainability issues and is a key part of the sustainability objectives developed by the Town of Clarkdale (Town of Clarkdale, 2020). The building sector is deemed a "major target for widespread energy efforts" nationally, as the main consumer of 40% of energy, 70% of electricity, and 54% of natural gas (Alliance to Save Energy, 2018). As such, this report focuses on energy and emissions specifically as related to buildings in the residential and commercial sectors, and incorporates the following eight sustainability values adopted by the Town of Clarkdale in the summer of 2020 as summarized below (Town of Clarkdale, 2020b).

1. **Natural Resources,** to take into consideration the environment and the impact on development location, remaining mindful and preserving native plant species and wildlife in the region
2. **Water Management,** as the Town understands how water is a highly scarce resource, and it is vital to think of the public interest when maintaining water limits and uses
3. **Infrastructure,** minimizing environmental consequences when designing infrastructure in the town, such as linking means of transit and the existing town infrastructure
4. **Green Building,** taking into consideration existing buildings while beginning to integrate advanced technologies to uphold sustainability standards, whether focused on the town's air quality, means of transit, alternative energy, or responsible innovation practices
5. **Design Principles,** taking into account existing built infrastructure while promoting renewable energy sources, preservation and, water security in new development projects
6. **Construction,** to adopt best practices in various sustainable projects such as "Energy Efficiency, Indoor Environmental Quality, Waste Minimization" and repurposing items
7. **Maintenance and Restoration,** to develop methods that reduce environmental impacts such as using long-lasting materials and diminish maintenance work
8. **Landscape Standards,** to create landscape plans that help preserve resources such as the current irrigation system and native vegetation

Clarkdale further illustrates its strong value of sustainable development through its mission to create a place that is "visionary, innovative,... [possesses a] sustainable quality of life, [all while engaging] community and enterprise" (Town of Clarkdale, 2020). The Town's collaborations with Project Cities and Arizona State University (ASU) students to further the vision for a Sustainability Park continues to demonstrate the desire to achieve a high standard of sustainability. Previous ASU student research and community engagement have yielded many focus areas, including "[embracing] sustainability, slow tourism, and outdoor recreation; [focusing] on adaptive reuse and renovation of historic buildings… [and developing] branding and design principles that celebrate the community and contribute to the sense of place" (Project Cities, 2020). This synergistic envisioned relationship between tourism activity and sustainability values in the town provides a wide array of opportunities for growth in the region.

Contemporary and historic infrastructure

In order to analyze the potential for energy efficiency and emissions reductions in the Town of Clarkdale, the different sectors of contemporary and historic infrastructure must be considered. Due to their valuable and vulnerable nature, historic buildings involve many different considerations than contemporary buildings. Within these two categories, the Town of Clarkdale features different focal sectors, including residential and business. As seen in Figure 4, residential zoning (green, orange, red and yellow) comprises the majority of Clarkdale's infrastructure, while business zoning (blue and purple) make up a smaller yet more densely populated area. While the commercial and residential sectors are the highest and lowest energy consumptive sectors respectively, with commercial buildings accounting for a quarter of end-use energy consumption in Arizona, energy consumption levels in across the state do not differ significantly between industrial, residential, and commercial buildings (EIA, 2020).

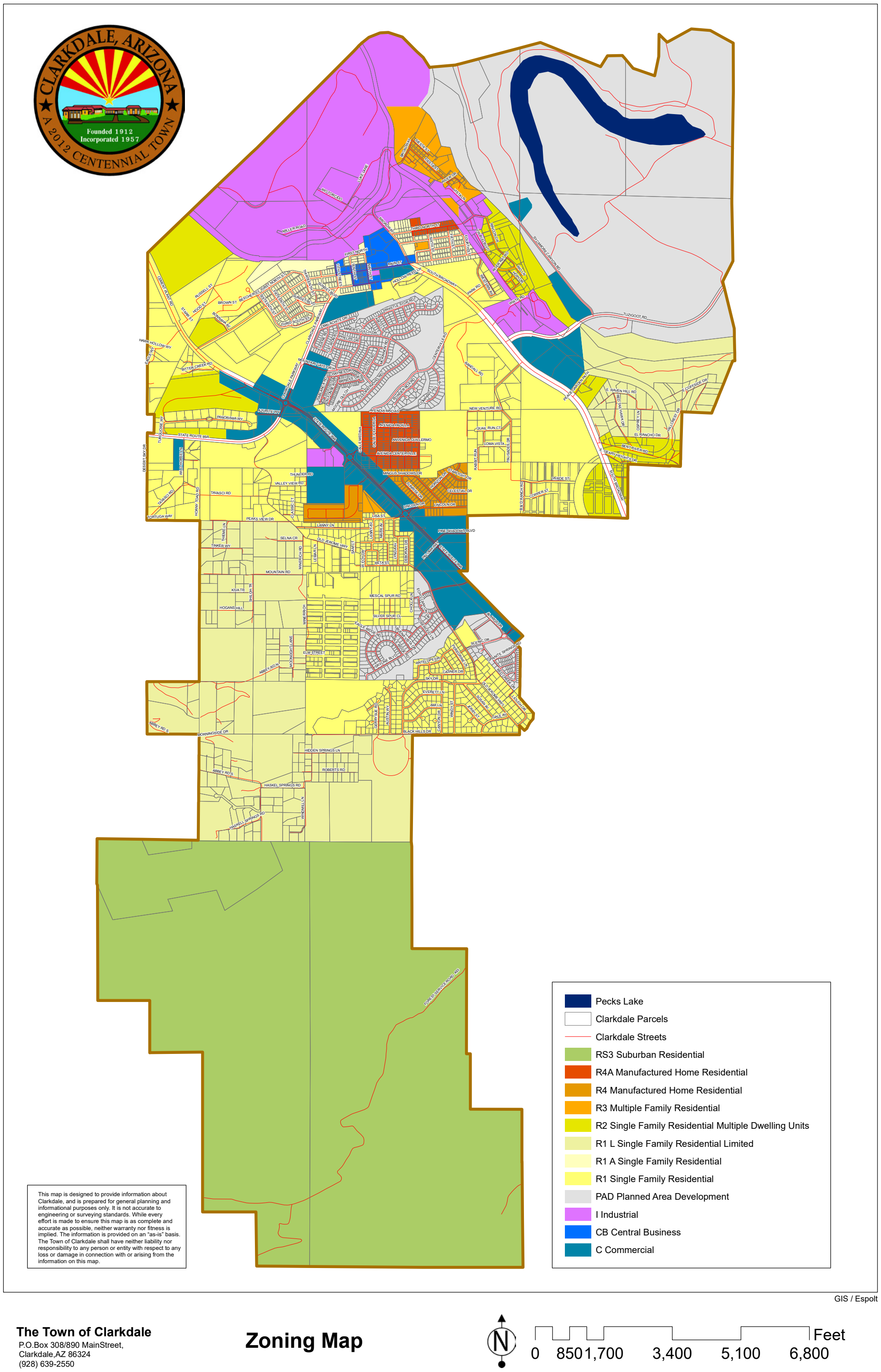

Figure 4 *Clarkdale zoning map, by Town of Clarkdale*

Residential area

Clarkdale's Downtown Business District comprises several different zones, including Central Business, Industrial, and single-family Residential zoning (Project Cities, 2020). As shown in Figure 4, aside from the Downtown District the majority of Clarkdale features residential zoning, including single-family, multi-family, manufactured home, and suburban home residential zones (Town of Clarkdale, 2020). The residential areas include historic as well as contemporary properties, each with their own unique considerations. The former are preserved for both historic value and their contribution to the tourism of the region. Many of the latter were constructed with sustainability considerations in mind, such as solar energy options, low water irrigation systems, and energy efficiency efforts (T. Hlavinka, personal communication, September 17, 2020).

In terms of energy rates and consumption for the residential sector, the average monthly electricity bill per household in Arizona is approximately $120 with an electricity rate of 11.29 cents per kilowatt-hour (Figure 5) (Electricity Local, 2020). Average monthly energy consumption in this sector is 1,061 kilowatt-hours, 17.5% higher than the national average (Electricity Local, 2020). In Clarkdale specifically, the average electricity rate is 5.93% higher than the state value, at 11.96 cents per kilowatt-hour (Electricity Local, 2020).

Historic corridor and business district

The Downtown District of Clarkdale mainly comprises Central Business zoning, which serves to present the historic character of the town through storefronts and attractive spaces for socialization and commercial activity (Project Cities, 2020). As such, much of the Downtown District is part of the Historic District of Clarkdale, including state and federally-recognized historically significant properties (Project Cities, 2020).

The Central Business District of Clarkdale is home to numerous historic buildings, including the town government complex, and remains a testament to the community's rich local history and culture. Signature annual events, such as Clarktoberfest and block parties, are also anchored downtown, and the Town Park hosts numerous free family-friendly events and concerts throughout the year (Project Cities, 2020). The town is home to 83 businesses, 90% of which have fewer than 20 employees (Project Cities, 2020). As such, the district is an energy hub of Clarkdale.

In terms of energy rates and consumption for the commercial and industrial sectors, the average monthly electricity bills are $772 and $8,754, respectively (Figure 5) (Electricity Local, 2020). Consumption levels are at 8,106 and 134,204 kilowatt-hours per month for commercial and industrial sectors, respectively (Electricity Local, 2020). The average Clarkdale electricity rates for commercial and industrial sectors are 10.22 and 7.87 cents per kilowatt-hour, respectively (Electricity Local, 2020).

Average electricity rates by sector				
	Arizona energy consumption	***Arizona electricity rates***	***Arizona monthly electricity costs***	***Clarkdale electricity rates***
Industrial	134,204 kWh	6.53 ¢/kWh	$8754	7.87 ¢/kWh
Commercial	8,106 kWh	9.53 ¢/kWh	$772	10.22 ¢/kWh
Residential	1,061 kWh	11.29 ¢/kWh	$120	11.96 ¢/kWh
kWh = kilowatt hour				

Figure 5 *Arizona state electricity metrics compared to Clarkdale electricity rates, by Electricity Local*

With Clarkdale's energy rates surpassing the statewide average, and overall residential and commercial sector energy consumption rates higher than the national averages (ranking 5th and 16th in highest energy consumption levels, respectively), Clarkdale could reap major economic benefits by investing in energy efficiency efforts, while simultaneously continuing to distinguish itself from the rest of the state as a leader in sustainability.

Exemplary energy efficiency cases

Climate change is an issue of global scale, and while mitigation efforts may seem daunting, cities and towns like Clarkdale are key to addressing it on a practical and effective level. In contrast with national governing bodies, cities and towns have the potential for faster region-wide policy and regulation adoption and implementation, as well as locally relevant planning (Alton, 2017). Notably, one of the world's "most successful" models for urban sustainability, the Vauban district of Freiburg in Germany, was also developed as an intentionally constructed community seeking to become a model for holistic environmental planning (Thorpe, 2017). One of the main areas that lend Vauban its title are sustainability standards and practices surrounding energy consumption and emissions (Thorpe, 2017).

Successful examples such as the Vauban district are used throughout this project's research and analysis to inform the subsequent recommendations on energy-related best practices for the Town of Clarkdale. In the following sections, three exemplary cities have been studied for their energy efficiency efforts: Phoenix, Arizona; Taos, New Mexico; and Malmö, Sweden.

Figure 6A *Downtown Phoenix, Arizona*

Figure 6B *Taos, New Mexico*

Figure 6C *Malmö, Sweden*

Figure 6 *Case study cities chosen for their excellence in energy-efficiency*

Case study 1: Phoenix, Arizona

Sectors served: Residential and commercial buildings

Program focus areas: Regulatory policy

Funding source: Policy incentives, public, and private funding sources

Key highlights: Shading and tree coverage, renewable energy sources

More information: **https://www.phoenix.gov/sustainability/energy**

Phoenix is the fifth largest city in the United States, and is part of the tenth largest metropolitan region in the country. Its massive size adds more weight to the City's future development and resource management plans. Phoenix has committed to becoming a Carbon Neutral City that operates on 100% clean energy by the year 2060, as illustrated in the "Long Term Goals" summary page from its 2015-2016 Sustainability Report (Figure 7) (City of Phoenix, 2017). In 2017, Phoenix also became LEED Platinum certified, the highest of green building rating levels. Through the setting of its diverse sustainability goals, Phoenix has also reduced its greenhouse gas emissions (GHG) by 15.6% since 2005. The City continues to push these initiatives forward by planning to rely on 15% renewable energy sources, including solar energy, and reduce 40% of overall energy usage by 2025 (City of Phoenix, 2017).

Among Phoenix's notable best practices, and perhaps most relevant to Clarkdale, is the City's drive to increase shading and tree coverage. Additional shading, whether by man-made structures or natural plantings, can offer multiple benefits to historic infrastructure, and help decrease energy use and costs for nearby buildings. As of 2016, Phoenix boasted an average tree cover of 12.4%, created by roughly 92,890 trees (City of Phoenix, 2017). The greening of Phoenix contributes to reduction of heat-related energy consumption in buildings, and improves air quality as the urban forest removes an estimated 1,700 tons of air pollution yearly (City of Phoenix, 2020). Subsequently, this initiative not only improves comfort and energy efficiency, but also contributes to the city's goal of achieving healthier air quality. Specifically, Phoenix aims to surpass federal air quality standards and exhibit a "good" or "excellent" visibility index on at least 90% of days per year by 2050 (City of Phoenix, 2017).

Figure 7 *City of Phoenix long term sustainability goals, from the 2015-2016 Sustainability Report, by City of Phoenix*

Case study 2: Taos, New Mexico

Sectors served: Residential, commercial, and government buildings

Key highlights: Renewable energy sources

More information: **https://renewabletaos.org/projects/**

New Mexico is steadily increasing its focus on renewable energy consumption, as illustrated in Figure 8 (EIA, 2020). Currently, 23% of the state's energy generated is attributed to wind and solar energy (EIA, 2020), (Wind Energy Technologies Office, 2020). The state's yearly wind energy potential, the highest among all renewable energy sources as of yet, is projected to be 435 billion kilowatt-hours (New Mexico Energy, 2020). This makes New Mexico a potential future exporter of wind power. Along with the New Mexico Energy Roadmap Project and in collaboration with the Energy, Minerals and Natural Resources Department (EMNRD) and Energy Conservation and Management Division (ECMD), the state paves the way for economic development, new job opportunities, and the adoption of renewable energy by a vast array of energy stakeholders.

In regard to Taos, the Town Council's 2009 residential and commercial Regulations and Ordinances included (1) increasing energy resource management; (2) the strategic designing of green infrastructure; and (3) the renovation of existing structures (Holmes & Henry, 2010). In addition to educating and raising community awareness surrounding these aims, they offer a tax incentive of one cent per kWh in the form of a corporate Renewable Energy Development Tax Credit to further encourage use of wind power (New Mexico Energy, 2020). Through the Renewable Taos initiative, the Town focuses on energy efficiency in large part through a shift to renewable energy sources (New Mexico Energy, 2020).

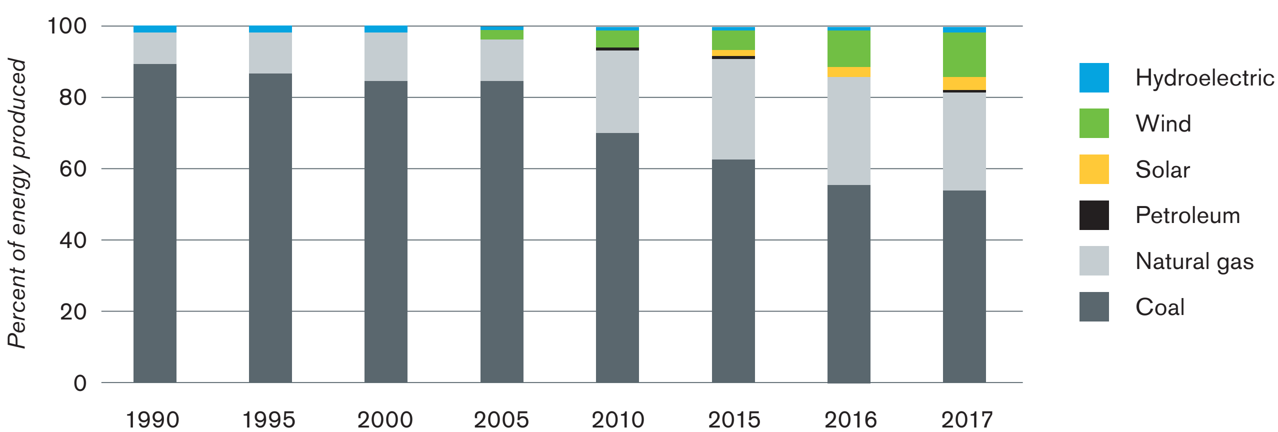

Figure 8 *New Mexico electricity production 1990-2017, by U.S. Energy Information Administration*

Case study 3: Malmö, Sweden

Sectors served: Residential and business buildings

Funding source: Municipality and private funding programs

Key highlights: LEED certification, renewable energy sources

A European leader in renewable energy, Sweden made the goal to reach full dependence on renewable energy by 2030 (IRENA, 2018), (C40 Cities, 2014). By 2014, Malmö had already surpassed its municipal goal of supplying 50% of its energy from renewable sources, originally targeted for completion by 2020 (C40 Cities, 2014). City-wide planning initiatives focus on fostering resilient and sustainable living spaces as well as combating climate change and its associated impacts, corresponding to SDG Goals 11 and 13 (United Nations, 2020), (UNStats, 2020). Among the various ongoing projects aimed at emissions reductions and increased energy efficiency in both residential and business buildings, the City employs technical and behavioral solutions such as persistent city-wide energy use measurement, transitioning to energy cluster use, and incorporating the use of smart grids (Zinkernagel, R., 2016). The City also commonly engages with residents to better understand user perspectives and educate the public on energy consumption patterns. There is also a strong focus on applying LEED Platinum energy standards to residential buildings throughout the city (Zinkernagel, R., 2016). Malmö also established strategic targets for the reduction of GHG emissions through solar, wind, hydro-power, and biogas renewable energy sourcing (IRENA, 2018). This is financed by a model in which the economic burden is distributed to both the municipality and private entities. Some examples of funding sources include green bonds, crowdfunding, urban development funds, and social impact bonds, in addition to other private and public investments (IRENA, 2018).

Figure 9 *Malmö*'s prominent *LEED Platinum energy certified Live building*

RECOMMENDATIONS AND RESOURCES

Energy efficiency recommendations specific to the Town of Clarkdale were developed based on the summarized case studies of successful city-wide initiatives, previous research by students at ASU's School of Geographical Sciences and Urban Planning (Baltazar et al., 2020), and additional best practice research, include the following topical areas: supporting policies, existing buildings, new construction, renewable energy sources, and other best practices (A. Floyd, personal communication, October 20, 2020; Henner, 2020). The following recommendations are categorized in general, contemporary infrastructure, and historic infrastructure sections.

General recommendations

The following general recommendations include town-wide policies, certifications, and projects intended to increase engagement on the town leadership level.

Recommendation 1: Adopt the International Green Construction Code (IgCC)

In terms of policy, there are two well-established tools that provide an impactful basis for town-wide energy efficiency (A. Floyd, personal communication, October 20, 2020). The first, the International Energy Conservation Code (IECC), is a well-established energy code that addresses efficiency in terms of cost, energy use, resource use, and environmental implications (IECC, 2020). Clarkdale has adopted an amended version of the 2018 code (Town of Clarkdale Town Code, 2020), and the 2021 version is to be released soon (IECC, 2020).

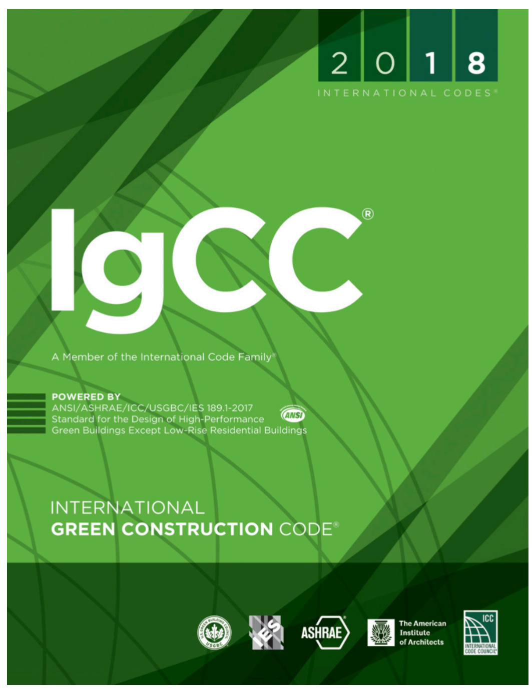

Figure 10 *2018 International Green Construction Code manual, available from the International Code Council*

Also recognized by the International Code Council, and the focus of our recommendation, is the adoption of the **International Green Construction Code** (IgCC), which is a set of guidelines for the design and operation of new construction that supports sustainability, resilience, and high-performance green building outcomes (IECC, 2020). The IgCC outlines building strategies that foster societal benefits, disaster resilience, climate change mitigation, and responsible resource consumption (IECC, 2020). For optimal performance, it is recommended to stay within two cycles of the most updated version of these codes (A. Floyd, personal communication, October 20, 2020).

Resource toolkit

For more information on the International Green Construction Code:

https://www.iccsafe.org/products-and-services/i-codes/2018-i-codes/igcc/

Recommendation 2: Obtain LEED certification for the Town

A well-established global tool for building resilience, reducing carbon emissions, conserving water, reducing waste, and increasing energy efficiency, the Leadership in Energy and Environmental Design (LEED) certification can be applied across new construction, existing buildings, residential spaces, and even whole communities (USGBC, 2020). Pursuit of this certification is highly recommended for the Town of Clarkdale to further increase energy efficiency, as well as demonstrate existing sustainability strengths through an easily accessible and well-recognized initiative.

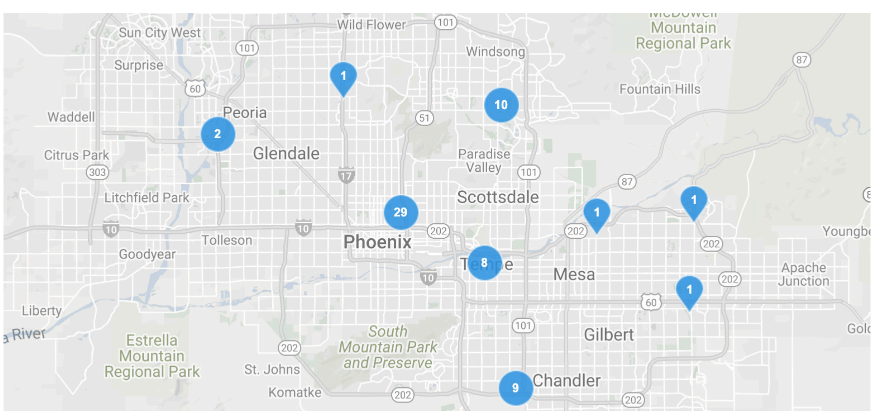

Figure 11 *Map of LEED for Existing Buildings certified projects in the Phoenix area, by the Green Building Information Gateway*

Over 110 cities and communities around the world, including Platinum-certified Phoenix, use LEED to demonstrate their commitment to sustainability and their continuously evolving performance (USGBC, 2020). Additionally, this tool allows for the benchmarking of performance against national and global standards, the guidance for data-driven and transparent decision-making, and the improvement of community standard of living (USGBC, 2020). The certification is all-encompassing while allowing for the selection of focal areas. While community-wide registration begins at $2500, cost-benefit analyses and returns are simultaneously trackable with progress.

Resource toolkit

For more information on LEED for Cities and Communities:
https://www.usgbc.org/leed/rating-systems/leed-for-cities

Recommendation 3: Participate in the SEEK Project

In partnership with communities and other entities, the Sustainable Energy, Education, and Knowledge-Sharing (SEEK) Project provides both an energy efficiency roadmap as well as funding for recommended action items (Graffy, 2018). The program allows for the measurement of impacts related to energy usage, renewable energy transitions, GHG emissions, energy expenditure, and more (Graffy, 2018). The program also facilitates energy innovation and the tackling of energy and climate issues, all at no cost.

Resource toolkit

For more information on the SEEK Project:

https://sustainability-innovation.asu.edu/research/project/sustainable-energy-education-and-knowledge-sharing-seek-project/

Contemporary infrastructure in residential and business sectors

Contemporary infrastructure is increasingly being built with energy efficiency considerations in mind. Clarkdale's Mountain Gate community is an example of a newer property that was constructed with solar energy options, low water irrigation systems, and energy efficiency considerations (T. Hlavinka, personal communication, September 17, 2020). At the same time, contemporary infrastructure often allows for a wide range of additions and alterations due to adaptability and newer materials. As such, the following recommendations are made based on contemporary infrastructure at residential and commercial scales.

Recommendation 4: Adopt APS Renewable Energy Goals by solar power

With regards to the current state of renewable energy sourcing, Arizona has the largest nuclear power plant in the nation which accounts for a third of energy production in the state and additional supply across the southwest (USGBC, 2020). However, it also has abundant potential for solar energy. As such, Arizona Public Service (APS) aims to acquire 45% of its electricity from renewable sources by 2030, and go completely carbon-neutral by 2050 (USGBC, 2020). Clarkdale was one of the first Verde Valley communities to partner with APS in becoming an Arizona Solar Community, and had over 5% of owner-occupied homes supplied with solar energy (Town of Clarkdale, 2020), (Google Project Sunroof, 2020). In this sense, Clarkdale is well on its way to setting an example for the contribution of smaller municipalities to attaining solar energy goals.

Installing photovoltaic panels is the most cost effective form of renewable energy for a zero energy home, and is a powerful tool to address climate change (Plumer, 2020). Solar roofing savings for a house in Sedona (based on the nearest available data) would include a return of around $12,000 over 20 years (The Climate Reality Project, 2019). Additionally, the cost of solar power in 2017 was less than half of the price of coal in the same year, and continues to steadily drop (Plumer, 2020).

Recommendation 5: Reinforce doors and windows

Using highly insulated windows and doors, and controlling heat and air-conditioning cooling loss, are the third most cost effective opportunity for keeping a home energy efficient. For a mountainous region like Arizona, the cost savings of Energy Star windows as compared with single-pane windows are around $295 annually (Mabery, 2013).

Recommendation 6: Replace conventional lighting with LED lighting

Light-emitting diode (LED) bulbs and light fixtures are one of the most energy efficient lighting systems, producing 90% more light, potentially using 75% less energy, and lasting 25 times longer than conventional incandescent light bulbs (Energy Star, 2005). This is a simple switch that can be done across industrial, commercial, and residential settings, with far-reaching impacts. According to one estimate, a nation-wide switch to LED lighting would save the equivalent yearly output of 44 large 1000-megawatt producing electric power plants by the year 2027 (Energy Star, 2020b). In a home setting, simply replacing the most regularly used lights with LED bulbs can yield an annual savings of $75 (Energy Star, 2020b). If this is replicated across commercial and residential spaces alike, the economic benefits would be multiple-fold while reducing energy consumption. These efficient lighting practices are also equally applicable to optimizing historic buildings.

Resource toolkit

Home Performance with Energy Star is a professional training and certification program based in the Southwest States for consultants relating to energy efficiency and other technicians. For more information:

http://www.azhomeperformance.com/index.html

For information on SRP or APS energy appraisal services:

https://www.srpnet.com/energy/rebates/homeEnergyCheckup.aspx

https://www.aps.com/en/Residential/Save-Money-and-Energy/Home-Energy-Checkup

Home Energy Saver Program allows users to calculate their energy consumption, compare other locations nearby, and other beneficial energy blogs, related videos, and case studies to specific systems in residential housing. For more information:

https://homeenergysaver.lbl.gov/consumer/

Recommendation 7: LEED Platinum energy certification

In addition to city-wide certification, LEED provides residential, commercial, and new construction certifications and guidelines.

Residential

While financial savings vary based on the scope of implementation, LEED certification has shown to promote a healthier living space and reduce utility costs, while boasting similar construction costs. On average, LEED-certified residential spaces save anywhere from 20 to 60 percent on energy usage. This is a significant figure when compared to the one-time registration and certification costs of around $150 and $225, respectively.

Commercial

LEED certification standards for existing buildings and interior spaces provide guidance on increasing sustainability while tracking energy, waste, water, transportation, indoor air quality, and occupant satisfaction performance. LEED recertification also allows for the continuous improvement of performance in a transparent fashion.

New construction

LEED for Building Design and Construction provides a holistic framework for the construction of green buildings, across buildings of all types, such as hospitals, businesses, and schools. This LEED program addresses the carbon impact of buildings through an energy metric that includes both cost and GHG emission levels.

Resource toolkit

For more information on LEED for residential buildings:

https://www.usgbc.org/leed/rating-systems/residential

For more information on LEED for existing buildings:

https://www.usgbc.org/leed/rating-systems/existing-buildings

For more information on LEED for new buildings:

https://www.usgbc.org/leed/rating-systems/new-buildings

Historic infrastructure in residential and business sectors

Studies have shown that buildings constructed before 1940 are more energy efficient than those constructed in the following 4 decades, as they use less energy for heating and cooling, and were designed to withstand the elements without additional support (USGBC, 2020). Scaling up energy efficiency in existing buildings is a key consideration for moving towards more sustainable city-wide energy practice (Henner, 2020). This is important in the context of Clarkdale's valued historic aesthetic, for which preserving and restoring existing buildings is at the core of the town's identity (USGBC, 2020). The following recommendations pertain more to historic buildings than contemporary.

Recommendation 8: Install shade structures and plant trees

Implementing shade structures, such as balconies and awnings, or planting native shade trees can be an effective barrier against the sun during Arizona's hot summer months. In addition to providing shade, trees can also increase the natural, vintage appeal of a historic home or building. As detailed in the case studies section, the City of Phoenix also used the planting of trees to help reach their air quality goals while improving building energy efficiency.

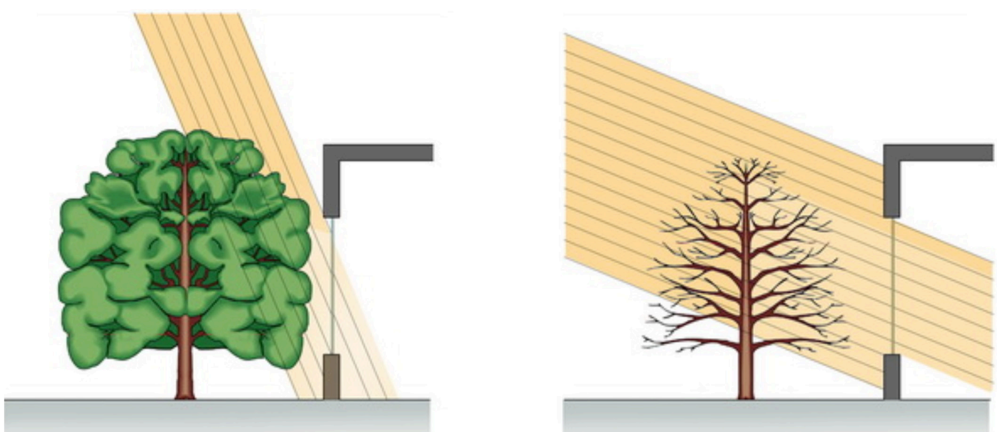

Figure 12 *Solar transmission rates for mature shade trees can be as low as 20% in summer (left) and as high as 70% in winter (right), by the American Institute of Architects (AIA) from the Carbon Neutral Design Project*

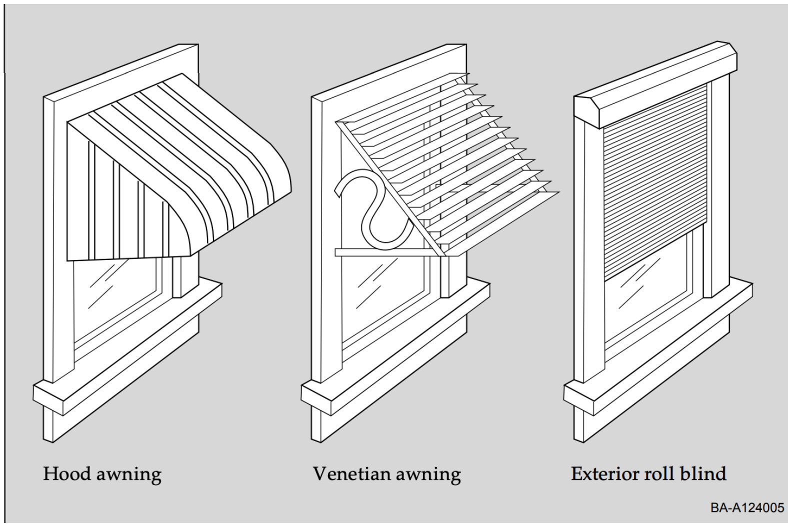

Figure 13 *Various exterior shading options that help improve building energy efficiency by shielding windows from direct sunlight, by U.S. Department of Energy*

In terms of shade structures, exterior shades such as awnings are generally more effective than interior shades, as they block sunlight before it enters windows (Figure 13) (Gromicko, 2020). Examples of exterior shading devices can include awnings, shutters, rolling shutters, shades, and solar screens. When used with air conditioners, awnings can save on cooling costs by up to 25%, or around $120 per month (Gromicko, 2020). In tree-shaded neighborhoods, the summer daytime air temperature can be up to 6 degrees cooler than in a treeless area. A well-planned landscape can help reduce an unshaded building's air conditioning costs by 15 to 50 percent (Office of Energy Efficiency and Renewable Energy., 2020).

Resource toolkit

For more information regarding programs such as the Community Development Block Grant, Home Investment Partnership initiative support streams, and the Weatherization Assistance Program:

https://housing.az.gov/community-development-and-revitalization

Recommendation 9: Reinforcement through storm windows

Storm windows are a prime method to increase energy efficiency in historic infrastructure as they provide a completely non-invasive method of addressing air leakage by providing additional insulation. Rather than completely replacing existing windows, storm windows act as a shield to keep primary windows in better condition for longer lengths of time (Figure 14). They also reduce noise transmission and do not affect the aesthetics of a historical building. Storm windows can help provide savings of approximately 12 to 33 percent on heating and cooling costs, or up to $158 per month (Office of Energy Efficiency and Renewable Energy, 2020).

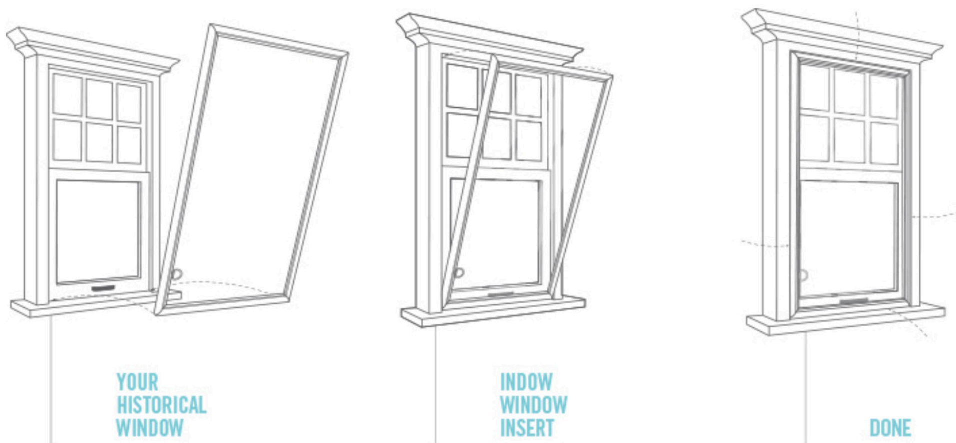

Figure 14 *The fitting of a storm window over a conventional window, by Indow Windows*

Resource toolkit

The Weatherization Assistance Program focuses on reducing the energy costs for families that qualify as low-income, specifically populations with children, elderly, and person(s) with disabilities, by maintaining their health and welfare when enhancing energy efficiency in their residential housing units. The program includes contracts via local community organizations, most of which are grant funded by the city.

https://housing.az.gov/general-public/weatherization-assistance-program

Recommendation 10: Insulate attics and crawl spaces

According to the U.S. Department of Energy, simply reducing air leaks in a home can provide savings of 10 to 30 percent on heating and cooling costs (Department of Energy and National Renewable Energy Laboratory, 1994). Some of the most common avenues of air leakage in older residential buildings include attics and crawl spaces (USGBC, 2020). While further insulating these spaces can help increase energy efficiency and cut energy costs, APS also provides a $250 rebate for air leakage related repairs and sealing of ductwork (APS, 2020). For historic buildings, air sealing is one of the least intrusive, most reversible, and cost effective methods of energy efficiency.

Resource toolkit

For information on self-insulation Energy Star resources:

https://www.energystar.gov/campaign/seal_insulate/do_it_yourself_guide

Recommendation 11: Replace outdated appliances with Energy-Star appliances

Energy Star appliances, such as dishwashers, clothing washers and dryers, and refrigerators, are a completely non-invasive method to save on operating costs (Energy Sage, 2019).60 Taking the example of one of the most energy-intensive home appliances, a clothing dryer (which consumes as much as a refrigerator, washing machine, and dishwasher combined), has an electricity savings rate of 20% with an Energy Star appliance (Energy Star, 2020a). This allows for approximately $210 worth of savings across the lifespan of the appliance (Energy Star, 2020a). For clothing washers, approximately $50 annually is saved from utility and water bills. Energy Star dishwashers save about $25 yearly, which may seem like a small figure but will compound over time.

Resource toolkit

For more information on Energy Star appliances:

https://www.energystar.gov/products/appliances

Recommendation 12: Implement smart meters

Smart meters measure a building's electricity usage and directly link with utility providers. They monitor and allow for bill utilization, detect remote switch on, and disconnect power failures (Durrenberger, 2017) (Rodvien, 2018). Across the U.S., 70 million smart meters have been installed, 88% of which are in residential properties (Rodvien, 2018). Net metering is typically a single bi-directional meter for consumers generating their own electricity (OEDER, 2016). Through the use of a rooftop solar installation, unit net metering allows electricity to flow both to and from consumers. Electricity flows to the grid when the generation exceeds the usage of the client, offsetting electricity used by the client at a different period over the same billing cycle (OEDER, 2016). In most states, net metering is mandated by law, although some policies and regulations may significantly differ. An estimate of savings while using Smart Meters is approximately 2% or 354 kilowatt-hours per year (OEDER, 2016). Smart meters are a powerful tool to understand and alter electricity usage in a very effective way.

Proposed energy efficiency plan

The following proposed plan for the Town of Clarkdale highlights a few key town-wide policies, certifications, and programs; contemporary infrastructure-specific best practices and certifications; and best practices specific to historic infrastructure. Overall, increased energy efficiency provides both environmental and economic benefits to the Town of Clarkdale, a few of which are summarized in Figures 15 and 16. In summary, specific recommendations to set the Town on track to reaching key energy targets include:

1. Adoption of the International Green Council Code
2. Obtaining LEED Certification for the town
3. Participation in the SEEK project
4. Adoption of APS renewable energy goals by solar
5. Reinforcing doors and windows
6. Swapping out conventional lighting for LED lighting (for both sectors)
7. LEED Platinum Energy Certification
8. Adding shading structures and planting trees
9. Reinforcement through storm windows
10. Insulation to attic and crawl spaces
11. Replace old appliances with Energy-Star appliances
12. Implementation of smart meters

Solar roofing

- Reduced emissions
- Most cost effective renewable energy option
- Cost and returns: Approximately $12,000 over 20 years

LED lighting

- Produce 90% more light, use 75% less energy, and last 25 times longer.
- Cost and returns: Over $75 per year

Reinforced or Energy Star windows

- Third most cost effective means for energy efficiency
- Cost and returns: Compared to single-pane, $295 per year

LEED certification

- Energy usage savings of anywhere from 20-60%

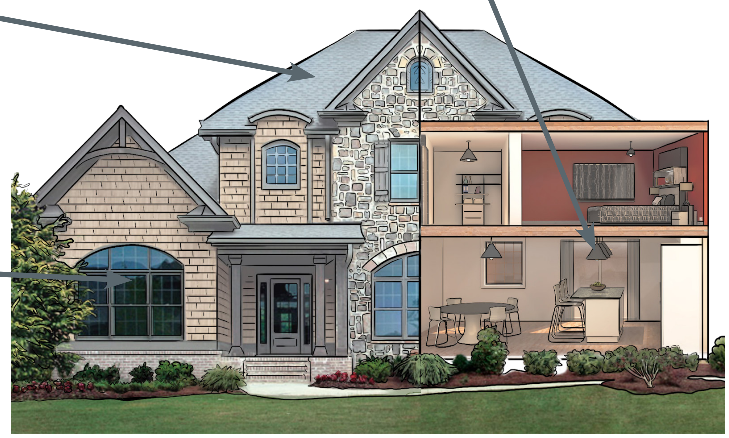

Figure 15 *Visual representation of energy efficiency recommendations for contemporary buildings, illustrated by Walid Elkhatib*

Shading structures and tree coverage

- Installing awnings on buildings or planting trees reduces energy needs
- Cost and returns: Up to $120 per month

Storm windows

- Reduces thermal transmission
- Similar energy savings while costing 1/4 the price of a complete window replacement
- Cost and returns: $57-158 per month

Crawl spaces and attic insulation

- Savings of 10-30% on heating and cooling costs

LED lighting

- Produce 90% more light, use 75% less energy, and last 25 times longer

Energy Star appliances

- Savings of 10-30% on heating and cooling costs

Figure 16 *Visual representation of energy efficiency recommendations for historic buildings, illustrated by Walid Elkhatib*

Based on the aforementioned recommendations, in order to reach the goals of sourcing 45% of electricity from renewable sources by 2030, and reaching full carbon neutrality by 2050, the following timeline of action is proposed for the next 3 years (Figure 17). While a longer timeline is necessary for the full attainment of these goals, the adopted recommendations within this period will provide for supporting policy, program, and community infrastructure to set in place successful goal attainment in the following years.

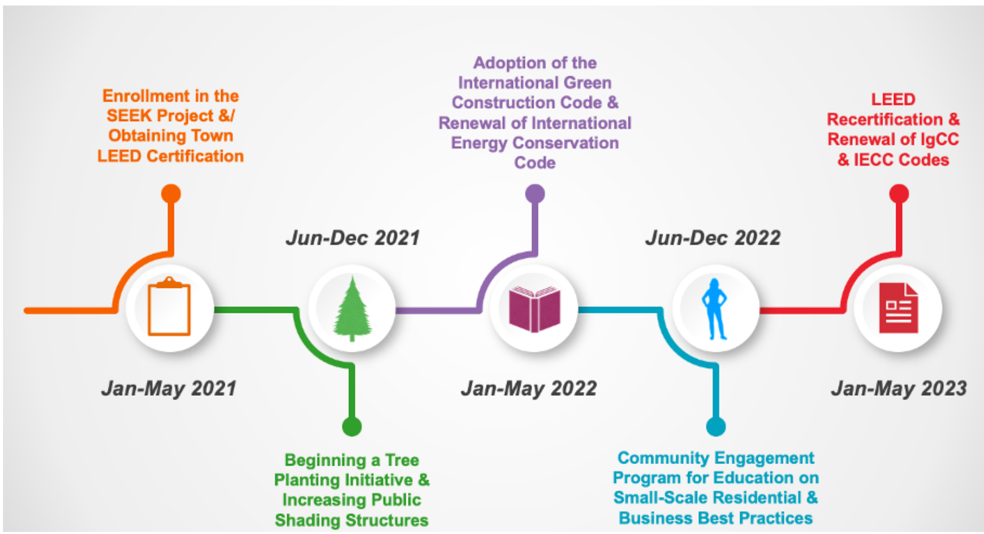

Figure 17 *Suggested recommendation implementation timeline*

Enrollment in the local SEEK Project (localized, but free of charge) and/or obtaining town-wide LEED Certification (nationally-recognized, with a one-time fee) are key actions to initiating the attainment of energy efficiency and emissions reduction targets for the Town of Clarkdale. These guiding bodies will facilitate the setting and accomplishment of town targets based on effectiveness-proven guidelines as exemplified in both the Cities of Malmö and Phoenix. Simultaneously, mirroring a tree-planting initiative similar to that of the City of Phoenix can allow for the protection of historic infrastructure while drastically reducing town-wide heat retention, and decreasing individual infrastructure energy costs. Greater town policy support for these targets as exemplified in the Town of Taos can come from the adoption and bi-yearly updating of two of the best-recognized codes for energy efficiency: the International Green Construction Code for all future new construction, and the already-adopted International Energy Conservation Code for the maintenance of the highest level of efficiency in existing infrastructure.

The backbone of all wide-scale efforts—community action—can be further fueled by planned energy-sustainability programming that addresses all of the smaller-scale residential and commercial recommendations on a building-by-building basis. This will be a highly effective tool to leverage existing community sustainability values and pair them with targeted planning for the most effective town outcome. While the adoption of guiding programs and projects such as SEEK and LEED will provide the basis for long-term goal attainment, the research has shown that the continuous engagement of each of these sectors will provide a comprehensive basis for the increase of energy efficiency and the reduction of emissions in residential and commercial infrastructure across the Town of Clarkdale.

CONCLUSION

Clarkdale has a unique opportunity to look to the future while preserving and honoring its rich past. Exploring various methods of implementing energy efficiency policies and initiatives has allowed Clarkdale to partner with a diverse array of students, facilitators, and experts in crafting their plans for the future. This report was the product of the hard work of graduate students Huda Khalife and Yaritza Hernandez Gil, both enrolled in the SOS 594 course at Arizona State University. Working closely with Clarkdale officials and course facilitators, Huda and Yaritza gathered information, reviewed literature, identified subject matter and points of importance, and brainstormed for several months over the course of the Fall 2020 semester to develop their recommendations for the Town of Clarkdale.

The research and suggestions in this report intend to provide a framework of ideas that Clarkdale can utilize as they see fit. This work includes case studies from Arizona, New Mexico, and Sweden to offer a diverse collection of perspectives and ideas. Increasing the energy efficiency of an older, historic town will be no easy task. The recommendations in this report address the historic infrastructure of Clarkdale while also addressing new construction and development, both commercial and residential. Among the recommendations are various certifications and projects for consideration, such as LEED and SEEK. These will provide a more detailed framework for Clarkdale to progress toward updating its energy systems. Various infrastructural updates and changes are also explored in detail in this report. The diverse set of ideas presented are intended to provide the town with many avenues to pursue in achieving improved energy efficiency.

There are challenges and opportunities for Clarkdale as the town looks ahead to the future. Though situated along the busy Route 89A, Clarkdale has not received the same level of tourism or commerce as the neighboring towns of Jerome and Cottonwood. There are also pressing environmental, infrastructural, and social challenges that must be attended to in the coming decades as Arizona seeks to remain resilient in the face of climate change and other issues. Adopting the initiatives for energy efficiency outlined in this report will afford Clarkdale the opportunity to serve as an example for the Verde Valley and the State of Arizona when it comes to sustainability. A heightened focus on sustainability and energy efficiency should be matched with a focus on the preservation of the historical character of Clarkdale. This report provides ideas that will allow the Town to do this, thus increasing tourism and strengthening the local economy. While many debates on sustainability seem to place it at odds with economics, this report shows that economics and sustainability initiatives can go hand in hand. Clarkdale has a bright future ahead of it, and with the focus on energy efficiency, it can be fully realized.

Figure 18 *Clarkdale municipal buildings, by Town of Clarkdale*

REFERENCES

Alliance To Save Energy. (2018). *Energy Use Overview.* **https://www.ase.org/categories/buildings**

Alton, L. (2017, January 13). *The 7 Most Progressive US Cities for Energy Efficiency and Renewable Energy.* Renewable Energy World. **https://www.renewableenergyworld.com/2017/01/13/the-7-most-progressive-us-cities-for-energy-efficiency-and-renewable-energy/#gref**

American Institute of Architects (AIA). (2012). *The Carbon Neutral Design Project.* Terry Meyer Boake. **https://www.tboake.com/carbon-aia/strategies1b.html**

Arizona Public Service (APS). (2020). *Duct Repair and Sealing Rebate.* **https://www.aps.com/en/Residential/Save-Money-and-Energy/Your-Energy-Your-Options/Rebates/Duct-Repair-and-Sealing-Rebate**

Arizona State University's Project Cities. (2020). *Activating Historic Clarkdale Through Sustainable Design and Policy.* **https://links.asu.edu/PCClarkdaleDowntownRevitalization19-20**

Baltazar, N., Che, Y., Du, H., Freelander, B., Hallac, S., Henn, M., Leftwich, N., Li, Y., Lu, Y., Ortiz Cortez, G., Ranallo, S., Sanchez Luna, N., Schultz, L., Stoddard, S., Torain, S., Vu, T., & Zambrano, A. (2020). *Design Principles and Guidelines for the Town of Clarkdale's Downtown District and 89A Commercial Corridor.* Arizona State University School of Geographical Sciences and Urban Planning. **https://sgsup.asu.edu/sites/default/files/2020_final_report_clarkdale_dt.pdf**

City of Phoenix. (2020). *Environmental Sustainability Goals.* **https://www.phoenix.gov/sustainability/goal**

City of Phoenix. (2017, March 27). *Sustainability Report 2015-2016.* **https://www.phoenix.gov/sustainabilitysite/Documents/Final%20COP%202015-16%20Sustainability%20Brochure%2003.27.17.pdf**

C40Cities. (2014). *Malmö: 100% Renewable Energy for the City of Malmö by 2030.* **https://www.c40.org/profiles/2014-malmo**

Durrenberger, M. (2017, February 15). *Different Types of Utility Meters for Solar.* New England Clean Energy. **https://newenglandcleanenergy.com/energymiser/2017/02/15/different-types-of-utility-meters-for-solar/**

Electricity Local. (2020). *Clarkdale, AZ Electricity Statistics.* **https://www.electricitylocal.com/states/arizona/clarkdale/**

EnergySage, LLC. (2019, January 2). *What are the most energy efficient appliances and are they worth it?* **https://www.energysage.com/energy-efficiency/costs-benefits/energy-star-rebates/**

Energy Star. (2005, February). *Cost and Energy Savings: National, Regional, and City Estimates, Factoids, and Their Use.* **https://www.energystar.gov/ia/partners/manuf_res/windows/ES_Windows_Cost_Energy_Savings.pdf**

Energy Star. (2020a). *Appliances.* **https://www.energystar.gov/products/appliances**

Energy Star. (2020b). *Learn About LED Lighting.* **https://www.energystar.gov/products/lighting_fans/light_bulbs/learn_about_led_bulbs**

Google Project Sunroof. (2020). *Explore Estimated Solar Potential of Your Community.* **https://www.google.com/get/sunroof/building/34.813284/-111.838267/**

Graffy, E. (2018, June). *Sustainable Energy, Education and Knowledge-Sharing (SEEK) Project.* ASU Global Futures Lab, Global Institute of Sustainability and Innovation. **https://sustainability-innovation.asu.edu/research/project/sustainable-energy-education-and-knowledge-sharing-seek-project/**

Gromicko, N. (2020). *Enhancing Energy Efficiency in Historic Buildings.* International Association of Certified Home Inspectors. **https://www.nachi.org/energy-efficiency-historic-buildings.htm**

Guevara-Stone, L. (2015, November 21). R*enewable Taos Seeks 100% Renewable Energy That Is "Accessible To All".* Rocky Mountain Institute. **https://cleantechnica.com/2015/11/21/renewable-taos-seeks-100-renewable-energy-that-is-accessible-to-all/**

Henner, N. (2020, June 18). *Mayors' Toolkit for Energy Efficiency.* American Council for an Energy-Efficient Economy. **https://www.aceee.org/sites/default/files/pdfs/mayors_toolkit_2020.pdf**

Holmes, M. H., & Henry, A. W. (2010). Building Sustainable Ordinances in Taos: The Taos High Performance Building Ordinance Demonstrates That the Citizens of Local Communities Can Be Powerful Assets in Achieving Sustainability. *The Public Manager, 39*(1). **https://www.questia.com/library/journal/1G1-344208305/building-sustainable-ordinances-in-taos-the-taos**

Indow Windows. (2020). *Block Drafts & Save Energy by Insulating Windows.* **https://indowwindows.com/solutions/insulating-drafty-windows/**

International Code Council Inc. (2020). *International Energy Conservation Code® Resource Page.* **https://www.iccsafe.org/advocacy/international-energy-conservation-code-resource-page/**

International Renewable Energy Agency. (2018, March). *Renewable Capacity Statistics 2018.* **https://www.irena.org/publications/2018/Mar/Renewable-Capacity-Statistics-2018**

International Renewable Energy Agency. (2018). *Steps To Achieving 100% Renewable Energy Use. Malmö, Sweden.* **https://irena.org/-/media/Files/IRENA/Agency/Publication/2018/Dec/IRENA_Cities_2018e_Malm.pdf?la=en&hash=15AAEB18677CA4C7575A1D86F75E9BA6C941661A**

Mabery, G. (2013). *Deploying Geo-Thermal Energy in Historic Buildings in Clarkdale, AZ.* International City/County Management Association. **https://icma.org/sites/default/files/305690_Clarkdale-Deploying%20Geo-Thermal%20Energy%20in%20Historic%20Building.pdf**

Martin, G., Saikawa, E. (2017). Effectiveness of state climate and energy policies in reducing power-sector CO2 emissions. *Nature Climate Change, 7*, 912–919. **https://doi.org/10.1038/s41558-017-0001-0**

National Renewable Energy Lab (NREL). (1994). *Cooling Your Home Naturally.* **https://www.nrel.gov/docs/legosti/old/15771.pdf**

New Mexico Energy, Minerals and Natural Resources Department. (2020). *Renewable Energy - Wind.* **http://www.emnrd.state.nm.us/ECMD/RenewableEnergy/wind.html**

Office of Electricity Delivery and Energy Reliability. (2016, September). *Advanced Metering Infrastructure and Customer Systems.* U.S. Department of Energy. **https://www.energy.gov/sites/prod/files/2016/12/f34/AMI%20Summary%20Report_09-26-16.pdf**

Office of Energy Efficiency & Renewable Energy. (2020). *Everything You Need to Know About Landscaping.* U.S. Department of Energy. **https://www.energy.gov/sites/prod/files/2014/04/f14/Landscaping101_finalv2.pdf**

Office of Energy Efficiency & Renewable Energy. (2020). *LED Lighting.* U.S. Department of Energy. **https://www.energy.gov/energysaver/save-electricity-and-fuel/lighting-choices-save-you-money/led-lighting**

Office of Energy Efficiency & Renewable Energy. (2020). *Storm Windows Energy Saver.* U.S. Department of Energy. **https://www.energy.gov/energysaver/storm-windows**

Plumer, N. P. (2020, October 28). *How Does Your State Make Electricity?* The New York Times. **https://www.nytimes.com/interactive/2020/10/28/climate/how-electricity-generation-changed-in-your-state-election.html**

Renewable Energy World. (2017, January 13). *The 7 Most Progressive US Cities for Energy Efficiency and Renewable Energy.* **https://www.renewableenergyworld.com/2017/01/13/the-7-most-progressive-us-cities-for-energy-efficiency-and-renewable-energy/#gref**

Renewable Taos, Inc. (2015, November). *Renewable Energy for Taos and Vicinity, New Mexico 2015 Status Report.* **https://renewabletaos.org/wp-content/uploads/Renewable-Energy-TaosVicinity-NM.pdf**

Rodvien, E. (2018, September 13). *Smart meters: What Every Solar Homeowner Should Know.* Solar United Neighbor. **https://www.solarunitedneighbors.org/news/smart-meters-what-every-solar-homeowner-should-know/**

The Climate Reality Project. (2019). *Things Are Looking Bright: The Facts About Solar Energy.* **https://www.climaterealityproject.org/sites/default/files/solarfactsebook_03_2019.pdf**

Thorpe, D. (2017, June 7). *The World's Most Successful Model for Sustainable Urban Development?* Smart Cities Dive. **https://www.smartcitiesdive.com/ex/sustainablecitiescollective/words-most-successful-model-sustainable-urban-development/229316/**

Town of Clarkale. (2020a, July 7). *Sustainability Values.* **https://www.clarkdale.az.gov/Town%20Departments/Community%20Development/Sustainable%20Clarkdale/Sustainability%20Values%20final.pdf**

Town of Clarkdale. (2020b, October 1). *Full website.* **https://www.clarkdale.az.gov/your_government/about_clarkdale/index.php**

Town of Clarkdale Town Code. (2020, September 8). *Adoption of the Energy Conservation Code.* **https://clarkdale.town.codes/CTC/7-9**

United Nations. (2020). *Make cities and human settlements inclusive, safe, resilient and sustainable.* United Nations Statistics Division Development Data and Outreach Branch. **https://unstats.un.org/sdgs/report/2020/Goal-11/**

United Nations. (2020). *Take urgent action to combat climate change and its impacts.* United Nations Statistics Division Development Data and Outreach Branch. **https://unstats.un.org/sdgs/report/2020/goal-13/**

United Nations. (2020). *The 17 Goals.* Sustainable Development Goals. **https://sdgs.un.org/goals**

U.S. Department of Energy and National Renewable Energy Laboratory. (1994, October). *Cooling Your Home Naturally.* **https://www.nrel.gov/docs/legosti/old/15771.pdf**

U.S. Department of Energy's Wind Energy Technologies Office. (2020). *Wind Energy in New Mexico.* **https://windexchange.energy.gov/states/nm**

U.S. Energy Information Administration (EIA). (2020, February 20). *Arizona State Profile Analysis.* **https://www.eia.gov/state/analysis.php?sid=AZ**

US EPA Archived: National Trust For Historic Preservation. (2020). *Energy Advice for Owners of Historic and Older Homes.* **https://archive.epa.gov/region5/sustainable/web/pdf/energy-advice-for-owners-of-older-homes.pdf**

U.S. Green Building Council. (2020). *LEED certification for existing buildings and spaces.* **https://www.usgbc.org/leed/rating-systems/existing-buildings**

U.S. Green Building Council. (2020). *LEED certification for new buildings.* **https://www.usgbc.org/leed/rating-systems/new-buildings**

U.S. Green Building Council. (2020). *LEED for Cities and Communities.* **https://www.usgbc.org/leed/rating-systems/leed-for-cities**

U.S. Green Building Council. (2020). *LEED for Residential Design and Construction.* **https://www.usgbc.org/leed/rating-systems/residential**

U.S. Green Building Council. (2020). *LEED rating system.* **https://www.usgbc.org/leed**

Zinkernagel, R. (2016, November 15). *Smart Energy Efficiency.* City of Malmö. **https://malmo.se/Nice-to-know-about-Malmo/Sustainable-Malmo-/Sustainable-City-Development-2016/About-the-conference/Programme/Smart-energy-efficiency.html**

To access the original student reports, additional materials, and resources, visit:

links.asu.edu/PCClarkdaleSustainability20F

PART 3:

Design and Eco-Tourism Principles for a Sustainability Park

INTEGRATING FEASIBLE DESIGNS THAT FUNCTION AS BOTH COMMUNITY RECREATION AND SUSTAINABILITY ASSETS

SOS 498: URBAN SUSTAINABILITY APPLICATIONS

SCHOOL OF SUSTAINABILITY

FACULTY
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PROJECT GOALS

This report was compiled with the objectives to provide Clarkdale with a clear understanding of the concepts presented and how to proceed with the subsequent recommendations. While most of these recommendations may not be implemented immediately, they are intended to provide a concise blueprint for when the Town is ready to move ahead with a sustainability park plan. The project goal for the students was to provide Clarkdale with specific recommendations, which together build a potential framework for a sustainability park to support the Town in its economic and sustainability initiatives. These efforts intend to assist Clarkdale staff in the preparatory phases of the long-term goal of developing a mining-impacted parcel of land into a regional example of sustainability in action.

INTRODUCTION

The prospect to design and implement a sustainability-themed public park in Clarkdale was introduced in the *2010 Proposal for the Clarkdale Sustainability Park*. This initial proposal identified a 100-acre parcel of land (highlighted green in Figure 1) owned by mining company Freeport-McMoRan as a location that could benefit the Town, both environmentally and economically, as a sustainability park. Located northwest of the town center (highlighted gold in Figure 1), and once the site of a now-defunct mining complex, the area is a prime site to develop a local attraction that incentivizes slow tourism and spurs a green economy in the region. The town's unique mining history, cultural assets, and natural resources like the Verde River (the only free-flowing river in Arizona) add to Clarkdale's already charming character, and which will continue to be enhanced with the addition of the sustainability park.

Figure 1 *Context map of Clarkdale (left), and closeup highlighting general area of the park parcel in relation to downtown Clarkdale (right), via Google Earth*

Unfortunately, Clarkdale has suffered significant economic leakage as a result of the construction of Route 89A. The neighboring towns of Jerome and Cottonwood (Figure 1) have benefitted from a steady stream of tourism that runs along 89A, while leaving Clarkdale with a diminished and underutilized tourism sector. The proposed sustainability park is intended to help combat this economic leakage by serving as a sustainability destination and example for the nearby towns.

Students have proposed a park plan, detailed in the following sections, featuring integrated and interdependent features including solar arrays, hydroponic greenhouses, composting facilities, transportation, a constructed wetland, and a plasma converter. These components are intended to be highly integrated with the Town, benefiting Clarkdale in both the environmental and economic sectors.

Plan overview

The proposed sustainability park plan (Figure 2) includes overarching design suggestions as well as specific interventions within the 100-acre area based on the needs, interests, and input of town staff. Students investigated the overall design principle of sustainability by focusing on green infrastructure, access, and walkability in regard to the proposed path layout. The plan features an integrated system of sustainability interventions, including agrivoltaics and solar panels strategically placed in and around the park to generate energy, and promote niche gardening through hydroponics. These are all connected with the overall green infrastructure design that features green mobility and transportation devices (e-scooters) throughout the area, ADA (Americans with Disabilities) accessible pathways, aesthetically pleasing solar arrays, and a neighboring constructed wetland adjacent to Pecks Lake. Composting facilities are suggested throughout the park that function as collection points for community green composting. Waste management is an important aspect of sustainability and both composting and plasma gasification are considered in the park's design.

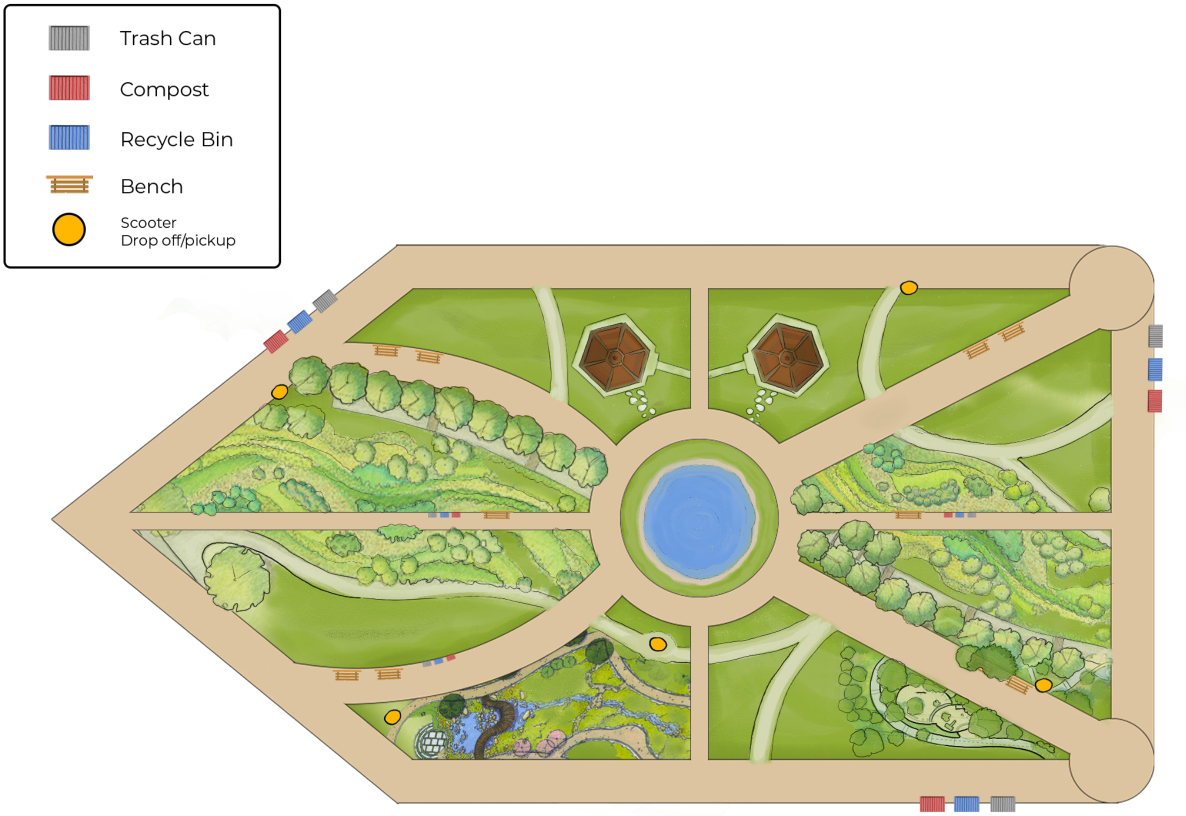

Figure 2 *A suggested layout plan for Clarkdale's sustainability park, illustrated by Walid Elkhatib*

The wide scope of this project, and subsequent diverse studied topics, are intended to benefit Clarkdale in multiple ways. By focusing on various attributes, this report proposes a park that benefits Clarkdale's environment, economy, and residents. The primary focus of the park is to promote sustainability and the local economy. Focusing on green and sustainable infrastructure ensures the park is a net positive for the surrounding environment while also creating a unique and desirable place for tourists and residents to visit. Constructing the park with accessibility in mind can further attract a wide range of people to the park. Increased tourism spurred by the park can help the local economy by attracting crowds to Clarkdale's historic downtown area, potentially increasing traffic at local businesses including restaurants, shops, and cultural areas. The scope of this report was kept deliberately wide, with the intent to present as many positive effects for the town as possible. Topics considered throughout the research process for potential implementation in the park plan are detailed in the following sections.

RESEARCH METHODS

The sustainability park plan development was prefaced by the creation of a scope of work document, available in Appendix A of this report. The scope of work outlines intended deliverables, and helped create and manage expectations on what to include in the final report. Though this is not a legal document, it helped structure expectations between the class and the Town of Clarkdale and was signed by students, instructors, and town leadership. This document helped guide students over the following months of research.

Students dove into a variety of topics and categories, including mobility and accessibility, green design and infrastructure, gardening and composting, and solar power. Each category was researched by a group of three students, each contributing a unique approach to their project. Students researched diverse aspects of each topic, such as general information, benchmarking case studies, funding opportunities, relevant literature reviews, best practices, and compiled strengths, weaknesses, opportunities, and threats (SWOT) analyses. The class worked very closely with Clarkdale officials, course facilitators, industry professionals, and each other. Approximately five meetings were held with several Town officials. These officials included former Mayor Doug Von Gausig, Town Manager Tracie Hlavinka, and Public Works Utilities Director Maher Hazine. These officials helped guide the direction of the report and provided key insights to the students. These meetings were in addition to the twice weekly class meetings with instructors Nalini Chhetri and Anne Reichman and independent brainstorming sessions amongst the students. Class meetings and meetings with officials covered information relevant to the project, including town demographics, characteristics, budgetary concerns, and future goals. Other information was also shared, such as drone footage and topographic maps of the park.

Students collaboratively combined their group findings and writings to a shared document, which was the basis for the following report. This final product is the result of an entire semester's worth of hard work and dedication by all participants mentioned, and was presented in a final presentation to course facilitators and town officials at the Project Cities Fall 2020 End-of-Semester Showcase event.

FINDINGS AND ANALYSIS

The following sections are organized topically based on the particular research conducted by each student group. While covering diverse subject matter, each section relates directly back to feasible actions recommended for the Town in achieving its local sustainability goals.

COMMUNITY ACCESSIBILITY

Editor's Note
Original SWOT tables for each topical subcategory are available in Appendix B of the student content at **links.asu.edu/PCClarkdaleSustainability20F**

Community engagement

The Town of Clarkdale is keen on preserving its historic character and highlighting the humble beginnings of the town, while also focusing on the needs of its residents. There is opportunity to use community resources and engagement to ensure that best practices are implemented throughout the park. Clarkdale is considered to be a "legacy town", which means that they are a post-industrial historic town that has experienced sustained job and population loss over the past few decades as a result of a declining mining industry. The proposed sustainability park serves as an opportunity to aid in revitalizing the town by highlighting the narratives of the former mining industry and culture that still exist today. Legacy cities and towns have the resources to regenerate and to phase in large scale projects such as the sustainability park. However, cities that have done this have had to capitalize on their pre-existing resources while collaborating with local leaders, residents, businesses, and other applicable stakeholders (Grogan, J. 2020).

Case study: Youngtown, Ohio

The Lincoln Institute of Land Policy found that improving legacy cities and towns can help regenerate local economies. This case study used several steps to center the community in its economic development. Youngstown, Ohio collected data to pinpoint which communities were struggling and subsequently prioritized funding for them. The steps that coincide with this specific plan are to implement inclusive economic development, build on the strengths of the community, engage in community and strategic planning, and to focus regional efforts on a strong urban core (Grogan, J. 2020). These all have to happen with phased approaches or incremental action. The City of Youngstown demonstrates this with a program where vacant lots were repurposed into urban green space. In the first 2 years of the program, over 115 vacant lots were transformed into regional parks, community gardens, and urban farms (Grogan, J. 2020).

Figure 3 *Excerpt from the Vacant Land Reuse Resource Guide, by the Youngstown Neighborhood Development Corporation, available at* **https://www.yndc.org/sites/default/files/Vacant%20Land%20Reuse%20Guide_0.pdf**

Clarkdale can utilize some of these principles to advance development in the park by using pre-existing data to pinpoint where sustainable and inclusive development is most needed, and what populations may be underserved. This can exist in the form of an Action Plan that takes into account data from the 2020 census to identify how funding for plans can take place.

Path and trail planning

Ideally, implementing the proposed sustainability park would advance Clarkdale's social, economic, and communal systems, in an equitable way for a diverse set of residents and visitors. To ensure greater equity, Clarkdale can create trails and pathways, within and connecting to the park, that are mixed-use and serve physical activities such as recreation, hiking, and biking. Multiple trail options should be available to support these activities and some should be concentric in design. Pedestrian trails can run alongside bike trails, with ample space provided for safety (Figure 4). Effectively shading these walkways is also necessary for comfort and safety, especially in the middle of the park where the sun is most prominent, and at the far east and west sides of the park.

Figure 4 *Example of a wide multi-use path, featuring designated bike and pedestrian lanes*

When planning paths and trails, it is important to provide a variety of experiences. Some walkways should be set up as "out and back" trails, and others as loops, to allow for residents and visitors to choose which path best suits their physical needs. Before the construction of these trails, it would be beneficial for Clarkdale to map the current usage of pre-existing walkways, and proceed with an open mind knowing that use will change with the emergence of their tourism industry. By building with an open mind and ensuring walkability from the beginning, it will become easier to build on more trails or park features in the future.

One relevant case study published by the Journal of Transport and Land used social demographics, characteristics of the population, and predictions of total trail use to determine whether or not a new trail would be beneficial. The study found the most important use-based measure of accessibility is "the explicit inclusion of the measure of elasticity of use with the overall level provision of opportunities" (Ottensmann, J., & Lindsey, G., 2008). This entails examining equity in the provision of trails, assessing the distribution of facilities (e.g., playgrounds), and predicting usage based on characteristics of a population to make informed decisions.

If Clarkdale does not conduct a study of existing paths before the construction of park trails, they can instead conduct one after some trails are already completed, and use the data to inform the construction of future trails. This can be accomplished by conducting surveys with residents and mapping areas where optimal usage of trails or walkability occurs. The information from these surveys and maps can be used to identify ideal locations for future trails, junctions, and other pathways.

American Disabilities Act guidelines

Surrounded by the Sonoran Desert, the 100-acre lot is situated on a hill with rough topography. Due to the unique landscape of the park, it is imperative that the town constructs walkways, bike paths, and infrastructure that is easily accessible to residents and visitors and complies with Americans with Disabilities Act (ADA) guidelines. By complying with the ADA and utilizing guidelines specific to the needs of residents, Clarkdale can improve equitable conditions for their population. The average age of a Clarkdale resident is 50+ years, so it is imperative to consider ADA guidelines in new construction for the health and well-being of residents.

According to the ADA and the needs of our park, accessible routes must have a running slope no longer than 1:20, meaning every one inch of height change should occur over a minimum 20 inches of length. Ramps, curb ramps, and ground surfaces are required to be stable, firm, and slip-resistant. Walkways with the greatest slopes should pitch downhill for drainage and a culvert can be used to help direct runoff in areas where it is not completely natural, providing the added benefit of reducing erosion. This can also be reflected in green infrastructure which can increase accessibility through cooling, potentially curtailing heat-related illnesses and maximizing the seasonality of trails. Due to the topography of the site, stairs may need to be considered throughout the park. Any stairs installed should be compatible with the class of trail they are associated with, and can be made of wood, stone, or concrete (U.S. Department of Agriculture, 2009). At the same time, there should be ramps adjacent to stairs where applicable to ensure maximum accessibility and coherence to ADA guidelines.

Figure 5 *Example of an accessible ramp alongside stairs at the Excursion Park entrance in Sea Isle City, New Jersey*

Shading and vegetation

Trails and outdoor structures should be built with ample shading in mind, to increase comfort as well as usability in the hotter seasons. This can be done with trees and native vegetation. Not only can they provide shade, but the evapotranspiration from these plants can provide a cooling effect and reduce the ambient temperature in the immediate area (Urban Climate Lab, 2016). Studies have shown that vegetative shading can reduce the temperature from 15 to 50 percent in buildings and that one hectare of healthy trees can store 2.6 tons of carbon each year (Yfantidou & Anthopoulos, 2017). Trees also enhance economic stability by increasing property value and can contribute to the town's tourist appeal. Shading can be accomplished through green infrastructure or man-made structures, such as ramadas, gazebos, picnic areas, and large umbrellas.

In addition to the human benefits, increased shading and vegetation also improve wildlife diversity by providing habitat for more birds and other animals, and reducing noise in the park. While a tree-planting initiative in the sustainability park will require long-term investment and maintenance, the subsequent benefits provide a high return by improving seasonality and comfort for visitors. More vegetation and shading in the park can also benefit environmental education by satisfying senses in terms of diverse shapes, colors, textures, sounds, and affective stimuli, which are all needed for environmental appreciation and conservation efforts (Yfantidou & Anthopoulos, 2017).

Figure 6 *Man-made structures such as shade sails (left) or natural shading through strategic landscaping (right) can help increase comfort of park visitors as well as increase habitat for native wildlife*

Environmental education

Education is another environmental feature that should be integrated into the park with maximum accessibility in mind, providing opportunities for diverse residents and visitors to learn about sustainability and the surrounding environment. The educational aspect must be synergistic with the park's design and features. One option is to design the park as an arboretum featuring native trees and plants. Placards can be installed nearby certain trees and vegetation to display information such as common and scientific names, native growing regions, medicinal properties, and cultural history. Placards or other signage can also detail the park's sustainability features, such as the green infrastructure, historic sites, and agrivoltaics. QR codes could be included that link to Clarkdale's website where additional educational resources can be found. This digital accompaniment can also serve as a virtual tour of the park that visitors can explore before even stepping foot on the site, further fulfilling the goal of wide accessibility. Over time, the park can continue to grow its accessibility resources by implementing sensory gardens and other centralized zones for blind, mute, deaf, and hard of hearing populations. Clarkdale could also collaborate with outside environmental organizations or work toward developing a mobile application to facilitate audio walking tours.

Editor's Note

Additional details and suggestions regarding environmental education opportunities are available in the Education and Transformative Learning section of this report, beginning on page 87.

Figure 7 *Examples of educational signage that could be incorporated in the sustainability park, including a pollinator habitat map (left), informational resources at a park entrance (center), and a plant identifier placard (right)*

Recommendations for community accessibility

- Map and record the current usage of existing walkways and trails before finalizing plans and constructing new paths in the sustainability park, in order to make informed decisions regarding new trail placement.
- Create mixed use trails and pathways in and around the park to support various activities such as recreation, hiking, and biking. Pedestrian and biking trails can be integrated with each other and include ample space for both activities.
- Plan some walkways as “out and back” trails, and others as loops, to allow for residents and visitors to choose which path best suits their physical needs.
- Examine the equity of trails and pathways, assess the distribution of facilities (like playgrounds), and predict usage based on the characteristics of the town and tourist population to make informed planning and construction decisions.
- Construct walkways, bike paths, and other infrastructure that is easily accessible to residents and visitors and complies with ADA guidelines.
- Shade pathways and facilities with native trees and vegetation, as well as green infrastructure or man-made structures, such as ramadas, gazebos, picnic areas, and large umbrellas.
- Provide opportunities for the park to be an educational experience. This can include placards and QR codes that explain vegetation names and details, park facilities and their uses, historic sites and facts. Leverage similar mechanisms, and other audio-visual or tactile features that make the park more accessible and inclusive.
- Highlight and respect the historical aspects of Clarkdale throughout the park, by focusing on revitalization of the town (while remaining true to its character) throughout the design and construction process.

GREEN INFRASTRUCTURE

Editor's Note
Original SWOT tables for each topical subcategory are available in Appendix B of the student content at **links.asu.edu/PCClarkdaleSustainability20F**

Green infrastructure (GI) is a water management system defined by the EPA as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters" (EPA, 2020b). GI reduces environmental impact where it is installed while being more cost effective when compared to traditional stormwater management systems. These more sustainable systems are important because they provide a number of ecosystem services to the local environment. GI is able to clean stormwater runoff, reduce the amount of pollutants absorbed into the ground, and minimize the chances of flooding by reducing the flow of water.

Figure 8 *Rain garden which captures stormwater runoff to support native plant landscaping*

Green infrastructure, such as the rain garden shown in Figure 8, is an important principle to consider for the sustainability park as it not only provides beauty and interest, but also valuable ecosystem services, and reduced stormwater management costs when compared to traditional systems.

Bioswales

Bioswales are a type of GI that can be used to facilitate interesting vegetation around the park while simultaneously offering important environmental services. Bioswales are constructed with native plants that are able to absorb stormwater runoff and help reduce the amount of erosion that occurs within the area (EPA, 2020b). Additional services this GI can provide include the reduction in pollution loads, purification of storm runoff as it is absorbed into the earth, and the slowing of water flow which provides more time for runoff to percolate and replenish underground aquifers.

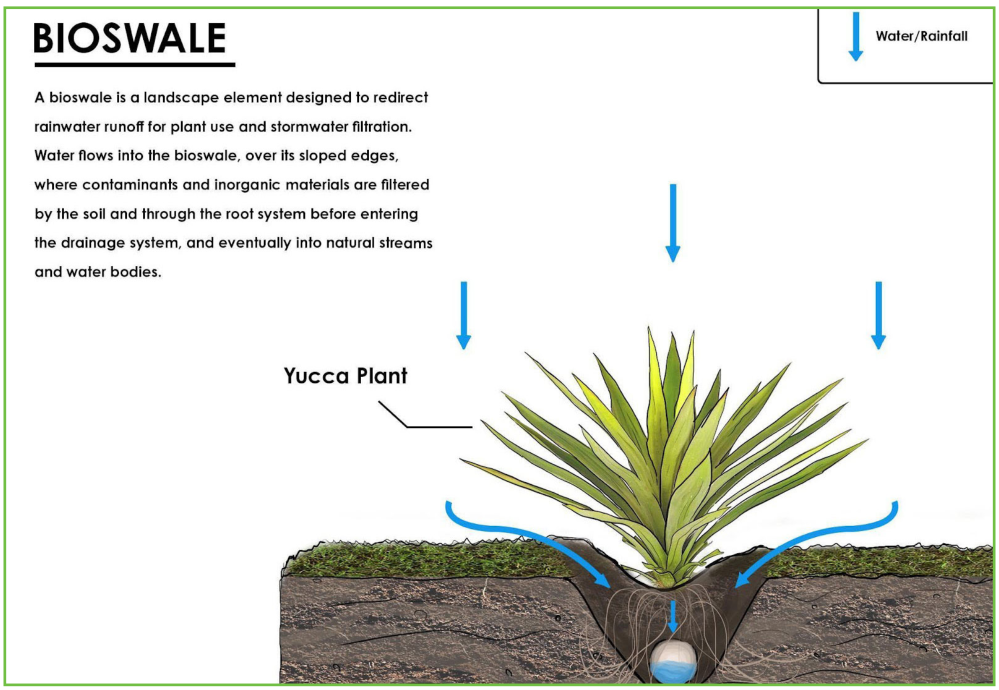

Figure 9 *Bioswale diagram illustrating the stormwater filtration process, by Walid Elkhatib*

Permeable pavement

Unlike traditional pavement materials, permeable pavement features voids within its structure that allow water to pass through. The water is then absorbed into the ground below, replenishing groundwater and reducing runoff. Permeable pavement comes in many forms including (but not limited to) specially designed pavers, concrete, and porous asphalt. Grid pavement systems are another way to include permeable surfaces at a desired location. By allowing water to pass through somewhat freely, these materials create a lower impact solution than traditional pavement (Sustainable Cities Network, 2019).

Permeable surfaces provide many benefits in their application, including the ability to absorb stormwater runoff and irrigation excess. This water absorption ability can render more traditional water collection systems unnecessary in some cases, and as a result, eliminates the need for investment in and development of said systems by the Town (Green Building Alliance, 2016). The absorbed water can then help recharge underground aquifers, which ideally would help provide the town with a more sustainable water source for the future, and lowering the possibility of future financial burdens associated with seeking new water sources.

Permeable pavement applications allow users to walk and ride bikes without impacting comfort or integrity of the structure (NACTO, 2020). The newer, plastic grid installations of permeable pathways are a strong option for the town to consider implementing, as they are less intrusive than laying concrete or asphalt, and more bicycle friendly than individual pavers. The LEED (Leadership in Energy and Environmental Design) rating system also encourages permeable pavement designs for their resilience and effectiveness (Green Building Alliance, 2016). Figure 10 displays just a few examples of the wide variety of permeable pavement solutions available today.

Figure 10 *Permeable pavement options can include plastic grid installations (left), "grasscrete" (center), or specifically designed stone installations, often installed on a sand-like substrate for maximum ground absorption (right)*

In addition to the water absorption benefits presented by permeable surfaces, they can also help lower the ambient temperature of their surrounding environment, subsequently facilitating a more pleasant experience for visitors. Studies have shown that a surface temperature difference of 20 degrees Celsius can be observed between traditional asphalt pavement and permeable options (Li et al., 2013). Lowering the surface temperature makes human comfort a priority by reducing the radiant atmospheric temperatures nearby the paved areas as well.

Lower temperatures can help provide a safer and more comfortable experience for diverse visitors of the park, including Clarkdale's older population. Focusing on comfort also increases the seasonality of the park, ensuring that pathways can be used throughout the year.

Permeable pavement is less efficient when installed on surfaces exceeding a 20% slope (Green Building Alliance, 2016). The increased slope allows water to pass over the permeable surfaces with minimal absorption. Ideally, park entrances would be designed with slopes below 20% to enable the successful installation of permeable paving. It is also recommended to restrict paths to pedestrians, cyclists, and occasional light duty maintenance vehicles, as permeable surfaces can be less effective if heavy duty vehicle traffic is present (Green Building Alliance, 2016). An important first step toward developing the park's permeable paving plan is to determine what types of vehicles will be necessary within the park, and within what areas, before choosing specific materials and installation locations. Water table levels should also be considered, as permeable surfaces are unable to effectively function if the area water table is within 0.6 meters of the topsoil. Permeable surfaces also allow sediment to collect within the voids in the pavement, and will require some maintenance once installed, typically consisting of occasional vacuuming to ensure optimal performance (Amekudzi, 2014).

Green infrastructure case studies

Monona, Iowa

Monona, Iowa has implemented permeable surfaces and other GI to help capture runoff and increase area water quality. The city of nearly 1,600 residents floods annually, and the previous infrastructure did a subpar job of alleviating problems associated with large amounts of stormwater (Biederman, 2018). The City was able to obtain federal and state loans and grants to assist in its installation of a new stormwater management system. The project first installed a new permeable paver parking lot in an area prone to flooding. The lot was designed with different colored pavers to make markings more permanent and reduce the need for future painting maintenance (Biederman, 2018). The successful installation and functionality of the permeable parking lot led the City to apply this technology to some of its streets. Monona also installed a crushed-stone base, which absorbs and slows the speed of runoff with the help of a gate valve system during larger rainstorms. The valve is able to be fully opened to help control the release of excess water. The base is designed to handle 100-year flood events, and to reduce the amount of flooding after extreme weather events (Biederman, 2018).

Clarkesville, Georgia

Another example of a small city that has implemented sustainable, green infrastructure to meet their specific needs is Clarkesville, Georgia. The City installed curbless bioswales near roadways and other high traffic areas, which capture storm runoff and filter water as it is absorbed into the ground. Bioswales also have the ability to reduce erosion in these areas as they lie below the surface that is experiencing the large influx of water runoff. The bioswales also add beauty and green space to the surrounding area (EPA, 2015). Interlocking pavers were also identified as a suitable strategy for dealing with runoff in Clarkesville's downtown area. The pavers were shown to be highly effective at absorbing runoff and reducing the amount of flooding experienced in the downtown corridor (EPA, 2015).

Key takeaways

Similar designs to those used in Monona and Clarkesville may prove useful in Clarkdale's sustainability park. Permeable surfaces help absorb and slow storm run-off, and a crushed stone base, as implemented in Monona, could improve the park's water management resilience and capacity. Permeable surfaces are also a low-impact solution, as it generally does not disturb the ecosystem at the same levels as traditional cement or asphalt. Many materials available to create permeable infrastructure are also able to reflect solar heat. For example, high albedo materials absorb far less solar radiation and can help mitigate the urban heat island effect that many cities are faced with.

Bioswales like those used in Clarkesville could be an excellent option to install in the sustainability park. In addition to their ability to capture water runoff and reduce erosion, bioswales can also perform bioremediation by utilizing strategic plant species that naturally clean the water they absorb by filtering out pollutants. The greenery and natural vegetation that can be used to construct these bioswales would add beauty and utility to the park for visitors to experience. The natural beauty of desert vegetation and the reduced impact to pedestrian infrastructure will highlight the park's sustainable design and ideally increase its attractiveness and usability.

Green infrastructure funding

Locating funding for the implementation of green infrastructure can be challenging, especially for smaller communities like Clarkdale. This section aims to overcome this hurdle by identifying multiple financial assistance options for the Town to take advantage of in the effort to implement green infrastructure throughout the sustainability park.

The Environmental Protection Agency (EPA) of the federal government offers low interest loans through the Clean Water State Revolving Fund (CWSRF) and other grant programs (EPA, 2019). CWSRF has been successful in funding projects in every US state and has provided over $68 billion in financial assistance since the late 1980's (EPA, 2008). A wide variety of stormwater management programs have been successfully implemented thanks to the funding options available through this program. Clarkdale would likely be able to implement green infrastructure initiatives throughout the park without the concern of having all funds available upfront, allowing the Town and visitors of the park to take advantage of the new infrastructure while giving the local government the ability to pay for the project over time.

Cities like Phoenix and Tucson have also been able to secure grants from the EPA to help fund the cleanup and conversion of contaminated lands (EPA, 2020a). These EPA grants could help remediate the environmental damage associated with the previous operation of the smelter in the vicinity of the sustainability park. Tucson has also been able to take advantage of grants offered through the Arizona Department of Environmental Quality (ADEQ), in one case using the grant to fund a green infrastructure project to mitigate problems associated with stormwater management in a specific neighborhood (Georgetown Climate Center, 2020). State level grants are another resource Clarkdale can use to finance many of the suggested amenities in the sustainability park plan.

The Water Infrastructure Finance Authority of Arizona (WIFA) also offers grant opportunities for communities seeking to implement water quality infrastructure projects (Water Infrastructure Finance Authority of Arizona). The website provides an application and lists the eligibility requirements for projects. This grant opportunity offers the town of Clarkdale another avenue for creating and funding sustainable water management practices within the park.

Final thoughts

Green infrastructure (GI) can provide the sustainability park with a host of benefits and strengths, including sustainable erosion control and stormwater management. Grey infrastructure (typical impermeable hardscape or paved infrastructure) and other traditional ways to combat environmental challenges can often be replaced or retrofitted with GI, such as bioswales and permeable pavements, as a more sustainable option.

Through the development of the sustainability park, Clarkdale has the opportunity to take advantage of the ecosystem services GI can provide, while avoiding the problems that arise with traditional grey infrastructure. The strengths and benefits of GI are vital to helping the Town meet its commitment to sustainability.

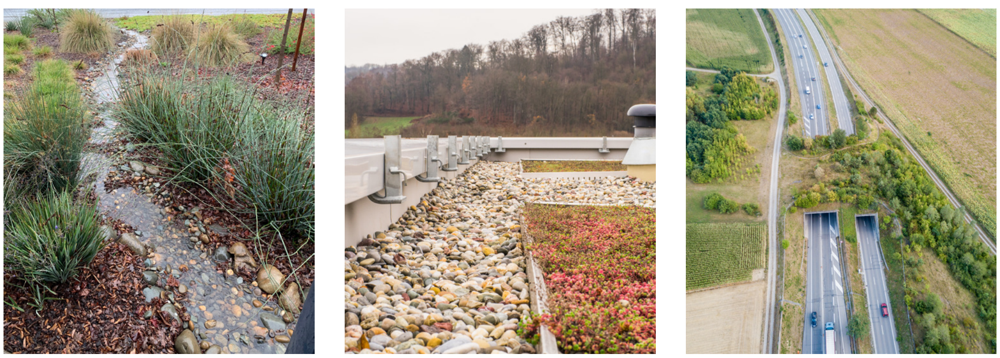

Figure 11 *Green infrastructure examples including a bioswale (left), a greened roof with gravel drainage (center), and a highway wildlife overpass (right)*

Recommendations for green infrastructure

- Construct bioswales with native vegetation to absorb stormwater runoff, reduce erosion and pollution, facilitate stormwater percolation, and beautify the park with native vegetation.
- Create trails and pathways with permeable pavement. This allows for water to percolate through the pavement, increases groundwater absorption, and lowers the ambient temperature of the park.
- Seek funding for green infrastructure initiatives through various loans and grants through relevant entities such as the EPA, Arizona Department of Environmental Quality (ADEQ), and Water Infrastructure Finance Authority of Arizona (WIFA).

MICROMOBILITY

Editor's Note

Micromobility is often defined as using lightweight, individual vehicles such as bicycles and scooters to travel short distances in an effort to reduce reliance on personal automobiles. This movement is often associated with small electric vehicle rental services such as Lime e-scooters and bike share.

Editor's Note
Original SWOT tables for each topical subcategory are available in Appendix B of the student content at **links.asu.edu/PCClarkdaleSustainability20F**

E-scooters

From large cities to small towns, electric scooters, or e-scooters, can help people navigate to their destinations in a fun, affordable, and sustainable way. As their popularity rises, e-scooters are contributing to a new era of the Micromobility Movement. Sustainable development aims to make visitor experiences as convenient and comfortable as possible, and e-scooters help realize this goal. However, there is a concern with the older age demographics that predominantly live in Clarkdale. According to the World Population Review, as of early 2020, there are 3,834 adults who permanently reside in Clarkdale, 1,659 of which are senior citizens (World Population Review, 2020). One of the sustainability park's main goals is to be inclusive to all ages so that everyone may enjoy the park's amenities. E-scooters may not be high on the residents' priority list, but they can attract and influence a new, dynamic demographic.

Figure 12 *Bird and Lime brand e-scooters, which function and charge customers through mobile applications*

E-scooters would also generate additional income for the Town which can be funneled back into the community for micromobility program improvements or alterations. As stated in the Town's *Design Principles and Guidelines* document, one of Clarkdale's economic goals is to advance tourism opportunities. As demonstrated in large metropolitan areas, e-scooters are generally appealing to travelers and could encourage tourists to stay in the sustainability park and surrounding areas for a longer period of time. The average rider uses a scooter for 16 minutes, which equates to approximately $3.50 per ride, though the cost per minute does vary depending on the selected scooter company (NACTO, 2018). It should be noted, however, since Clarkdale is not a large metropolitan area the revenue generated will differ from other city's projections. Moreover, Clarkdale should consider the initial investment and ongoing maintenance costs of the scooters before moving forward with their implementation.

E-scooter integration

A possibly significant concern surrounding e-scooters is the potential to become a nuisance and create disarray in Clarkdale's peaceful town. Many cities have experienced an abundance of reports regarding abandoned and broken e-scooters, in turn feeding a negative perception of the devices. To curtail this, the proposed sustainability park plan features several charging banks to keep the park's scooters appropriately stored. Ideally there would be one charger at every entry point of the park, as well as a few strategically placed within the 100-acre area. Studies have also shown when scooter companies require users to take a photo of the device's final location for verification purposes, there is a significant decrease in scooter misplacement, and an increase in overall care (Irfan, 2018). To further contain the scooters to the site, there should be a service boundary in place which surrounds the sustainability park, confining the devices to the area and keeping the rest of town a scooter-free zone. The primary reason for this containment is to keep the rest of the town unaffected by any additional traffic and congestion caused by the scooters. Dual lanes are also suggested to be integrated into the final park design to minimize the possibility of a collision between a pedestrian and an e-scooter rider.

Whether a town or city accepts e-scooters is a matter of how they integrate them into the public. To be successful, integration of these scooters should be informative and transparent. On average, there is a 70% acceptance rate for scooters. The remaining 30% of the people who disapprove are usually concerned with how others interact with the scooters, rather than the scooters themselves (Irfan, 2018). With a slow integration process and sessions on adequately using the scooters, there is a higher assurance for appropriate usage and acceptance in general. Accomplishing this first will create a positive community mindset on how to treat the scooters, which in turn can demonstrate to visitors how to interact with the scooters.

Integrating e-scooters into the sustainability park can contribute to an environment of new and efficient innovations. The entire micromobility movement has sparked a conversation around different ways to regulate devices like e-scooters, “including geofencing, zoning, mandatory data sharing, and mandatory cooperation” (Fearnley, 2020). Whether people are for or against e-scooters, there is no denying that this once niche marketplace is working its way into the spotlight. The presence of this technology alone allows for people to think beyond their daily transit norms and drive their community to make advancements as they see fit.

E-scooter data and statistics

Given the fact that e-scooters are a relatively recent phenomenon, comprehensive data surrounding their use is minimal. However, the micromobility movement as a whole does have an abundance of user and company feedback. Currently, one complaint surrounding e-scooters is the "dockless" option, which does not hold users accountable for where the device ends up after its use, and tends to create a mess. However, when manufacturers made it mandatory for users to photograph the end placement of scooters, the “littered” complaints decreased significantly while proper order increased to 97%: "Only 3% of scooters were parked on unpaved surfaces, such as vegetation or bare dirt. Though these scooters did not block the pedestrian flow, such parking raises questions about aesthetics and the impact on landscaping" (Fang et al., 2018). Even though this is a significant concern for larger cities, the enforcement of end placement pictures and designated "recreation" lanes can help communities reclaim their walkways and address safety concerns.

E-scooter job creation

Introducing e-scooters into Clarkdale's sustainability park will also bring new job opportunities to the area. When e-scooters run out of charge, they need to be delivered to a recharging facility. Workers who carry out this task for the company Lime, are casually referred to as "juicers" and can earn an average of $5 per returned scooter, though this rate may vary between companies (Lime, 2020). This job is also limited to people aged 18 and older who possess a valid driver's license.

Unfortunately, throughout the COVID-19 pandemic there have been no predisposed jobs to sanitize the scooters. During this time, e-scooter usage has generally declined. To combat the drop in revenue, several e-scooter vendors have applied upcharges to their services. At the time this report was written, it was determined that shared electric scooters may need to be reconsidered at a later date in order to avoid high implementation and service costs associated with the pandemic.

Solar golf carts

A safe and potentially more comfortable option to encourage micromobility in the area, especially for Clarkdale's senior population, is public golf carts. While ready-made “solar carts” are not currently manufactured, electric golf carts can be fitted with specific solar panels on their roofs to capture and store energy. The potential solar power feature of these vehicles aligns well with the sustainability goals of the park, while also serving as a more accessible micromobility option for anyone who finds e-scooters uncomfortable to ride. Additionally, the intended layout of the park allows for non-disruptive use of scooters and golf carts alike, with designated lanes to separate these amenities from pedestrians.

Figure 13 *Solar powered golf carts, by OkSolar*

A standard two-passenger electric golf cart can generally cost between $5,000 to $7,000 each. Alternatively, used electric cart prices can range from $2,500 to $5,000 (Rosen, 2020). Electric carts without solar panels could conveniently charge overnight using electricity generated by the suggested solar array on the park's north side. This area can also serve as the designated parking and charging place for the carts. The golf cart compatible solar panels that can be added to existing electric carts typically cost anywhere from $650 to $850 (Enervolt, n.d.). The overall benefit of adding solar panels to the golf carts includes an increase in life usage and ability to charge while in use: "The average golf cart takes around 7000w to 9000w to fully charge from a low battery state. This means it costs around 70 to 90 cents to charge a golf cart from empty" (SolarGreenCompany, 2013). The addition of solar panels can prolong the range and life of golf cart batteries, and is a low-cost investment that can save thousands of dollars annually when compared to purchasing a standard gas-powered golf cart.

Micromobility funding

Acquiring funding can be a significant obstacle for public works projects, and in some cases halt progress altogether. Thankfully, Arizona State Parks & Trails offers grants up to $10,000 per project, if selected. The office holds monthly workshop meetings and attendance of at least one workshop is mandatory before submitting an application for funding. Their website indicates the requirements for the grant and other programs (Arizona State Parks & Trails, n.d.).

In addition to the Arizona State Parks & Trails grant, the Federal Transit Administration awards various grants that aid in the process of attaining e-scooters and solar golf carts. Grant types range from competitive to a formulaic selection. Clarkdale is encouraged to apply for a variety of these grants. Some grants that may be of interest include, but are not limited to, Flexible Funding Programs - Surface Transportation Block Grant Program - 23 USC 133, Metropolitan & Statewide Planning and Non-metropolitan Transportation Planning - 5303, 5304, 5305, Mobility on Demand (MOD) Sandbox Demonstration Program - 5312, and Zero Emission Research Opportunity (ZERO) (Federal Transit Administration, n.d.).

Final thoughts

It is imperative to serve multiple demographics through micromobility efforts, including Clarkdale's sizable senior demographic. In order for the park to increase tourism activity in the town, its amenities should be widely accessible regardless of age or ability. "There must be a conscious effort to utilize partnerships and thoughtfully analyze data to ensure transportation professionals are getting it right" (Stowell, 2020). Many efforts to promote equity start in the planning process prior to implementing scooters or golf carts in real-time. Hiring a company that focuses on urban planning rather than earning a profit is vital to securing longevity and higher assimilation rates.

Figure 14 *Multi-use path being utilized by bicyclists and scooter riders*

Recommendations for micromobility

- Allow e-scooters in the park to allow for easy access throughout the park area. In addition to the enhanced micromobility the scooters provide, they can also be a point of entertainment or recreation for visitors and make the park more memorable.
- Install e-scooter charging ports in strategic locations around the park to store scooters in accessible places and avoid cluttering or abandonment of equipment.
- Consider providing golf carts as another micromobility option to navigate the park, particularly for Clarkdale's older demographic and others with limited mobility.
- Fit provided golf carts with solar panels to increase battery life, decrease charge time, and contribute to the park's overall sustainability.
- Explore different funding sources which may help offset costs of micromobility initiatives, such as Arizona State Parks & Trails, the Federal Transit Administration, and other statewide funding.

EDUCATION AND TRANSFORMATIVE LEARNING

The Town of Clarkdale is keen on preserving their rich history and incorporating it into the design of the sustainability park. To do this effectively, the Town of Clarkdale can benefit from four focal points which are to incorporate *Transformative Learning, Action Based Learning, Partnerships with Local Conservation Organizations,* and the recognition of *Place-Based Systems*.

Editor's Note
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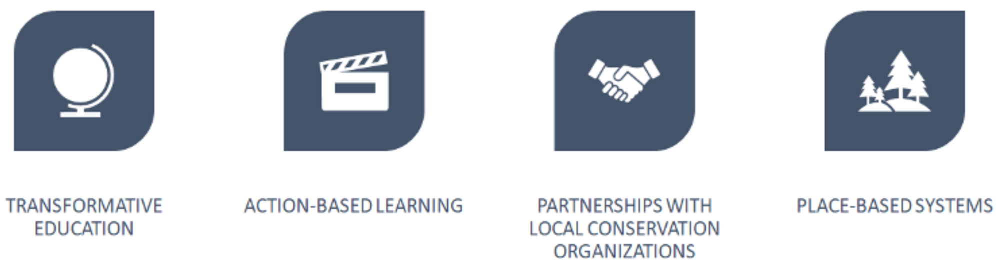

***Figure 15** Key focal points to incorporate via transformative learning, by William Walker VI*

Organizational partnerships

Environmental education is imperative to the synergy of the sustainability park and must be included in the overall design in order to be effective. Furthermore, the sustainability park will thrive in its education sector if there are strong partnerships between the Town of Clarkdale and local conservation organizations. In Northern Arizona, several different relevant organizations exist, such as the Sierra Club Grand Canyon Chapter, The Nature Conservancy, Arizona Conservation Corps, and the Arizona Conservation Experience (ACE). These organizations can potentially offer beneficial feedback and educational resources, such as suggested seasonal additions to the park (e.g., plants or exhibits). They may also be able to communicate which environmental decisions are integral to the park's success to ensure long term sustainability.

Case study: Tres Rios Wetland

Partnerships should be mutually beneficial and solve a challenge that each stakeholder faces. In Clarkdale's case, the challenge is to provide a community space focused on sustainability, tourism, and environmental protection. The park also aims to help restore the natural ecosystem which faced environmental degradation from past industrial processes.

Similar efforts have been seen in the West Valley at the Tres Rios wetland. A former agricultural field, the wetland has been engineered by the City of Phoenix to create a riparian habitat adjacent to a wastewater treatment plant. Phoenix partnered with several organizations to build the wetland, including the EPA, U.S. Army Corps of Engineers, and the Sonoran Audubon Society, to create a strong ecosystem with flourishing biodiversity.

Figure 16 *Aerial view of the Tres Rios Wetland as seen from the northwest*

Tres Rios was created with three central purposes in mind, including flood control, habitat restoration, and recreation and environmental education. The plant and animal communities have thrived in this constructed ecosystem, as the wildlife uses the plants as habitat, and the plants use the animals to disperse their seeds. As the ecosystem is composed of native plant species, they can grow and sustain the animals for generations (City of Phoenix, 2020). Clarkdale could also benefit from partnering with organizations such as the EPA to aid with planning and construction of micro habitats throughout the park. A constructed wetland could provide an attractive environmental learning opportunity that fuels engagement from visitors looking to learn more about Northern Arizona's ecological features. Able to function as another outdoor tourist attraction, the installation could also help further stimulate the local economy.

Local school engagement

The sustainability park could serve as an educational resource for local schools throughout Northern Arizona. Accessible design makes the park an ideal destination for students, staff, and faculty at various institutions to learn more about urban conservation, agriculture, sustainability, and the environment, if partnered with the right organizations. This can be exemplified through the construction of an educational center that talks about the rich mining history of Clarkdale juxtaposed with the Towns sustainability leadership. The center could be modeled after a museum or visitor center, featuring self-guided tours and exhibits about the town's mining history and the construction phases of the sustainability park. It could be beneficial to thoroughly document each phase, such as the breaking of the ground, the construction of the trails, and installation of features. Supported by the presence of an educational center, the park can engage in action-based learning where visitors physically engage with the park's features like that of a National Park or museum.

Figure 17 *Outdoor educational center in the Scottish North Highlands*

Education through sense of place

Sense of place, in an environmental context, refers to how a place is perceived, and the lens through which people experience something. Sense of place is located at the "...intersections of culture, environment, history, politics, and economics, and is impacted by global mobility, migration, and blurred boundaries between the natural and built environment" (City of Phoenix, 2020). It also raises questions such as "What kind of place is this? What does this mean to you in a social, cultural, or environmental context?", and gives agency to visitors by asking them "What does this make you want to do or feel" (City of Phoenix, 2020)? A vivid sense of place can be fostered in the park as residents and visitors are given a chance to learn about the complex ecologies and systems present in their own backyards.

Final thoughts

The ecological and biophysical elements that comprise any given ecosystem are unique, and environmental education provides additional ways to protect and sustain these elements for future generations. By employing strategic partnerships, learning opportunities can be maximized through a variety of resources, such as seasonal teaching by park rangers about land use management, land stewardship, restorative experiences in nature, and local ecology. These are all forms of experiential and transformative learning, which are key contributors to fostering environmental appreciation. Environmental education is diverse, and can also take place through storytelling, communication from environmental leaders and community members, student narratives, and ultimately asking questions (City of Phoenix, 2020). Clarkdale can tap into these storytelling principles through the educational center, and by recruiting historians and public servants of the community to curate the history of the Town throughout the park, whether it be through events, exhibits, or annual gatherings.

Recommendations for education and transformative learning

- Continue preserving Clarkdale's history and culture by incorporating it into the park through the four educational focal points: Transformative Learning, Action Based Learning, Partnerships with Local Conservation Organizations, and Place-Based Systems.
- Partner with local environmental organizations, such as Arizona Conservation Corps, which may be able to offer beneficial feedback and educational resources regarding the park.
- Engage with local schools by constructing an educational center modeled off a museum or visitor center. Potential topics taught at the educational center can include that area's mining history, and the construction phases of the park. This will allow visitors to physically engage with the park's features, similar to a National Park or a museum.
- Foster a sense of place at the park by giving residents and visitors a chance to learn about the ecosystems, histories, and cultures in their own backyard. This can be done by hosting community events, exhibits, and annual gatherings in the park.
- Draw upon the town's own residents to develop sustainability education programs for the park.

COMPOSTING

Food waste and other organic wastes are a major issue in sustainability. Though Clarkdale offers yard waste pickup, a profitable solution to manage other forms of organic waste has not yet been actualized. The sustainability park has the potential to change the way Clarkdale manages their organic waste stream while simultaneously reducing the costs associated with waste management. A composting center in the park would not only provide a cost-effective way to process organic waste, but could also be an extraordinary way to engage visitors on the fundamentals and benefits of different composting methods.

Editor's Note
Original SWOT tables for each topical subcategory are available in Appendix B of the student content at **links.asu.edu/PCClarkdaleSustainability20F**

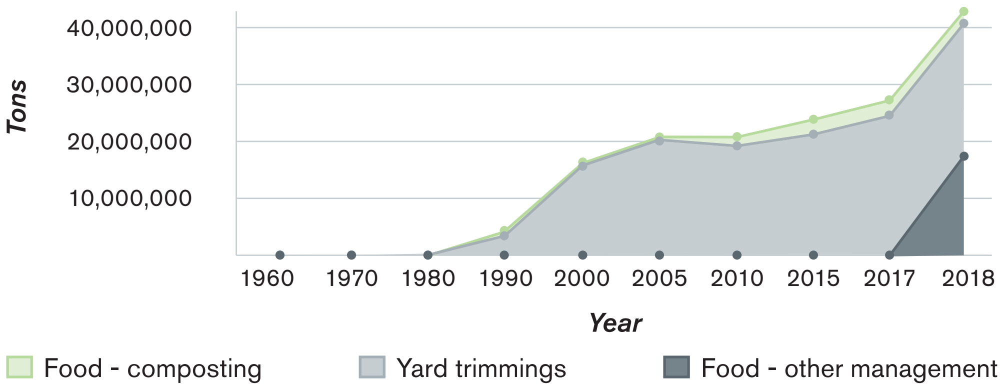

Figure 18 *Composting and other food management tonnages 1960-2018, illustrating an increasing national trend of composting, by U.S. EPA*

The composting center could be implemented in three distinct phases based on the growth of the program and interest shown throughout the community. The three phases include conventional composting utilizing the three-bin method, continuous flow-through vertical vermicomposting, and lastly producing vermicompost tea to use in the hydroponic garden and for potential retail opportunities.

Editor's Note

Due to the extent of specialized knowledge required, it may be helpful to seek out professional or expert assistance for the early planning, development, and implementation stages of building a local composting program.

Conventional composting: Three-bin method

To initiate community composting, it is crucial to start small and build worker or volunteer knowledge before expanding the capacity of the composting center. In phase one of the composting initiative, a three-bin method could be utilized. The three-bin method requires a specific process to be executed in order to achieve quality and fully "cooked" soil.

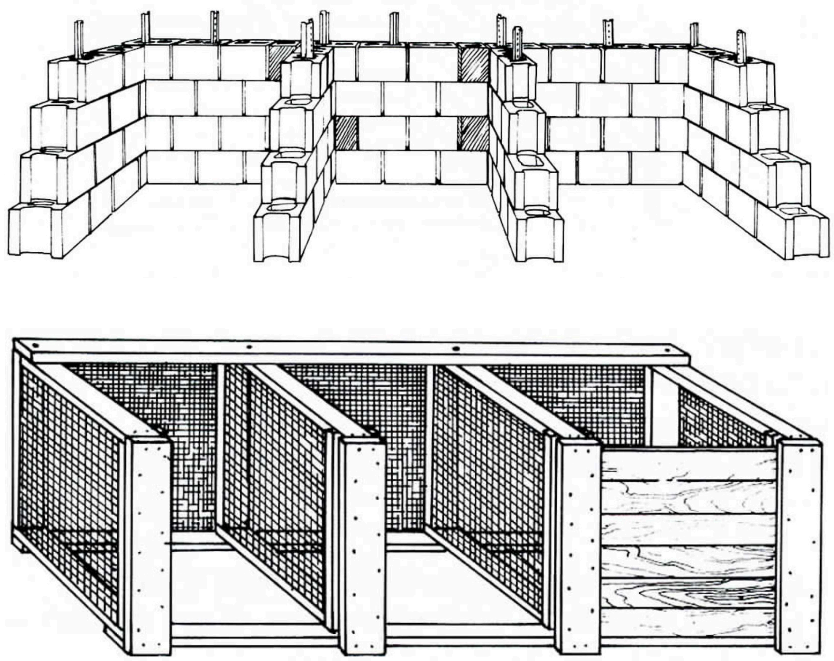

Figure 19 *Two common styles of composting using the three-bin method, cement block (top) and wooden with screens (bottom), by Dickson et al., 1991*

Organic waste sourcing, preparation, and common problems

In order to effectively gather organic waste, strategically positioned compost bins could be placed along the park's hiking trails, within leisure areas, and near buildings such as the visitor center. These bins can collect plant-based food waste and paper waste products only. Meat and dairy items should be discouraged from depositing in the three-bin compost setups, as they can be more difficult to compost and pose the risk of pathogens entering the soil. Meat and dairy could instead be collected and utilized in the suggested bio gasification facility detailed later in this report. The park's composting facilities could also help divert some green organic waste from the residential bulk pick-up program, to help obtain the high carbon materials needed for composting.

The first bin in the three-bin process, is referred to as the "compost preparation" and functions ideally when a certain ratio of "green" to "brown" organic waste materials are added (UCCE, n.d.). Green material refers to items that are high in nitrogen such as manure, fruit waste, vegetable peels, and general plant-based food waste. Brown materials refers to items high in carbon such as shredded cardboard, wood chips, and saw dust. Generally, a 1:30 ratio of green to brown material is advised, however, compost recipes frequently require adjustments and experimentation based on their components.

Editor's Note

In practice, it can be virtually impossible for municipal-scale composting operations to attain an exact 1:30 nitrogen-to-carbon ratio, due to the unpredictable nature of the inputs from the public waste stream. Since composting operations require high levels of carbon-heavy inputs, the Town may consider identifying large-scale suppliers of organic waste products that would otherwise be discarded, such as spent grain from breweries or sawdust from workshops.

Process

In the first bin, begin by layering carbon and nitrogen materials, ensuring all food waste is completely covered to deter pests. It is recommended to water the pile while layering to ensure adequate moisture throughout. The size of the pile should be at least 3 feet in diameter to generate enough heat to kill pathogens. Only add new waste to the first bin and aerate the pile each time waste is added to help accelerate decomposition. When adding new waste to the first pile, mix the material thoroughly, moving "exterior" waste to the "interior" and vice versa, to ensure all waste receives equal amounts of external air flow and internal heat throughout the process.

Editor's Note

A student in the Composting group had professional experience working in the composting industry, and drew upon their prior knowledge of composting for some of the information in this section.

Temperature and moisture are two critical elements of composting that must be monitored carefully throughout the entire process. The pile should never be soaking wet or completely dry at any time. If the pile remains dry for too long, it can turn anaerobic, killing the beneficial bacteria and slowing decomposition. If the pile is excessively odorous, it could indicate too much moisture or a surplus of nitrogen-rich materials (Mitchell & Says, 2019). To address this issue, add more brown materials to the pile and turn it thoroughly. Some of these issues can be prevented by covering the three-bin compost station overhead to limit excess rainwater from soaking the compost.

Compost thermometers are key to monitoring pile temperatures and ensuring the compost is consistently generating proper heat levels. The ideal interior temperature of a compost pile is around 150 degrees Fahrenheit (Earl, n.d.). If the pile is below 135 degrees, harmful pathogens and weed seeds will not be killed. Additional nitrogen-rich materials can help if the pile is consistently not reaching an adequate temperature. If nitrogen materials do not raise heat levels, the compost could be lacking microorganism activity. If this occurs, it may be helpful to add completed compost to jumpstart microbial activity (Plant Natural Research Center, 2019). If the compost pile is too hot (over 160 degrees) beneficial microbes begin to die. To curb this, turn the pile and add more carbon material. The pile should reach 140-150 degrees internally by the end of the first stage, which indicates it is ready to move to the second bin for further decomposition or “cooking” (McDowell, 2008).

Cooking, monitoring, and machinery

When the first bin is ready to be transferred to the second bin, it is important to thoroughly mix the contents to further aerate the pile. If the bin is small, a pitchfork can be used to transfer and mix the materials. More substantial piles could utilize a small bulldozer to simplify the turning and transfer process, while saving time and energy. Purchasing this equipment could come at a later date, as the size of the composting operation expands. Purchasing a small sized, preowned dozer could cost between $2,500 to upwards of $13,000 depending on the size, brand, and model (Crawler Dozers & Loaders, n.d.). Another piece of equipment to potentially consider at a later stage is an industrial shredding machine. Utilizing a shredder can help decrease the amount of time taken to produce fully finished compost as the surface area of the added materials is increased (Goldowitz Jimenez, 2020). Industrial food waste shredders can cost between $5,000 to $15,000 depending on the size and capacity of the machine (Compost Shredder Machine for Sale, n.d.).

After the material from the first bin is moved to the second bin, new material can then be added to the first pile, thus initiating the process over again. To expedite the decomposition process in the second bin, refrain from adding new waste to the second pile after the first pile has been fully transferred. The second pile can take anywhere from a few weeks to many months to reach a substantial level of decomposition. The size and recipe of the compost pile heavily determines the rate of decomposition and maintenance required (3 Bin Compost System, 2020). It is recommended to monitor the moisture and temperature of each pile daily to ensure any corrective measures are taken in an appropriate amount of time. After the necessary time, food waste in the second pile should be mostly unrecognizable, at which point it can be transferred to the third and final bin. As compost is added to the final bin, it is once again turned, further aerating the mixture. During the last stage, conditions (i.e., temperature and moisture) should continue to be monitored so corrective actions can be taken accordingly. In the final stage of the three-bin method, compost should appear dark brown, rich in color, have no unpleasant odor, and not contain any recognizable food scraps. When the pile fulfills this description, it is considered finished compost. The finished compost or soil can then be utilized in the community garden to grow nutrient-dense, organic produce, or in the vermicomposting area.

Vermicomposting

Vermicomposting is the process of using earthworms to decompose organic matter and turn waste into nutrient-dense soil amendments (Working Worms, n.d.). Vermicompost is the finished product of this process that includes composted food waste, worm castings, and worm bedding. As worms digest organic material, they secrete waste which is referred to as worm castings. Worm bedding refers to the high carbon material worms require in their habitat in order to thrive. Proper bedding provides a temperate, aerated, pH neutral, moist environment, and helps ensure the worms have a safe retreat if other areas of their habitat degrade (Madsen, Richardson, & Powney, 2020). When constructing worm bedding, it's recommended to include a variety of materials, which ultimately results in a greater mix of nutrients, thus improving the quality of the product. The most popular species of worms for vermicomposting is the Eisenia foetida, commonly referred to as Red Wigglers (Figure 20). Red Wigglers are highly valued composting worms that have a high reproductive rate, capable of tripling their population in only 12 months (Aalok, Tripathi, & Soni, 2008).

Vermicompost adds many beneficial attributes to soil health, including increased moisture infiltration and permeability, soil nutrient retention, microbial activity, and the ability to act as a pH buffer What Are The Benefits, n.d.). Vermicompost has notably higher levels of micronutrients compared to traditional compost, and is associated with enhanced germination, plant growth, and crop yield, as well as improved root growth and structure. Practicing vermicomposting can also help break down harmful pathogens in soil as the worms filter the soil via biological processes.

Figure 20 *Red wiggler worms commonly used in vermicomposting (left) and valuable worm castings which can be used to brew "worm tea" (right)*

Continuous flow-through (CTF) method

In conjunction with the three-bin composting method, finished compost could be used in a continuous flow-through (CTF) vermicomposting system. Though using finished compost is not necessary to practice CTF vermicomposting, it can help accelerate the time needed to harvest castings from vermicompost. A CTF system works with earthworms' natural instincts to decompose waste in the topsoil. As the worms digest organic matter they travel vertically and leave behind their castings. As the worms eat, more compost or food waste is added to the top of the composter and reinforces the cycle. As time progresses, castings are pushed to the bottom of the compost receptacle where they can be harvested (The Daily Gardener, 2020).

Michigan Soil Works technology

Michigan Soil Works (MSW) is an innovative worm farming company that sells high-quality medium to large CTF vermicomposting systems (Michigan SoilWorks, n.d.). MSW offers modular designs with four different system sizes. This includes expansion modules to fit every composter's needs. The vermicomposters are made from high-density polypropylene for long term durability, and come with a stainless steel cutting bar to help easily harvest castings from the bottom of the device. All models except the most basic model also include motorized drivetrain for easy operation. The single module motorized drivetrain model (Figure 21) currently costs $6,795 and occupies 32 square feet. Depending on the feedstock, weekly output can reach 160 pounds of vermicompost from an input of 200 pounds of organic waste. In a single year, a one module system can produce 8,700 pounds of vermicompost. Notably, adding non-composted food waste will reduce output by approximately half, so using finished compost in this system is the most efficient way to utilize it. The addition of worm bedding can also reduce output by up to ¼, however, bedding in a vermicompost system is paramount to provide worms with adequate habitat, moisture, and temperature. MSW reports an average payback time of only 16 months for its modular systems, with larger systems having an even shorter payback time.

***Figure 21** Michigan Soil Works CTF vermicomposting modular setup, by Michigan Soil Works*

Vermicompost products

The end product of the MSW CTF system is quality vermicompost that can then be screened for worm castings. The screening process can be operated by hand or with the help of an electric sifter. The Brockwood sifter is a semiautomatic worm sifter that separates vermicompost so pure worm castings can be extracted from the mix. It is also useful in separating out worms, cocoons, and other organic waste. The Brockwood worm sifter currently retails for about $2,900 (Hopkins, 2018). This investment could be considered at a later date as vermicomposting operations and output capacity are expanded.

Another valuable interest for the vermicomposting center could be investing in machinery used to create “worm tea”. Worm tea is essentially worm castings brewed in water to be used as liquid fertilizer for plants. In some cases, additional nutrients are included to maximize microbiological activity and the health benefits to plants. Creating worm tea can be accomplished simply by soaking collected worm castings in a gallon of water, or can become as complex as using industrial sized brewing equipment and aerators to create the highest quality worm tea for a large operation.

The Vital Tea Brewer by Vital Garden Supplies is a very good tool for medium to large vermicompost operations. The most basic model features a 75-gallon brewing capacity and currently costs $1,500 (Dripworks, n.d.). Though a substantial investment, quality worm tea has the potential to generate substantial profits. Currently, the Arizona Worm Farm in Phoenix sells 1 gallon of worm tea for $9 (Products, n.d.). Worm tea created at the sustainability park could potentially be sold to visitors as they tour the composting facilities and become interested in trying out the benefits of vermicomposting in their own homes. The worm castings and tea could also be used in the suggested community garden and hydroponic greenhouse.

Figure 22 *Additional vermicomposting products that could be useful, especially as operations scale, including the Brockwood worm sifter (left) and Vital Tea Brewer (right)*

Educational and tourism opportunities

There are numerous ways Clarkdale can facilitate memorable and impactful experiences for park visitors. The composting center in conjunction with the community garden (detailed in the following sections) could offer Clarkdale residents the special opportunity to actively participate in a community composting program that teaches invaluable skills on how to maintain a compost yard. The composting center could also offer tourist hands-on learning experiences through demonstrations and classes on the fundamentals and benefits of at-home composting. For a small fee, the classes could also provide starter materials necessary to build worm composters, thus generating more revenue to finance the program.

Editor's Note

Arizona Worm Farm is an active example of encouraging at-home vermicomposting through their classes and starter kits. More information on this organization can be found at www.arizonawormfarm.com

The composting center is intended to have a lasting impact on visitors, as they leave the park with the notion that composting does not have to resemble its less than ideal stereotypes. The ultimate message being that composting does not have to be complicated, unpleasant, and practiced only by the agribusiness industry. At-home composting can produce positive environmental impacts and reinforce the importance of organic farming methods.

Case study: Cost analysis of composting

In 2014, the University of Minnesota-Morris (UMM) conducted a cost-benefit analysis of their composting program over a 9 month period. UMM implemented a composting program using the windrow method, which uses rows of compost, as opposed to three separate piles, for rotation. Generally, the windrow method has a lower upfront investment cost but requires more labor to turn the compost (Beattie, 2014). Windrow composting can also be used to compost animal products, though this adds the risks of excessive odor and pathogens entering the soil if the composting is not properly executed. For the basis of this report, only the cost benefit of UMM's waste disposal and carbon dioxide emission reduction will be analyzed.

UMM stated 1 ton of organic waste disposal in their city costs the university approximately $280 due to hauling (Beattie, 2014). Over the 9 month period, the university claimed to have diverted 14,009 pounds or 20.25 tons of organic waste by using their composting program. This resulted in avoiding almost $5,700 in waste hauling fees over nine months, or over $6,100 per year. UMM also reported that a reduction in approximately 2 metric tons of carbon dioxide was a result of their composting initiative compared to their traditional method of waste disposal of incineration.

Editor's Note

The City of Phoenix's Compost Study may also be useful to investigate, especially considering the climate similarities between Clarkdale and Phoenix. For more information, visit **https://www.phoenix.gov/publicworks/phx-compost-study**

Funding opportunities

Grant opportunities could be extremely beneficial in ensuring the successful implementation of the proposed initiatives. The Urban Agriculture and Innovative Production (UAIP) Competitive Grants Program is one potential avenue of financing. This competitive grant offered by USDA has 3 million dollars allocated to supporting urban farming projects (Farm Service Industry, n.d.). This includes start-ups of community gardens to help stimulate the local economy, increase local food access, and provide education to urban gardeners.

USDA Rural Development also offers funding for food waste reduction projects. The Waste Management Grant Program provides funding for communities of less than 10,000 people. The program's goals are “reducing food loss and waste to divert food waste from landfills, improve overall food security, and secure natural resources” (USDA Rural Development, 2016).

Recommendations for composting

- Install multiple waste bins for food and other organic waste around the park to minimize litter in the area.
- Initiate composting efforts with a conventional three-bin system. This will help residents learn about basic composting while ensuring the efficacy of the park's compost system.
- Explore vermicomposting options as a way to expedite the decomposition process while generating compost with higher nutrient levels.
- Implement the vermicompost system via the Continuous Flow-Through (CTF) Method, which stacks compost vertically, thus allowing earthworms to follow their instinct to crawl upwards to decompose topsoil waste.
- Use the valuable end result and byproducts of the vermicomposting process, such as nutrient-dense compost, worm tea, and worm castings, in other park efforts such as the community garden, or to sell to visitors.
- Once established, offer composting classes for a small fee to help generate revenue for the town and interest in the sustainability processes of the park. These classes can also help spread the idea that composting is simple and can be done at home.

HYDROPONICS

Editor's Note
Original SWOT tables for each topical subcategory are available in Appendix B of the student content at **links.asu.edu/PCClarkdaleSustainability20F**

With the construction of the sustainability park in Clarkdale comes many opportunities for the town and its residents. The park has the potential to improve both the environment and the economy of the community. The park as planned in this report can help remediate a former mining site and revitalize a stalled tourism industry, propelling Clarkdale into a similar position as the neighboring towns of Jerome and Cottonwood.

This section of the report specifically explores how hydroponics can be implemented in the park. Hydroponic gardens are not only sustainable, they are also beautiful, educational, and fun. The idea behind hydroponics is very simple. Rather than growing plants in the traditional soil-in-ground manner, plants can be started and grown in nutrient-enriched water. Soil holds nutrients and plants statically in place. Alternatively, hydroponics allows for delivery of nutrients directly to the plant's roots without the necessity of filtering through soil to obtain said nutrients (mainly nitrogen, phosphorus, and potassium, among others). While hydroponics can get complicated, there are passive forms of hydroponic agriculture that are inexpensive and simple to learn and maintain.

Environmental issues associated with typical modern agriculture make hydroponics an important endeavor to consider implementing. Massive monocultures, pesticide and herbicide use, toxic runoff, and carbon emissions are just some of the negative effects on the environment that our current food systems can inflict (Union of Concerned Scientists, 2011). Fortunately, there are several hydroponic methods that can be used to grow crops, whether for personal use or on an industrial scale.

Figure 23 *A small-scale greenhouse hydroponic setup using PVC pipe as structure and water delivery system*

There are many benefits associated with growing hydroponically, including faster growth, little to no use of pesticides or herbicides, higher yields, less space, and the freedom to grow without waiting for a growing season, among many others (Sweetser, 2019). This can be especially beneficial for Clarkdale, as the area that is to be the sustainability park does have contamination leftover from the copper smelter. Instead of relying on the contaminated soil for community gardening and crop growth, the Town can implement a soilless growing method.

Hydroponics can be categorized into either passive or active systems. Active systems typically use pumps to move water and nutrients, while passive systems allow the water to remain still. There are several methods of hydroponic growing, ranging from simple to complex. These can include deep water cultures, ebb and flow systems (Figures 24 and 25), nutrient film technique, and the Kratky method (Hamdan, 2018). While passive hydroponics are suggested for Clarkdale, for simplicity and ease of learning, knowledge of other systems can be useful should the Town choose to implement more extensive hydroponic techniques.

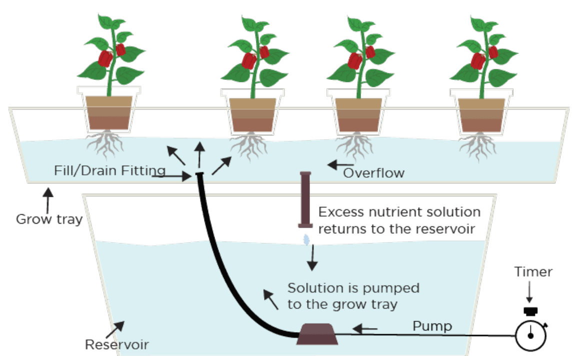

Figure 24 *Ebb and flow system diagram, where nutrient solution is pumped to the plant grow tray*

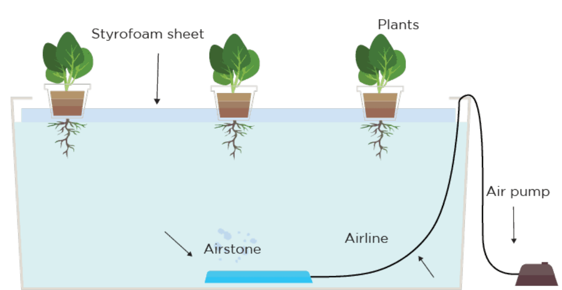

Figure 25 *Deep water culture diagram, where oxygen is pumped into the plant water reservoir*

The Kratky method

The Kratky method is a very simple yet effective way to grow smaller, leafier plants that do not require much input for nutrients or attention. These can include lettuce, spinach, and herbs like basil and rosemary. It is also possible to grow larger, fruit-bearing plants as well with the Kratky method, but this method and garden will be best suited for the growth of the aforementioned crops. Figure 26 below explains the simplicity with which crops can be grown with the Kratky method. In some cases, all that's needed is an opaque jar, a small absorbent sponge or material to hold the seed (known as a medium), and added nutrients which often come in bags and can be found at many gardening stores or online. In this system, the roots drink the water and absorb nutrients while the space in the jar provides oxygen. No electrical components are needed. Kratky plants can be grown and stored side by side on shelves or other surfaces, using minimal space in comparison to traditional agriculture or more involved forms of hydroponics.

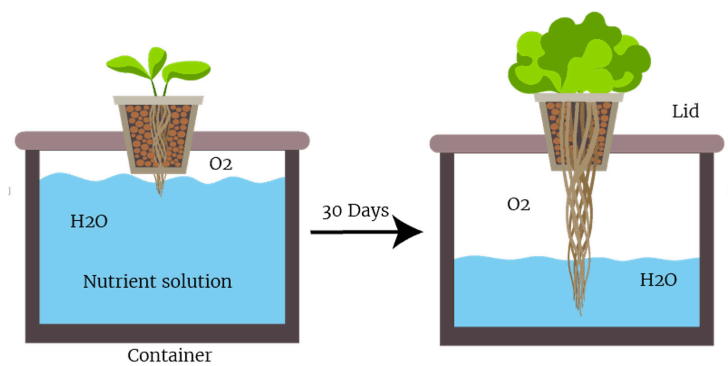

Figure 26 *Kratky method diagram, showing its similarities to the deep water culture method*

The main needs of a Kratky system are water replacement and nutrient replenishment. Water may need to be refilled up to once daily, depending on the container size, temperature, and type of plants being grown. When water is refilled, nutrients must also be added to ensure a steady supply of food to the plant. Aside from basic maintenance, there are a few negative effects that must be guarded against. Roots can often rot when left in water for extended periods and hinder or stop the growth of the plant. The best treatment for this is prevention, again by replacing water frequently and ensuring that there is enough room in the container for oxygen to flow.

Water pH factors into all hydroponic systems, but can typically be ignored when dealing with passive hydroponics and less intensive crops. However, it is relevant knowledge to have and will be necessary to understand when dealing with more intensive crops and systems. The pH of a liquid indicates how acidic or alkaline it is. The scale is from 0-14, with the liquid becoming increasingly acidic from 6.9 to 0 and increasingly alkaline from 7.1-14. Water is a neutral liquid with a pH rating of 7. This is important because plants are used to a particular pH level within soil, meaning the same levels must be replicated for hydroponic growth to be successful. Additionally, nutrients become more or less available to a plant depending on the pH level. Proper pH level ensures the plant can absorb the nutrients in the solution. Most hydroponically grown crops require a pH of about 5.5-6.5, though this can vary by plant. The pH level can be tested using test strips, liquids, or meters. If pH needs to be adjusted, there are very easy to use “pH up” and “pH down” solutions that raise or lower the pH level in a hydroponic solution (Smart Garden Guide, 2019).

Wastewater as a water source

Hydroponic gardens already use less water than their traditional soil garden counterparts, even though soil and hydroponic plants absorb the same amount of water. Hydroponics reduces percolation and evaporation, ensuring every bit of water is used efficiently (Barbosa et al., 2015). To further increase the sustainability benefits, wastewater can be used as a possible source of water in a hydroponic system as long as non-edible crops are grown. Clarkdale is in an excellent position to implement the use of treated wastewater for their hydroponic garden once it reaches that capacity, and would be following in the footsteps of other states and nations that reuse water to grow food: “Israel is the leader in effluent reuse, with over 70% of its wastewater reused for agriculture. In California, about 63% of effluent reuse was in agricultural irrigation” (Oyama, 2008).

Editor's Note

Expert advice on utilizing treated wastewater for agricultural purposes can be conflicting and may warrant further exploration before fully investing in its use to grow edible crops.

As there are other water-scarce places reusing wastewater, it appears that this method can be successful in Clarkdale as well. Despite this, there may be a concern for pathogens and infections, though this can be greatly mitigated with proper wastewater treatment like filtration and disinfection. To further mitigate the risk of any contamination, edible parts of crops should be kept away from the water and their final products should be thoroughly washed and cleaned (Oyama, 2008). One main concern would be how comfortable the Town is with using wastewater. There are different types of wastewater, including blackwater and greywater. The former is wastewater with fecal matter in it, while the latter is typically associated with typical household use such as water from washing machines, dishwashers, drains, and pipes. It will be necessary to ascertain the type of wastewater Clarkdale stores in the park and learn what the Town is comfortable with should the community decide on growing non-edible plants.

Usage or disposal of used nutrient solution

Whether or not the Town decides to use wastewater in the hydroponic garden, there will need to be a procedure in place on what to do with the nutrient solution water when it needs to be disposed of. As previously mentioned, hydroponic crops require a nutrient solution in order to grow. The nutrient solution mainly contains nitrogen, phosphorus, and potassium, but there are many other nutrients that are present in a smaller quantity. When it is time to change the nutrient solution, residual nutrients are typically present and cannot be simply tossed out. Irresponsibly disposing of leftover nutrient solution can create hazardous runoff and be detrimental to environmental health, especially at larger quantities.

To mitigate potential hazards, nutrient solutions can be diluted or purified before disposal. When diluting, it is important to add an equivalent amount of clean tap water to the nutrient solution. When it is diluted, it is still important to avoid dumping this mixture directly into the environment. Instead, it can be used to water potted plants, or disposed of down the drain. Certain filters and UV lighting can also purify the water before disposal, but can often be more cost prohibitive than simple dilution (GAIACA, 2020).

Greenhouse design

Hydroponic gardens are typically housed in some type of greenhouse facility. The greenhouse that houses Clarkdale's hydroponics will need to be suitable for the many specifications that come with hydroponic growing. These factors can include orientation for sunlight capture, ventilation systems, water supply, type of hydroponic system, plants to be grown, ease of access, waste disposal, site characteristics, etc. This is demonstrated by Figure 27 (Roberts, 2004). Each input and output must be considered when selecting and designing a greenhouse. Greenhouses can be very energy efficient if all considerations are taken into account. Some factors are easier to deal with than others because they can flow in and out of their own accord, such as ventilation, sunlight, and heat. Selecting a greenhouse will require an evaluation of resources at hand, the goals the Town may have for this project, and any plans for possible expansion. Modular designs, or being able to add on to an existing greenhouse design as an operation grows is also important to consider. Designing and selecting a greenhouse that allows for future add-ons can help the Town grow its hydroponic operation, especially if they decide to move into more intensive forms of indoor agriculture, such as utilization of automation, aquaponics, aeroponics, vertical farming, or other forms of growth that require more intensive care and maintenance (Roberts, 2004), (Giacomelli, 1996).

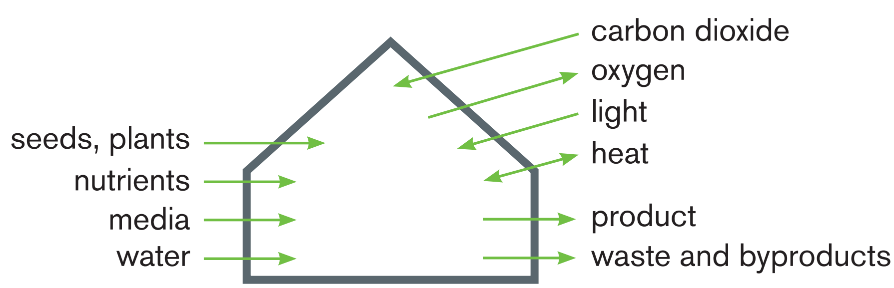

Figure 27 *Parameters required for optimal greenhouse production, by Roberts, 2014*

Best practices and examples

Greenhouses come in diverse shapes and sizes, allowing for flexibility when seeking to maximize efficiency. Different structure types can be utilized in the same operation for a more varied harvest. The University of Arizona does an excellent job at modeling what can be achieved with hydroponics and different types of greenhouses. Figure 28 on the following page shows a sawtooth, curved roof, and A-frame greenhouse. These are only a few of the various designs and are quite common due to their efficacy.

Figure 28 *Different greenhouse styles utilized by the University of Arizona, including A-frame (top), curved roof (center), and sawtooth (right). More information on the designs and their specifications is available at* **https://ceac.arizona.edu/about/facilities**

Sawtooth greenhouses are beneficial for their ventilation and work well in desert environments where rain and snow are not pressing issues. Curved roof greenhouses allow for the maximum amount of sunlight to enter for optimal plant growth and are better than traditional greenhouses, which can often reduce sunlight that reaches the plants by 10% or more (Government of New South Wales, 2007). Curved roofs often require less materials for construction, but have less roof structure to hang and support lighting or other equipment and leave a flat spot that is susceptible to rain or snow accumulation (Westbrook, 2016). A-frames have trusses and internal roofing support structures, which can hang lighting, irrigation piping, and other structures, and are less prone to dripping condensation than curved roof structures (Westbrook, 2016).

These are all common structure designs in hydroponic operations, each with their own benefits and drawbacks. As Clarkdale is a desert town, any one of these structures would be effective, though a sawtooth design might be preferable for its natural venting. With the typical greenhouse costing into the thousands of dollars, considerations on location, budget, and crops will all contribute to the final selection of greenhouse design for the sustainability park.

Facility energy management and agrivoltaics

As previously stated, energy efficiency considerations are important when selecting a greenhouse. As hydroponics are a more sustainable form of agriculture, the greenhouse must also be a sustainable facility. There is great potential to build a highly efficient greenhouse in Clarkdale as the Town receives plenty of sunlight year-round. Other factors also have great potential for sustainability, such as ventilation, cooling, and the use of solar energy. Natural ventilation through open side walls and greenhouse positioning that is parallel to the wind can provide a completely free source of cooling for the facility. Industrial fans installed at the ends of greenhouses are also effective in cooling plants in a uniform manner, especially if the floor layout of the systems run parallel to the long walls of the greenhouse. Lighting can also be done with minimal energy or monetary input, especially if the greenhouse is on a North-South orientation. This allows for maximum sunlight to reach plants each day and is especially beneficial in the winter months (Giacomelli, 1996). To ensure maximum efficiency, plant uniformity is recommended. When there are multiple crops with differing growth requirements, energy use can increase as cooling, lighting, nutrients, and labor needs change. The hydroponic garden can mitigate energy use and ensure the overall health of the plants by keeping uniform crops in the greenhouse.

Solar panels are a viable option for powering a greenhouse facility, while tying into the circular and interconnected nature of the park sections. A hydroponic facility typically has lighting, pumps, ventilation, and other equipment that requires electricity. The power requirement can be even higher if the operation grows more complex by utilizing automation or computer-run functions. Another section of this report discusses the implementation of agrivoltaics, or the farming of crops under solar panels. This concept can be extended to the greenhouse as well to reduce the impact of the structure's power needs on the municipal electricity grid. With many different ways to provide power and regulate the temperature of the greenhouse, a hydroponic operation utilizing agrivoltaics has the potential to be enormously energy efficient.

Case study: Hydroponic cannabis in Pueblo County, Colorado

A possible avenue for Clarkdale to explore is the cannabis industry, which is often associated with hydroponics. The legalization of recreational cannabis in Arizona with the passing of Proposition 207 in the fall of 2020 presents another opportunity for the Town to use hydroponics to their economic advantage. Cannabis is often grown hydroponically for the same reasons as food crops, including low resource input, speed, and quality. Clarkdale has an opportunity to replicate successful hydroponic cannabis operations around the country and potentially be a leader in the Verde Valley and Yavapai County for this industry.

Cannabis, both medicinal and recreational, is becoming legal in many states across the country. Colorado was one of the first proponents of legalized cannabis (legalizing recreational use in 2014) and has had several years to gauge the effects of legalization in their state. Colorado State University (CSU) has conducted a study on the impacts of legalized cannabis in Pueblo County, Colorado. This study covers many areas, including usage trends, student use, poverty rates, and education. Perhaps the most relevant to Clarkdale would be the study on the economic impact of legalization in Pueblo County. This report will focus on tourism and collected sales tax. The CSU study found that "Cannabis business employees spend significant portions of their income with local businesses, extending the impact in the local economy. Taxes collected are reinvested in designated areas, further stimulating the economy. Finally, cannabis tourism can also leave beneficial economic impacts in the area.

Economic benefits

Pueblo County has a sales tax of 2.9% for cannabis. In 2014, the County collected $1,750,907 in taxes from cannabis sales. That number increased in 2015 to $2,209,540, and then to $3,448,842 in 2016. The CSU study being cited in this report was conducted mid-2017, and as of July 2017 the study recorded $2,642,414 in tax revenue for the County, more than the entirety of taxes collected in 2015 (Wakefield & Hassan, 2017). By the end of 2019, Pueblo County collected $3,860,887 in cannabis excise tax, with the first half of this money "[...] allocated toward local scholarships and the second 50%... allocated toward voter approved capital infrastructure projects" (Pueblo County, 2019). While these numbers are from when Colorado was the only state with legalized cannabis and would not be repeated at the same level in Arizona, the potential for more revenue for Clarkdale and Yavapai County is promising should the Town pursue a cannabis industry.

Tourism benefits

The CSU report shows a clear benefit of cannabis tourism in the area. Clarkdale could potentially see a similar uptick in tourism, especially due to its location between the popular tourist destinations of Jerome and Sedona. Tourism can bring money to several different businesses and industries, with the study finding that "[...] cannabis tourism infuses money from out of the region when the sale is made, and some customers may use local lodging and restaurants, visit local attractions, or purchase souvenirs, increasing the impact upon the local economy" (Wakefield & Hassan, 2017). Figure 29 below shows the economic impact of the cannabis industry, including taxes and tourism, reported in the CSU study.

Estimated economic impact of cannabis industry in Colorado

Year	*2.9% tax collected*	*Calculated annual gross sales*	*Percent change from previous year*	*Economic impact using multiplier=$2.29*
2014	$415,037	$14,311,621	N/A	$32,773.611
2015	$468,083	$16,140,793	12.78%	$36,962,416
2016	$726,319	$25,045,483	55.17%	$57,354,156
2017 (through July)	$597,438	$20,601,310	N/A	$47,177,001
2017 (projected)	$1,024,179	$35,316,532	42% estimated	$80,874,859

Figure 29 *Economic impact of the cannabis industry in Colorado illustrating a steady rise followed by significant upturn in projected impact, by Wakefield & Hassan, 2017*

While the numbers are impressive, it is important to recall that Colorado was the first state to legalize a cannabis industry, These numbers will likely be much lower for Clarkdale, especially with statewide legalization with the passing of Proposition 207. While having a cannabis industry is not projected to be anything revolutionary, it can still draw crowds from the Jerome and Sedona tourism industries. When combined with other initiatives in the sustainability park, this could be a very successful endeavor for Clarkdale and make it a destination for tourism in the area.

Funding and grants for hydroponics projects

Starting a hydroponic operation can be a significant investment. Buying and building a greenhouse, acquiring an energy source, disposal of waste, labor, and upkeep can be barriers to starting the project. Even a smaller greenhouse can cost thousands of dollars (Farmtek, n.d.). It would be beneficial to seek grants to help begin the project, especially as a small town that is trying to attract more revenue. Fortunately, there are grants from many different sources that Clarkdale can apply for. These grants can come from government or non-government organizations, such as the USDA or non-governmental initiatives or organizations.

The United States Department of Agriculture is a large federal contributor to grants for agricultural projects through the Agriculture and Food Research Initiative (AFRI). This initiative focuses on different categories, one of those being Sustainable Agricultural Systems. This seeks to provide grants for agricultural projects that demonstrate sustainability. There are many grants offered, with some grants being up to $15 million. The year of 2020 has $290 million worth of funding across several different categories, including "Plant Health and Production and Plant Products; Animal Health and Production and Animal Products; Food Safety, Nutrition, and Health; Bioenergy, Natural Resources, and Environment; Agriculture Systems and Technology; and Agriculture Economics and Rural Communities" (National Institute of Food and Agriculture, 2020). In fact, the application for this grant directly mentions hydroponics, aquaponics, aeroponics, and vertical farming (National Institute of Food and Agriculture, n.d.).

This is not the only source of funding for this type of project. Other entities also disperse grants that can help get a hydroponic project off the ground. Many offer grants to schools, which could be an avenue that Clarkdale explores should they decide to involve the local public schools. Organizations such as the National Farm to School Network provide grants or resources to find grants for schools that want to be affiliated with sustainable farming and local agriculture (National Farm to School Network, n.d.). Conservation Innovation Grants (CIG) are another avenue to be considered. CIG is affiliated with the USDA and is another governmental agency that can provide funding for agricultural projects. One of their success stories is working with the Agricultural Conservation Planning Framework, an organization that works to restore wetlands (Natural Resources Conservation Service, 2020). This could be especially helpful if the constructed wetland project is implemented in the sustainability park, as is mentioned previously in this report. Again, as a small town seeking to increase revenue, any financial assistance should be pursued and utilized to the fullest extent. There are many resources available to help with sustainability projects such as this.

Final thoughts

While an attractive, sustainable agriculture method, it should be kept in mind that hydroponics require frequent maintenance and monitoring. Jars or plant receptacles need to be checked everyday to ensure the plants are healthy and thriving. Specific factors such as water pH levels also need regularly monitored, as does algae growth, which can often flourish when water reservoirs are outside in hot weather and exposed to sunlight. However, most of these problems can be avoided if there is at least one dedicated person attending to the system once daily.

As an operation scales up, hydroponics can become very complicated and require extensive knowledge of gardening, carpentry, electrical work, and other components. However, the Kratky system proposed for Clarkdale is a simple and effective introduction to growing hydroponically. While the beginning stages of this project would be focused on community members growing their own crops for home use, there are greater possibilities. Schools, restaurants, and businesses can eventually acquire their vegetables through hydroponics once the garden is more integrated with the Town and more productive methods are implemented.

Recommendations for hydroponics

- Explore different methods of hydroponic gardening, such as small community-led efforts, or larger industrial scale setups. Hydroponics are a sustainable way to grow crops and can help teach park visitors about new, interesting ways to interact with nature.

- Utilize and teach park visitors about the Kratky method, which is one of the easiest ways to grow hydroponically. This method does not require any electricity or moving parts, making it a great entry-level method for anyone learning about hydroponics.

- Develop a plan for used nutrient solution disposal. The leftover nutrient solution can often be harmful for the environment and should be either diluted and reused for plant watering, poured down the drain, filtered, or disinfected by UV lighting. This ensures that unnecessary nutrients do not make their way into the surrounding environment.

- Design or select a greenhouse to construct in conjunction with the hydroponics initiative. Greenhouse cost can vary greatly depending on size and style. It is important for the town to gauge what crops and how much they are planning to grow in order to select a greenhouse based on their needs.

- Explore ways to make the greenhouse as sustainable as possible by including natural ventilation and lighting, solar panels, and other ways to mitigate power usage and cost.

- Consider allowing a legal hydroponic cannabis operation. With the recent passing of Proposition 207, cannabis has been legalized for adult recreational use throughout Arizona. Hydroponic gardening is a popular cannabis growing method and can help bring industry and economic revenue to Clarkdale. This may be especially helpful in efforts to increase tourism numbers.

CONSTRUCTED WETLANDS

Originally a mining town, Clarkdale sustained its economy and population through the decades through the mining of minerals and ores, such as copper. Though mining is no longer the driving force of Clarkdale's economy, many pollutants remain. This has had an adverse effect on the surrounding environment. Fortunately, there are forms of remediation for these issues. Constructing an artificial wetland can help clean wastewater and improve water quality, provide habitats for native and migratory species, and improve the quality of the soil. Clarkdale has an excellent opportunity to become a model for wetland construction and restoration should they choose to pursue this method.

Editor's Note
Original SWOT tables for each topical subcategory are available in Appendix B of the student content at **links.asu.edu/PCClarkdaleSustainability20F**

Bioremediation of Pecks Lake area

The Town Council believes the best location for the sustainability park is near the Pecks Lake area, which allows for sustainable use of a sensitive and challenged area. Location of the smelter is by the Verde River, the same area of the proposed sustainability park. The sustainability park is between a smelter, a railroad, and a slag pile from metals during the smelting. Much of the landscape is no longer usable due to mine tailings from the copper mine. Historically, the extensive mining practices in the area led to the depletion of soil vitality in areas closest to the smelter operation. Despite this, the land can still be used for energy production through photovoltaic panels. This is helpful, as much of the soil is unlivable for many organisms and ecosystems. Significant amounts of ground contamination from high levels of lead and arsenic and lower levels of cadmium, chromium, copper, mercury and zinc were found at the bottom of the lake (Town of Clarkdale, 2010). This amount of contaminants makes it unlivable for aquatic ecosystems and is a health threat to residents if a park were to be built adjacent to Peck's Lake.

Figure 30 *Constructed wetland in Boynton Beach, Florida*

In discussion of the vision for the sustainability park, a bird watching trail and possible “artificial” wetland area that could benefit the surrounding environment was suggested. Peck’s Lake area is adjacent to the east of the park and is in the process of eutrophication. Eutrophication happens when it becomes overly enriched with minerals and nutrients which induce excessive growth of algae. This disrupts ecosystems and doesn’t allow for new growth due to loss of oxygen.

According to the proposal for Clarkdale sustainability park, the town also mentions the lake contains high contents of lead, arsenic and low levels of mercury (Town of Clarkdale, 2010). Freeport-McMoRan, a large copper trade company, has been increasing the flow of influent (wastewater) that improves oxygen levels and dilutes nutrients. A constructed wetland ranging from 10 to 20 acres in size can be a sustainable way to revitalize Pecks Lake by rebuilding the aquatic ecosystem and providing habitats for birds. A nature observation trail inside the first Audubon Society “Important Bird Area” (IBA) in the state, the Tuzigoot IBA, provides a great opportunity for an artificial wetland to thrive.

Figure 31 *Envisioned constructed wetland for the sustainability park, illustrated by Walid Elkhatib*

A “constructed” wetland serves as a shelter for birds and, if properly built, maintained, and operated, can effectively remove many pollutants associated with municipal and industrial wastewater and stormwater as well as contaminants such as metals (Gelt, 2016). A constructed wetland is considered the secondary act of treating wastewater; it is recommended there is primary treatment of influent before it is disposed of into the wetland to hinder clogging. There needs to be an established and balanced food web in which the bird species can rely on; marsh is vital for waterfowl to breed and shelter in. Native aquatic vegetation is currently absent from the lake and should be introduced to shallow areas to address this. Native shrubs that thrive off the riparian edge and provide bird habitat, such as graythorn, can help encourage a scenic bird trail. Bulrushes create the best habitat for waterfowl, the significance that vegetation possesses within a wetland supports the surrounding wildlife. Common animals that were seen in the area include beavers, sonoran mud turtles, grey fox, whitetailed deer and so many others that can soon make a reappearance into the area. Establishing nutrient-rich soil will help foster the bottom tiers of a healthy ecosystem, such as vegetation and insect populations.

Native aquatic vegetation and animals may help to attract year-round bird species endemic to the Verde Valley like the Virginia Rail and the great blue heron. Native fish should be prioritized over non-native fish, as they are more adapted to local climate, soils, and surrounding plants and animals. Common fish in the Verde Valley are rainbow trout, largemouth bass, sunfish, channel catfish, and crayfish. Specific fish species to be introduced to the wetland should be decided by state personnel and local authorities through informed methods.

There are different types of wetlands that can be utilized for various reasons, whether it’s for treating wastewater or prevention of floods, but they all take in carbon from plant photosynthesis. Carbon is stored in a mixture of organic soil, vegetation, and built-up sediment at the bottom of the lake. Besides benefiting the bird population, the wetlands could also be a means of bioremediation for the mining remains. In addition to the lake’s high contents of lead and arsenic, it is also congested with invasive vegetation, most commonly known as Eurasian Milfoil, which tends to spread quite quickly. In order to stop and reverse this process it’s necessary to either physically remove it or dredge it out, allowing for new growth to occur. Construction of a wetland along with its bioremediation advantages attracts economic development and opportunity by replenishing the area that was once a premier recreational destination where fishermen, nature lovers, families and hikers visited extensively.

Wetland components

Aside from wastewater treatment, it is important to note that the structure of a constructed wetland depends on desired outcomes. A constructed wetland consists of a properly designed basin that contains water, a substrate, and, most commonly, vascular plants (DuPoldt et al., n.d.). Substrates like soil, sand, gravel, rock and organic composted materials are used to construct a wetland.

There are three types of flows for wetlands, each with their own uses and advantages (Halverson, 2004):

1. **Surface Flow (SF) Wetland** has running water and emerging vegetation in which water flow is primarily above ground. Sometimes referred to as free water surface wetlands, the water closest to the top is aerobic; the deeper you go and the more substrate there is, the less aerobic. Although they do require a great deal of land, they're more affordable and maintenance is very straightforward.
2. **Subsurface Flow (SSF) Wetlands** can be more expensive to construct, thus smaller flows are often used and no water is exposed. Most constructed wetlands to treat domestic wastewater are subsurface systems. In this occurrence, wastewater then is not exposed on the surface of the yard or property, addressing odor, insect, public health, and safety concerns.
3. **Hybrid** systems integrate both surface and subsurface flows. They usually have a higher treatment effect because of all the different components working together to promote aerobic and anaerobic reactions. Aerobic bacteria attach to the roots of aquatic plants and anaerobic bacteria attach to the rocks as wastewater is flowed through it and is treated by this process. Hybrid systems utilize horizontal and vertical flow.

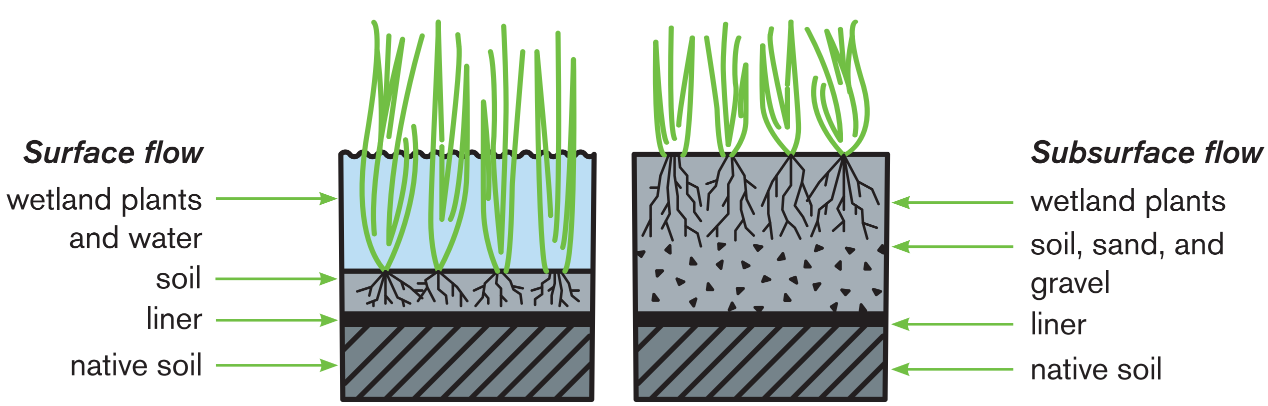

Figure 32 *Surface flow (left) and subsurface flow (right) diagrams, based on Halverson, 2004*

In a vertical flow wetland (Figure 33), soil, sand, and gravel are common mediums that provide greater surface area for treatment contact. Wastewater/influent is dosed through the inlet pipes, the water then flows vertically down to the bottom where it is collected in the drainage pipe. Substrate acts as a filter for removing solids in which bacteria can attach itself to and vegetation can grow from. The roots from the aquatic vegetation transfer oxygen so that aerobic bacteria can colonize the area and degrade organics. It is prone to clogging due to shallow water, thus maintenance activities should focus on ensuring that primary treatment is effective at breaking down solids in the wastewater.

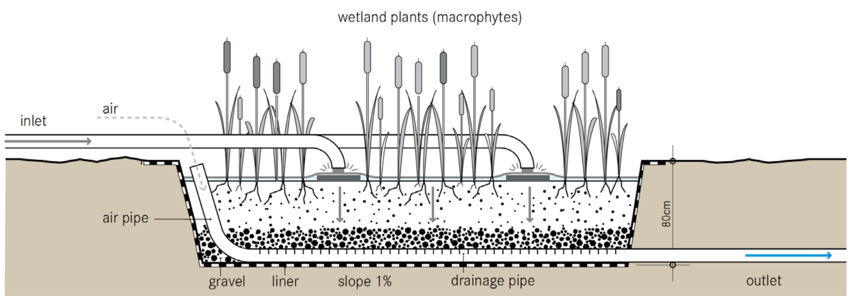

Figure 33 *Vertical flow diagram, by Tilley et al., 2014*

In a horizontal subsurface flow, wastewater is transferred through vegetation and small gravel. Instead of gravel being at the bottom, it is placed on the sides of the basin, therefore allowing for much more water movement. It is critical for the wetlands efficiency to be wide and shallow so that the influent touches all vegetation and ensures even distribution of flow. Advantages of this flow include high reduction of Biochemical Oxygen Demand (BOD) and suspended solids and pathogens (DuPoldt et al., n.d.). If there is more Dissolved Oxygen (DO) consumption by bacteria than the supply of it from aquatic plants through photosynthesis, unfavorable conditions occur due to high BOD such as eutrophication.

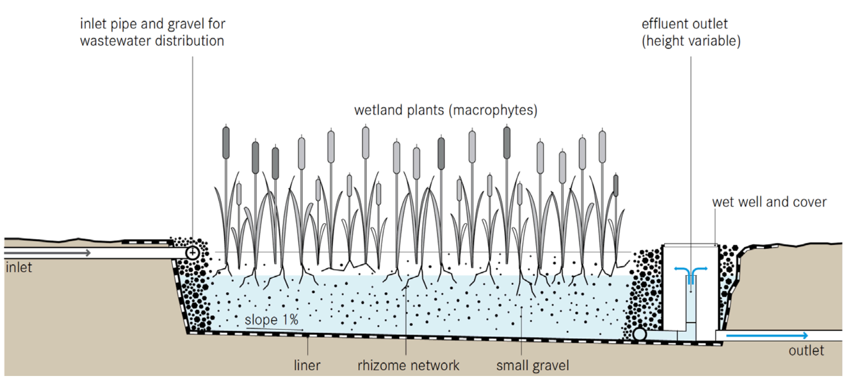

Figure 34 *Horizontal subsurface flow diagram, by Tilley et al., 2014*

Planning

The design of a constructed wetland is site-specific; therefore, there is natural variability in its functionality if Clarkdale personnel are inclined to future expansions. It must be built, maintained, and monitored diligently by skilled workers to ensure its lifetime is not finite, as contaminant build up in the deposits is likely to happen without proper care. The soil is considered the most important aspect of constructing a wetland. The pH of the soil affects the availability and retention of heavy metals and nutrients (DuPoldt et al., n.d.). Organic material also helps take in carbon from the atmosphere to feed necessary microbial activity. Compost, hay, and chicken litter are examples of some organic material options.

When selecting vegetation, it is advised to focus on creating dense habitat that is adapted to local climate and soils. The more diverse the marsh and emerging vegetation are, the more wildlife they attract. Hybrid systems that include deep and shallow pools provide important habitat for waterfowl and nesting. The presence or absence of shelter will determine whether birds will inhabit the wetland area. This area will provide food for the bird species in forms of plants, vertebrates and invertebrates. Some feeders forage for food in the soils, some find food in the water column, and some feed on the vertebrates and invertebrates that live on submerged and emergent plants (Stewart, 2016).

Figure 35 *Plants installed at the Tres Rios wetland that may be helpful to consider include various cattail species (left), broadleaf arrowhead (center), and water speedwell (right)*

Wetland design varies depending on the treatment target and amount and quality of influent. Gravity can help bolster flows within a wetland; Figure 34 has a slope of 1%. Constructed wetlands combine aquaculture and agriculture (irrigation), which contributes to the optimization of the local water and nutrient cycle (Stauffer & Spuhler, 2019). Not only do they conserve water by improving water quality and function as natural wastewater treatment, they also enhance the surrounding environment.

Case studies

Tres Rios wetlands: Phoenix, Arizona

Constructed wetlands are generally in need of more research on water treatment efficiency and what appropriate regulations are needed to protect public health without inconveniencing designers. The City of Phoenix partnered with the U.S. Army Corps of Engineers to improve a 7-mile long, nearly 700-acre section along the Salt and Gila Rivers in southwestern Phoenix. Tres Rios was constructed for flood control, habitat restoration and recreational and environmental education. It is both an operating facility and testing site. Waterfowl nesting islands, known as cells, were constructed as natural edges to foster microbial communities, determine the effectiveness of the constructed wetlands on wastewater polishing, and to determine the best cell configuration for optimum water quality. Tres Rios is a three phase wetland: It first receives wastewater that moves through marsh, then on to a deep pool, then back to the marsh moving through emergent and free surface flow waters. Each of these mechanisms ensure even further treatment. Pecks Lake area is much smaller, but is still heavily polluted. Treatment phases used in the Tres Rios project could be integrated for further experimentation.

Figure 36 *Tres Rios wetlands visitor map, by City of Phoenix*

Pintail Lake: Show Low, Arizona

In northeastern Arizona, Show Low constructed one of the first wetlands in the nation made up of several in the area referred to as Pintail Lake. Creating wildlife habitat for waterfowl was central to the design of this 47 acre wetland. Initially the lake was receiving 200,000 gallons of wastewater and has increased up to 500,000 gallons (Gelt, 1997). The complex now consists of nine cells covering about 200 acres that can handle 1.42 million gallons of wastewater daily to serve a population of 13,500 (Gelt, 1997). The treated water is not discharged from the wetlands but remains to evaporate and create habitat. There are several options for what to do with the treated water. It can be of further use for the Clarkdale sustainability park and irrigating the land. These wetlands were constructed by two government agencies, the United States Forest Service and the Arizona Game and Fish Department. Multiple opportunities arise from constructing a wetland, from funding resources to collaborations amongst agencies. Clarkdale possesses a unique possibility of such circumstances because of community involvement and interest with reopening Pecks Lake Area.

Funding resources for a constructed wetland

The U.S. Fish and Wildlife Service contributes to grants and partnerships through the North American Wetlands Conservation Act (NAWCA) to organizations and individuals. There are many State and Federal agencies, foundations, and private organizations that are possible sources of funding for specific studies and projects pertaining to rural watershed groups (Arizona Department of Water Resources, 2020).

Recommendations for constructed wetlands

- Construct an artificial wetland in the Pecks Lake area to help revitalize the ecosystem which has been polluted from past mining activity.
- Explore different types of wetlands construction, including a Surface Flow (SF wetland, a Subsurface Flow (SSF) wetland, and hybrid systems that integrate both.
- Hire specialists to monitor pH levels, ecosystem health, water cycles, and other markers of environmental health.
- Research and integrate processes of similar projects, such as the Tres Rios Wetlands in Phoenix, Arizona. Tres Rios is considered a successful constructed wetland, as it serves as a habitat for many species, helps remove pollution from the water, and provides a myriad of other environmental benefits to the area.

SOLAR ARRAY

The new age of solar energy generation and carbon-free, renewable energy is upon us. Due to economies of scale and manufacturing efficiencies, solar installation prices have dropped a staggering 70% in the last decade (SEIA, 2020). This has led to an increase of installations with no signs of slowing down. The Energy Information Administration (EIA) is predicting solar photovoltaics (PV) to be the largest source of renewable electricity for the United States by 2050 (EIA, 2019). Clarkdale has an opportunity to join the economic movement and create strong local jobs, along with configuring the solar photovoltaic arrays to attract tourists.

Editor's Note
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Economic impacts

The solar industry has created a vast number of good paying jobs that boost local economies. Such jobs could help provide a needed economic boost for Clarkdale's local workforce. "As of 2019, the National Solar Jobs Census found: American solar jobs have increased 167% over the past decade, adding 156,000 jobs. In the five-year period between 2014 and 2019, solar employment increased 44%, five times faster than job growth in the overall U.S. economy" (The Solar Foundation, 2020). Many of the job opportunities needed for constructing a solar PV site could be offered to local residents. By triggering job opportunities within the community, a strong connection between the town and the park can be made.

The public interest in sustainable forms of energy is immensely popular. A Pew Research poll found that "89% of Americans favor more solar panel farms" (Kennedy, 2020). With this resounding interest in renewable energy from the general public, a curiosity can be formed of the properties of a solar farm drawing tourists and visitors to the sustainability park. Through increased tourism interest, Clarkdale could turn into a great middle attraction between the tourist towns of Jerome and Cottonwood. An interesting and attractive design of the solar arrays, along with integration with the rest of the park, could do very well toward attracting tourists who are curious about sustainability and renewable energy.

Potential solar farm designs

By creating a unique and recognizable solar PV design, Clarkdale can cement an iconic image for the town. Cities and companies all around the world are arranging their solar panels to create interesting designs. Figure 37 shows a solar array in Datong, China, where a large 50MW solar PV farm was designed to resemble giant pandas by using two different shades of solar panels (Nace, 2017). Similar concepts have been executed in the United States, such as Disney's Micky Mouse shaped solar farms (Brinkmann, 2019). Clarkdale could use these arrays as inspiration for their own solar farm design, to generate interest while promoting the sustainable image of the Town. Suggestions for Clarkdale include spelling out "Clarkdale" using two different shades of panels (Figure 38), a town logo, or image that can bear resemblance to the town's mining history. This would be a respectful way to honor the past, while still being transformative and embracing a carbon-free future.

Figure 37 *Panda bear solar array in Datong, China, via Google Earth*

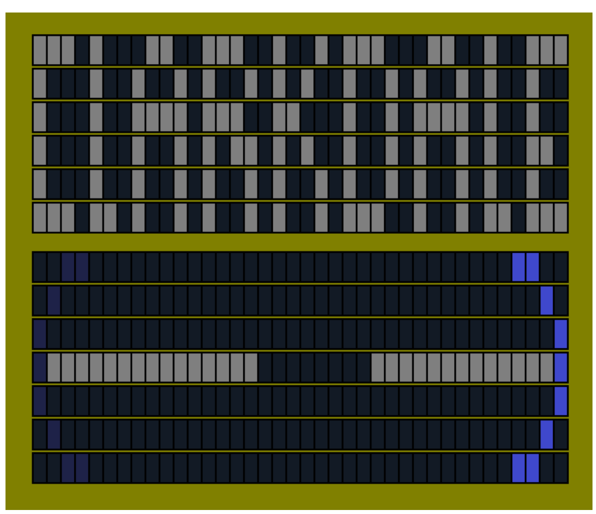


Figure 38 *Solar array design referencing Clarkdale's mining history, by Tyler Skirvin*

Tracking considerations and the solar process

Single axis tracking solar photovoltaic (PV) systems can provide high energy production for an otherwise empty plot of land. Modules that are installed on the single axis tracker can generate about 23.9% more energy than south-facing fixed angle panels (Perraki & Megas, 2014). Solar PV trackers can also be utilized and incorporated in the agrivoltaic systems suggested in this report. Intertwining agrivoltaics and solar trackers is a new and developing field that combines PV technology with agriculture. Depending on the crop selected and its sunlight requirements, tracking software can be used to further increase the productivity of the crop and energy generation of the panel. Downsides for single axis trackers include higher upfront cost and additional moving parts requiring more ongoing maintenance.

Editor's Note
Some sources in this section could not be verified. The corresponding in-text citations have been removed.

The 100-acre area of the proposed sustainability park provides a wonderful natural landscape to accommodate single axis trackers, fixed angle arrays, or a combination of the two. The relatively flat ground of the northern section of the park (Figure 39) could be a prime location for solar arrays and potentially contribute to lower construction costs. The land in this area is fairly elevated, sparsely vegetated, and provides an opportunity for efficient southern orientation of panels. These prime conditions can further lower the solar array startup costs as ground preparation and plant removal would be somewhat minimal.

Figure 39 *Suggested placement for solar array north of the sustainability park*

There are many different options to consider when planning the layout and makeup of the park's solar panel system. The following list outlines some potential options for review.

1. **Tracking:** Utilize as much space possible and install a solar PV tracking system. This would likely create the highest long-term energy generation and profit. Rows of solar panels would need to be adequately spaced to prevent shading onto other panels, and be placed in a north-south orientation to allow the trackers to track east to west. This option presents the highest upfront cost if it is used over the entire planned space.
2. **Fixed:** Install fixed solar panels in rows arranged east to west, to allow for south facing panels. This setup can be oriented in a way that the rows can be closer together as compared to a tracking system. This option would likely be the most cost effective as it would require less parts and ongoing labor.
3. **Combined:** A mix of option 1 and option 2 would provide an opportunity to monitor various forms of energy generation. This could be used to provide data and ongoing information on renewable systems to the community.

Applicable to any of the above options, the following list provides a rough concept of a phase plan for the sustainability park's solar energy project.

Editor's Note
Curtailment, in this instance, refers to the reduction or restriction of energy delivery from the generation source to the electrical grid. Energy curtailment may be practiced for a multitude of reasons, such as oversupply or transmission constraints.

1. **Set the project perimeter:** The northern section of the park is an ideal location for a solar array as it is already south-facing, flat, and has relatively little vegetation to remove. To determine proper boundaries, it should first be decided whether the array will be fixed, tracking, or a combination.
2. **Utility transparency:** Coordinate with the local utility company (APS) on the substation and determine any legal requirements for the generation facility. It appears this step may have already begun regarding preliminary decisions. It is important to note the utility company needs to be fully involved and aware of the progress of the project. They will likely require internet capabilities at the site for monitoring, reclosing functions, and **curtailment.**
3. **Design and onsite surveying:** Initial plotting of the site will help determine the scale of the quantity of electrical components, modules, trackers, and labor needed for the project. An idea of startup cost and ongoing cost can also be established based on the calculated material figures.

4. **Construction:** The construction phase consists of taking engineered designs and coordinating with the construction team to acquire materials, specialists, electricians, and project managers. A cohesive unit can ensure the project is done safely, on budget, and on time.
5. **Testing:** Site testing with regulators, utilities, and technicians need to be extensive and thorough to ensure safety, longevity, and prevent further complications and costs due to missed errors.
6. **Commencing:** After testing is concluded, the commencement of the facility will start with ongoing monitoring via technicians, operators, and constant communication with the utility/APS. The power plant shall be fully operational at this stage, and routine and preventative maintenance should be conducted according to the manufacturer recommended intervals.

Though there are many steps to constructing a solar farm, the economic and environmental potential for Clarkdale is very encouraging. By building a solar facility, the town can ensure that it has a strong economy and sustainable power source for many years to come.

Grants and funding

Currently, Arizona Public Service (APS) provides the electricity for Clarkdale and would continue to be in charge of the solar farm. To curtail the costs of building the facility, it is recommended to investigate the federal business energy investment tax credit (ITC), federal clean renewable energy bonds, and federal renewable electric product tax credit (PTC) to potentially fund the solar farm and other sustainability initiatives throughout the park (Baltazar et al., 2020).

Recommendations for solar array

- Use the park's ample space for a solar installation or solar farm, which could generate a large amount of power for the town. Solar panels will also require maintenance, repairs, and supervision, spurring additional job opportunities with the installation and boosting the local economy.
- Determine whether to install tracking or fixed solar panels, or a combination of both. This can be determined by the solar farm's position and how much sunlight it receives.
- Consider arranging solar panels in an eye-catching design that reflects Clarkdale's history and values. A unique design can add another reason to visit Clarkdale and help it stand out from surrounding towns.

AGRIVOLTAICS

Editor's Note Original SWOT tables for each topical subcategory are available in Appendix B of the student content at **links.asu.edu/PCClarkdaleSustainability20F**

Arizona is a prime location for agrivoltaics. The University of Arizona's Biosphere 2 is one of the premier locations for agrivoltaics research and serves as a resource that Clarkdale can tap into (McDonald, 2019). Arizona has the highest solar radiance in the U.S., but the state's increasing temperatures decrease the solar energy capacity. Agrivoltaics can help maintain solar panel efficiency while providing a renewable source of energy that mitigates the impacts of climate change.

Agrivoltaic facts and methods

The use of solar panels above agriculture, known as agrivoltaics, provides many benefits for the panels, the crops, and the park. This idea was first introduced in 1982 by scientists Armin Zastrow and Adolf Goetzberger (Majumdar and Pasqualetti, 2018). While Clarkdale does not have a need for crop production, they have stated the importance of achieving energy independence and diversifying their energy portfolio. Agrivoltaics can help the town achieve this. Research has shown that agrivoltaics have increased crop production through impacting the air temperatures, direct sunlight, and demand for water (Barron-Gafford, 2019). The plants below the panels reduce the overheating of the panels; this is especially important since the efficiency of solar panels decreases with increased temperatures (Pigot, 2019). In fact, agrivoltaics were found to be cooler in the daytime (compared to regular solar panels) by about 9 degrees Celsius (NREL, 2019). The solar panels are cooled by the water plants emit through transpiration, which cools the air temperature. Agrivoltaics also help conserve water. A study found that the use of agrivoltaics can result in water savings of 14 to 29 percent. This is especially beneficial considering that Arizona is a drought prone region (Pearce, 2016).

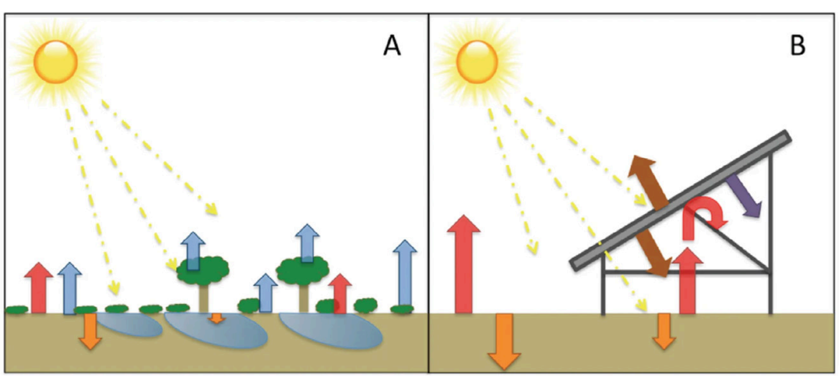


Figure 40 *Illustration of the cooling effect vegetation has on its surrounding area (left) versus the warming effect lone solar panels can cause on their surrounding areas, by Barron-Gafford, 2016*

It is also important to refrain from growing crops between the solar panels as the dust from these crops can decrease the efficiency of the solar panels (Pearce, 2016). In general, crops have higher productivity under indirect sunlight. However, crops should not be completely covered by solar panels, as they can lose up to 50% of their productivity. Ultimately, crops that are 50% shaded by solar panels can result in productivity rates that are better than crops without solar panels above (Majumdar and Pasqualetti, 2018). Successful agrivoltaic crops can include lettuce, taro, yam, cassava, and sweet potato (McDonald, 2019). This structure would also be beneficial for Clarkdale as the structure can attract visitors who are interested in innovative energy platforms, allowing the town to generate revenue through selling some of these crops. It will aid in community cohesion through the collaborative nature of the agrivoltaics.

There are also mechanisms to maximize the power generated by agrivoltaics. These include tilting the panels at the perfect angle to maximize solar radiation (Pearce, 2016). Agrivoltaics are most favorable on land that has a slope of less than 5 degrees, is south facing, and is within the 20-30-degree range of due south (Majumdar and Pasqualetti, 2018). Some research suggests that the optimal height for agrivoltaics is to be 3.3 m off the ground at the lowest point, and have a tilt of 32 degrees (Barron-Gafford, 2019).

Current state of agrivoltaic implementation

There is currently little agrivoltaic specific policy. Many states have policies that prohibit the conversion of agricultural land for solar generation, but agrivoltaics can allow both the production of food and energy. Massachusetts' Solar Massachusetts Renewable Target (SMART) program is one of the few programs that address agrivoltaics specifically (Chambers, 2020). There's little agrivoltaics in most parks as it requires relatively high capital costs, and is still a relatively new concept. However, it would help Clarkdale's sustainability park become energy independent and allow an increase in crop productivity. Clarkdale can generate revenue to fund other public projects through the sale of crops grown and the surplus energy generated. Agrivoltaics installed by Sun'Agri in France have been successful. Here, 600 square meters were covered with solar panels, with 280 panels installed to have a total capacity of 84 kW (Rollet, 2020).

Some of the drawbacks to agrivoltaics are that their installation costs are much higher than that of ground-mounted solar, and their smaller size decreases their overall capacity. It is recommended that agrivoltaics be smaller than ground solar, but larger than rooftop solar. According to a study, the amount of crop land reduced by 48% between 1961 and 2016 (Schindele, 2020). The levelized costs of energy for agrivoltaics falls between $50-$100/MWh (this counts for power production and impacts of crops), ground-water stressed areas are found to have 11.2-37.6 PWh/yr from agrivoltaic power generation (Hunt and Parkinson, 2020). The costs of agrivoltaics are another important factor to consider. In Arizona, residential electricity rates average around $0.12/kWh, and an average acre can generate about 600 MWh per year with half-density panels (Majumdar and Pasqualetti, 2018). Additionally, solar PV can increase the property value of the land.

Implementation and next steps

Once the size, location, and tilt of the solar array is determined, the next step is deciding whether to have a fixed or tracking solar array. The one-axis and two-axis tracking systems create about 20% to 35% more energy than a fixed PV array (Majumdar and Pasqualetti, 2018). However, these systems cost between 3 to 5 percent and 12 to 14 percent more for the single and double axis systems respectively. The tracking systems also require about twice the amount of land area than the fixed array (Majumdar and Pasqualetti, 2018). In fact, the installed capital costs for fixed-tilt PV systems are $1.85 per watt and $2.11 per watt for single-axis tracking systems (Energy Information Administration (EIA), 2018). Once the type of solar array is decided, the type of solar panel must be determined. While polycrystalline silicon is the most popular type of PV, monocrystalline cells have a maximum efficiency of 25%, and polycrystalline only has a maximum efficiency of 20.4% (Majumdar and Pasqualetti, 2018). Solar panels can create 7.5% more energy with a tilt between 20 and 40 degree (Majumdar and Pasqualetti, 2018).

Having an additional source of energy and the ability to source their own food could benefit Clarkdale's residents. Thus, through the use of agrivoltaics the town can accomplish both goals. The town was one of the first to partner with the Arizona Public Service (APS) and become an "Arizona Solar Community." The Town has prioritized solar power, and agrivoltaics will be kept in line with this prioritization while expanding to include a new form of solar. Clarkdale's Sustainable Development Guidelines state that energy efficient designs that incorporate both solar and the natural climate are a key part of the town's mission.

Their guidelines also state the importance of preserving existing vegetation and mention opportunities for energy independence (Town of Clarkdale, 2018). Currently, the Arizona Public Service (APS) provides the electricity for Clarkdale. APS would continue to be in charge of these solar panels. The Project Cities combined Clarkdale Downtown Revitalization report from May 2020 states that the federal business energy investment tax credit (ITC), federal clean renewable energy bonds, and federal renewable electric product tax credit (PTC) are possible mechanisms for green building practices, and it could also be used to fund agrivoltaics (Baltazar et al., 2020). While these are for residential purposes, the town can work with APS to collaborate on funding mechanisms. Furthermore, Clarkdale's sustainability park proposal mentions having a diverse array of renewable energy producers. This installment would fulfill this requirement. According to the Clarkdale sustainability park white paper, all of Clarkdale uses about 8.5 MW of electricity (Town of Clarkdale, 2011). While this number is from 10 years ago, and the population of Clarkdale has grown, the agrivoltaic project would still supply a considerable amount of electricity to the town. Additionally, having a community supported agriculture (CSA) market was mentioned in the 2018-2019 Clarkdale Economic Development Plan as a sustainable idea (Town of Clarkdale, 2018).

Figure 41 *Example of a tracking solar panel setup, which tilts to maximize the amount of direct sunlight on the panel*

Case studies

Despite the fact that agrivoltaics have been around for a few years now, much of the agrivoltaics farms are either in the pilot stage or are for research purposes. As many of the plants are still relatively new, there is not much concrete data coming out of these farms. Though this is a newer concept, many places around the world are implementing agrivoltaics. From Tucson to Oregon to Montpellier and the Netherlands, agrivoltaic solutions are becoming more viable every day.

Tucson: Biosphere 2

University of Arizona students successfully implemented their agrivoltaic "salsa" garden in the Biosphere 2 research facility consecutively establishing the Agrivoltaics Learning Labs (ALL). It is engaged and hands on learning by K-12 students as well as university undergraduate research programs that want to participate in the research as part of the tour as well. It is referred to as the salsa garden because they grew every vegetable that goes into making a salsa. These include tomatoes, peppers, onions, garlic, and herbs, which are also sold to local restaurants. Their original test plots of tomatoes, peppers, and cilantro grew better than a control garden exposed to sun with no shade – producing more fruit and using less water. The experimental plants also helped keep the solar array cooler during the day, increasing efficiency by 5 percent (University of Arizona, 2019). This information concludes the practice and implementation of agrivoltaics benefit crop growth and solar panel productivity. This serves as a great opportunity for Clarkdale to transition to cleaner energy production and agricultural practices not done before specific to the town of Clarkdale.

Figure 42 *The expansive Biosphere 2 research facilities in Tucson, Arizona*

Oregon State University

Besides the University of Arizona, Oregon State University is another major research hub of agrivoltaics in the United States. Their experiment focused on the effects of agrivoltaics on Rabbit Hill, a solar farm on the Oregon State campus. The researchers discovered that there was a 328% increase in water efficiency of crops under partial solar, and there was a 90% increase in productivity during the May-August period, suggesting that mid-arid pastures were among the best climates for agrivoltaics (Hassanpour, Selker, Higgins, 2018). Additionally, while the climate in Clarkdale is different from Oregon, studies do consistently state that solar panels increase crop productivity and water efficiency of crops. While much of the agrivoltaic systems in the U.S. are experimental, there is an example in Maryland of an agrivoltaic system that has just been launched.

Montpellier, France

The farm in Montpellier, France is the world's first agrivoltaic farm, and is also arguably one of the most successful. In 2010, Christian Dupraz and researchers at the Institut National de la Recherche Agronomique (INRA), created a pilot agrivoltaic farm on 860 square meters. These solar panels were 4 meters off the ground, 44.8 meters long, and had a tilt of 25 degrees. The panels for Clarkdale will be much larger in terms of length, but have the same tilt and length off the ground. Using these dimensions can allow the solar panels to capture the most amount of sunlight while allowing crops to be grown beneath it. If we assume that one acre (or 4046 square meters) of land will be allocated for agrivoltaics, then the length of the solar PV would need to be 210.76 meters in total. They will be split into rows, and assuming it is a 300-watt solar panel with a 20% efficiency, it could produce about 1908 watts per square meter. Additionally, beneath these panels, the researchers grew crops such as wheat and lettuce. While the climate in France is Mediterranean, this study does show the large-scale feasibility of agrivoltaics, and researchers at INRA can serve as a valuable resource for Clarkdale.

The Netherlands

An agrivoltaic farm in the Netherlands is a great example on a more commercial scale. Here, BayWa r.e. and its Dutch subsidiary, GroenLeven, are constructing five agrivoltaic power plants, which involves testing the following crops: blueberries, red currants, raspberries, strawberries, and blackberries. This power plant will be made of monocrystalline solar panels, and the largest power plant will consist of a 2.67 MW solar array over 3.2 hectare filled with raspberry plants. The companies are also experimenting with transparent solar panels to increase available sunlight for the raspberries. While the companies have not explicitly stated the total costs of this project, they have stated that the installations are currently much more expensive than regular ground-mounted installations. The companies' hope is that economies of scale and better supply chains will decrease the costs of this practice in the future.

Additionally, the Arizona Sustainability Alliance (AZSA) is working with Maya's Farm to create an agrivoltaics structure, and while the panels have not been installed yet, there has been preliminary research done. Clarkdale can use AZSA as a resource.

Crop considerations

Arizona has an arid and semi-arid climate, therefore it's important to choose crops that will be well-suited in this region. Research suggests that strawberries are a great crop to grow in the Northern Arizona climate, but Clarkdale would need to work with researchers at the University of Arizona to determine what types of crops (if any) are suitable for growing in the town (Warner Companies, n.d.). American grapes are another great crop for this climate and the culture of Clarkdale as there are many local wineries (Warner Companies, n.d.). However, growing this crop requires much more care, and thus may not be suitable for the park unless there is a dedicated group of people in charge of the garden.

The garden below can also grow a variety of flowers, which could be sold at the Clarkdale nursery. Whether or not the town wants wildlife like deer and rabbits to enter the park will determine what type of plants to grow. For example, the blackfoot daisy grows well in a low-medium moisture environment, attracts bees and butterflies, but is deer and rabbit resistant (City of Flagstaff, 2017). However, rocky mountain penstemon provides forage for deer and antelope, and is thus likely to attract these animals (City of Flagstaff, 2017).

While deciding on the types of flowers to plant, it is also important to check the necessary water requirements. Flowers that thrive under indirect sunlight and require low to medium amounts of water are the best. These include the purple geranium, mountain meadow-rue, and the golden columbine (City of Flagstaff, 2017). Besides providing economic revenue through their sale at the local nursery, these crops can also enable a market for herbal remedies. For example, the mountain meadow-rue was used by Native Americans for medicinal purposes. As many of these flowers attract birds such as hummingbirds, bird watching is another economic industry that could come about from the agrivoltaic garden (City of Flagstaff, 2017). All of the plants mentioned are native to Northern Arizona, and would have a maximum height less than that of the solar panels.

Recommendations for agrivoltaics

- Start an agrivoltaic community garden in the park. Placing solar panels above a garden reduces the need for water by shielding plants from excessive heat and sunlight. Additionally, the plants below reduce the heating of the panels, as the evaporated water passes through and above the solar panels. Generating electricity and growing crops with this method is appropriate for dry places like Arizona.
- Ensure that plants are only partially covered by panels to avoid excessive shading. Aim to cover about 50% of the plants beneath the panels.
- Avoid planting between panels, as the dust from the crops could cover the panels and reduce their productivity.
- Determine which crops would grow best in Clarkdale's environment. Common crops grown in agrivoltaic gardens include lettuce, taro, yam cassava, and sweet potatoes. Gauge community interest for crops and ensure that there will be someone to maintain the garden.
- Select an area in the park that is most suitable for agrivoltaics. Agrivoltaics are most favorable on land that has a slope of less than 5 degrees, is south facing, and is within the 20-30-degree range of due south.
- Consider selling crops or flowers grown in the agrivoltaic garden at a local farmer's market, nurseries, or other retail opportunities.

PLASMA GASIFICATION

Editor's Note
Original SWOT tables for each topical subcategory are available in Appendix B of the student content at **links.asu.edu/PCClarkdaleSustainability20F**

In addition to solar energy, the sustainability park could also generate sustainable power through plasma gasification or conversion. A plasma converter is an alternative to a landfill, as it burns waste for energy while diminishing carbon and environmental pollutants. One example of plasma conversion is the creation of biodiesel from algae through an algal fuel facility, where the algae is grown in a controlled environment and converted to fuel oil via plasma conversion. This process yields many benefits, as using biodiesel as vehicle fuel increases energy security, improves air quality, and prevents environmental pollution. A plasma gasification facility in the sustainability park adds another energy efficiency component to the plan and further serves Clarkdale's vision toward economic and environmental strength.

How plasma gasification works

Plasma gasification, or plasma conversion, is the process of using plasma to break down organic matter into its more base elements. Gasification uses high heat to break down organic matter, such as waste, into a more combustible gas (syngas) in an oxygen starved environment. "Syngas or synthetic gas, is a gas mixture of hydrogen, carbon monoxide, and very often some carbon dioxide" (Mariana, 2016). Figure 43 outlines the basics of a gasification system and its outputs, including a natural gas combined cycle power plant. The other output besides syngas is slag from metals present in whatever material is fed into the gasifier. This metallic slag can be separated into usable metals which can then be sold.

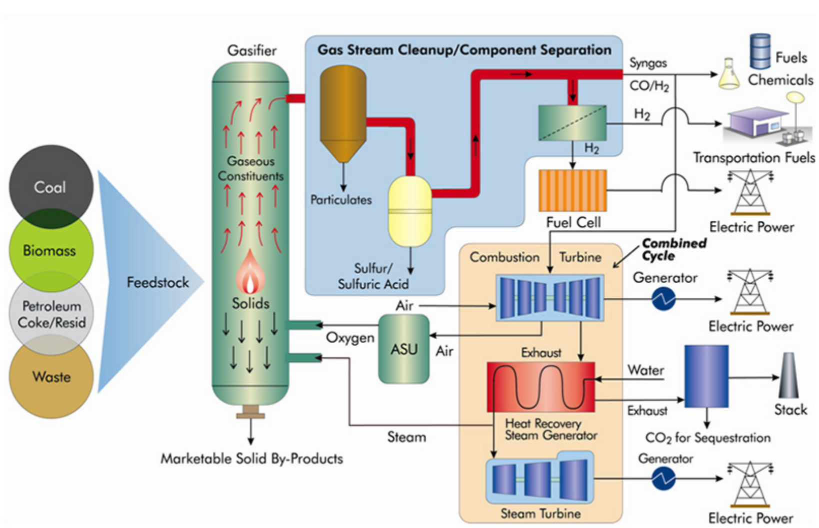


Figure 43 *Plasma gasification process diagram, by National Energy Technology Laboratory*

The most notable use of gasification in history was during World War II, when gasoline was very limited in continental Europe. Wood was abundant, so people found a way to power their cars using it. They would install gasification systems into their cars, which would produce syngas from wood that ordinary combustion engines can run on without modifications.

Plasma gasification is the newest iteration of this technology. Instead of burning coal, gas, or wood to produce the heat necessary for gasification, plasma is used to break down the input materials. Plasma, referred to as the fourth state of matter, is a very high temperature, highly ionized (electrically charged) gas capable of conducting electrical current. Examples of plasma in nature include lightning and gas at the surface of the sun (NETL, n.d.). Since plasma is capable of reaching much higher temperatures than fire, it is more efficient for breaking up other matter into its component elements.

Including a plasma gasification facility in the Clarkdale sustainability park could provide the town, and the greater Verde Valley, with a local outlet for its municipal solid waste (MSW). MSW contains typical items thrown out by homes and businesses, such as product packaging, food scraps, clothing, newspapers, appliances, and paint, among others (Municipal solid waste, 2016). Combined with the already existing recycling facility in Clarkdale, and the plans for a composting center in the park, a plasma gasification facility could help Clarkdale and the Verde Valley become self-sufficient in dealing with much of their MSW.

Syngas produced by a plasma gasification facility could be sold or used in a gas turbine to generate electricity for the town. A cost-benefit analysis should be conducted to determine the potential savings and profitability of a gasification facility. This analysis should take into consideration the amount of waste produced in Clarkdale, as well as the surrounding cities of Jerome and Cottonwood, to determine the recommended size of the facility. Clarkdale may not be able to support this facility alone, hence the inclusion of the other towns and cities of the Verde Valley.

Interconnectedness between each component of the park is crucial to show the relationship between each facility and the benefits provided for Clarkdale residents. There is currently a wastewater treatment plant in the town that produces potable water and could supply necessary electrical power to the plasma gasification facility. According to the Clarkdale sustainability park white paper, the water plant can also supply heat that could be used in a purification process (Town of Clarkdale, 2010).

The sustainability park has the potential to be transformative for the Town of Clarkdale in how it procures its electricity, how its water and wastewater are supplied and treated, and how it fulfills its commitment to economic and environmental sustainability. Energy, environmental, economic, and cultural impacts of a sustainability park are substantial considering the synergistic correlation between projects and facilities.

Case study: Cheongsong, Korea

A 10 ton per day (TPD) gasification facility was constructed and tested in Cheongsong, Korea. The plant had been operating for 3.5 years collecting data for economic and design analysis at the time of the case study. This data was used to generate estimates of how larger 100 TPD facilities might operate. Cheongsong has a population of 30,000 people and produces 15 tons of MSW per day. The 10 TPD facility consisted of 6 main components, listed below.

- Waste feeding system
- Integrated plasma furnace
- Heat exchanger
- Bag filet
- Water quencher and scrubber
- Secondary combustion chamber

The integrated plasma furnace is the key part of the system, as it is where the gasification occurs. The heat exchanger provides cooling to the system, while the bag filter, water quencher, and scrubber filter out toxins in both the syngas and slag outputs. The secondary combustion chamber on this system was included because it did not produce enough syngas to justify a full energy recovery system.

For every ton of MSW put into the furnace, 75.8kg of slag was produced, which equals about 7.8% of the input (Byun et al., 2012). The volume reduction from MSW to slag was up to 99%, as MSW has a density of .09 tons per cubic meter and slag has a density of 2.6 tons per cubic meter. Testing was done on the slag produced from MSW and showed no heavy metals were present, and the material was therefore non-toxic. Air pollution was also measured at two points, the exit from the furnace that the syngas flows through, and the stack. The amount of pollution at the stack was 2,654 Nm3 (normal cubic meters), more than double the amount exiting the furnace due to the facility combining the syngas with LPG (liquid petroleum gas) in a combustion chamber. Due to the small size of the facility, the syngas was not originally used to generate electricity. Later on they combined the syngas output with a 50kW fuel cell and installed systems to make high purity hydrogen. This high purity hydrogen was then used to generate 50kW using the installed fuel cell.

Final thoughts

A 100 TPD gasification facility is a large investment, and as such it is key that all factors be considered. Partnership with the surrounding communities of Cottonwood, Jerome, and Sedona could reduce the cost burden on Clarkdale. A possible option would be to ask for investment up front, and then provide free or discounted service of equivalent value once the facility is in operation. Another viable option would be to enter a public private partnership (PPP), where a private company would operate the town-owned facility. APS could be a good option for a company as they already provide electricity to the area and would have the knowledge to operate and maintain electricity generating facilities.

The gasification facility could also potentially accept sewage so long as it is further processed before entering the plasma furnace (NETL, n.d.). By adding this sewage, and working in conjunction with the composting facility in the sustainability park, Clarkdale could stop paying to have waste removed and use it to produce more syngas, in turn generating more revenue. If the facility is used in concert with the planned solar farm, Clarkdale should be able to produce more than enough electricity for its own use. The solar panels produce the most energy at the same time as peak demand in the summer, so running the gasification plant in the evenings and at night should provide coverage for the whole day and require minimal input to the town from the electrical grid. The waste heat produced by the facility could be used for a secondary turbine and/or be piped to the nearby cement factory in the form of steam. This would reduce the need for burning coal at the cement plant which is beneficial to the plant and the town by saving money and emitting less pollution.

The increase in traffic is a downside to consider, but proper planning allows for Clarkdale to minimize the negative effects. The Town could plan a set route for garbage trucks entering and leaving the facility so as to avoid downtown and tourist areas. In the sustainability park, it would be best to pave a separate back entrance specifically for the plasma gasifier so that its traffic won't be coming through the main entrance that park visitors will be using. The facility should also be constructed in a way that least impacts aesthetics in the town and park. The outer walls could even have a southwestern style façade, or perhaps use living walls and a green roof to better blend in with the natural landscape.

Recommendations for plasma gasification

- Consider constructing a plasma gasification facility in or around the park. Plasma gasification can take various forms, and burns waste to create energy while diminishing carbon and other environmental pollutants.
- Possible ways to implement plasma gasification facilities include algal fuel facilities, where the algae is grown in a controlled environment and converted to fuel oil via plasma conversion.
- The end product of plasma gasification, syngas (synthetic gas), could be sold or used in a gas turbine to generate additional electricity for the town. However, a thorough cost benefit analysis should be conducted to determine the actual benefits for Clarkdale.
- Explore ways to promote interconnectedness with the other components of the park and town. The water used in the gasification process could come from the town's wastewater treatment plant. The town could have much of their waste diverted to the park with the compost facility and the plasma gasification site.
- Forge partnerships with other cities, companies, or government agencies. A 100 ton per day gasification facility is a large investment. Clarkdale could partner with surrounding towns like Cottonwood or Jerome to reduce the cost to Clarkdale. A public-private partnership could also be beneficial by having a private company run the town's facility. APS may be a good option for a company as they already provide electricity to the area and would have the knowledge to operate and maintain electricity generating facilities.

CONCLUSION

As part of ASU's Project Cities program, the Town of Clarkdale and Dr. Chhetri's Urban Sustainability class worked together to design a sustainability park. The residents of Clarkdale deserve a sustainability park that will reflect the town's values and history, while allowing it to transform into the best version of itself. Each of these individual projects are connected with one another and allow visitors to experience the full range of sustainability topics while highlighting the beauty of Clarkdale. This plan provides recommendations for Clarkdale on each of the initiatives. The benefits are outlined along with potential drawbacks and shortcomings. It is meant to guide the town in designing a sustainability park that best reflects their vision.

This report is the result of rigorous research, collaboration, and dedication between students, facilitators, town officials, and outside professionals. Students split into various groups, and from there researched individual topics that they were passionate about. Along with twice weekly class meetings, there were also numerous brainstorming sessions, where information and ideas were shared between students and groups. Meetings and presentations were also held with town officials and course facilitators to understand their perspective and acquire specific information. After reviewing many pieces of literature, reports, articles, and other pieces, students were able to select the most relevant practices and ideas for Clarkdale to utilize in their future sustainability park.

Over the course of the Fall 2020 semester, the class and the Town of Clarkdale built a solid relationship based on mutual enthusiasm for sustainability solutions. As School of Sustainability students, the authors of this report seek to find ways to implement their passions as achievable solutions. With climate change comes a myriad of problems. Focusing on sustainability and new ways forward is more important than ever. This report demonstrates the commitment to sustainability that Clarkdale and ASU have. By building this park and becoming an exemplary model for small town sustainability, Clarkdale can lead the way and show that an ambitious approach to sustainability is not only possible, but desirable.

REFERENCES

Aalok, A., Tripathi, A. & Soni, P. (2008). Vermicomposting: A Better Option for Organic Solid Waste Management. *Journal of Human Ecology. 24*(1), 59-64. **https://doi.org/10.1080/09709274.2008.11906100**

Adeh, E. H., Selker J. S., & Higgins, C. W. (2018, November 1) Remarkable agrivoltaic influence on soil moisture, micrometeorology and water-use efficiency. *PLoS ONE 13*(11): e0203256. **https://doi.org/10.1371/journal.pone.0203256**

Amekudzi, A. (2014). *Green streets, highways, and development 2013, advancing the practice.* Proceedings of the Second Green Streets, Highways, and Development Conference, November 3-6, 2013, Austin, Texas. American Society of Civil Engineers.

Arizona Department of Water Resources. (2020). *Rural Programs.* **https://new.azwater.gov/rural-programs/grants**

Arizona State Parks & Trails. (n.d.). *Apply For Grants.* Retrieved February 01, 2021, from **https://azstateparks.com/apply-for-grants**

Arizona Worm Farm. (n.d.). *Worms and Worm Products.* Retrieved December 08, 2020, from **https://arizonawormfarm.com/red-wiggler-worm-products-2**

Baltazar, N., Che, Y., Du, H., Freelander, B., Hallac, S., Henn, M., Leftwich, N., Li, Y., Lu, Y., Ortiz Cortez, G., Ranallo, S., Sanchez Luna, N., Schultz, L., Stoddard, S., Torain, S., Vu, T., & Zambrano, A. (2020). *Design Principles and Guidelines for the Town of Clarkdale's Downtown District and 89A Commercial Corridor.* Arizona State University School of Geographical Sciences and Urban Planning. **https://sgsup.asu.edu/sites/default/files/2020_final_report_clarkdale_dt.pdf**

Barbosa, G. L., Gadelha, F. D. A., Kublik, N., Proctor, A., Reichelm, L., Weissinger, E., Wohlleb, G. M., & Halden, R. U. (2015). Comparison of Land, Water, and Energy Requirements of Lettuce Grown Using Hydroponic vs. Conventional Agricultural Methods. *International Journal of Environmental Research and Public Health, 12*(6), 6879-6891. **https://doi.org/10.3390/ijerph120606879**

Barron-Gafford, G. A., Minor, R. L., Allen, N. A., Cronin, A. D., Brooks, A. E., & Pavao-Zuckerman, M. (2016, October 13). The Photovoltaic Heat Island Effect: Larger solar power plants increase local temperatures. *Sci Rep 6*, 35070. **https://doi.org/10.1038/srep35070**

Barron-Gafford, G.A., Pavao-Zuckerman, M.A., Minor, R.L., Sutter, L. F., Barnett-Moreno, I., Blackett, D. T., Thompson, M., Dimond, K., Gerlak, A. K., Nabhan, G. P., & Macknick, J. E. (2019). Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands. *Nat Sustain 2*, 848–855. **https://doi.org/10.1038/s41893-019-0364-5**

Beattie, A. (2014). Cost-Benefit Analysis of Food-Waste Composting Program at UMM. *Scholarly Horizons: University of Minnesota, Morris Undergraduate Journal.* **https://digitalcommons.morris.umn.edu/cgi/viewcontent.cgi?article=1000&context=horizons**

Bellini, E. (2020, July 23). Special solar panels for agrivoltaics. *PV Magazine.* **https://www.pv-magazine.com/2020/07/23/special-solar-panels-for-agrivoltaics/**

Biederman, J. (2018). *Small Iowa Town Becomes Model for Rural Stormwater Control.* Concrete Construction. **https://www.concreteconstruction.net/projects/infrastructure/small-iowa-town-becomes-model-for-rural-stormwater-control_o.**

Brinkmann, P. (2019, April 5). *Disney's new solar farm is not-so-hidden Mickey.* Orlando Sentinel. **https://www.orlandosentinel.com/business/os-disney-duke-solar-20160412-story.html**

Byun, Y., Cho, M., Hwang, S., & Chung, J. (2012, October 24). *Thermal Plasma Gasification of Municipal Solid Waste (MSW).* InTechOpen. **https://www.intechopen.com/books/gasification-for-practical-applications/thermal-plasma-gasification-of-municipal-solid-waste-msw-**

Chambers, M. (2020, July 10). *Agrivoltaics: How you can have your kale and eat it too.* Leaders in Energy. **https://leadersinenergy.org/agrivoltaics-how-you-can-have-your-kale-and-eat-it-too/**

City of Flagstaff. (2017). *Northern Arizona Native Plans.* **https://www.flagstaff.az.gov/DocumentCenter/View/58057/Northern-AZ-Native-Perennials_2017-Master-Gardner-Class**

City of Phoenix. (2020). *History of Tres Rios.* **https://www.phoenix.gov/waterservices/tresrios/wetlandsinfo**

Compost Shredder Machine for Sale. (n.d.). Alibaba. Retrieved December 08, 2020, from **https://www.alibaba.com/showroom/compost-shredder-machine-for-sale.html**

Crawler Dozers & Loaders. (n.d.). eBay. Retrieved December 08, 2020, from **https://www.ebay.com/b/Crawler-Dozers-Loaders/97121/bn_1511550**

The Daily Gardener. (2020a, December 3). *Flow-Through Worm Bin: What you need to know.* **https://www.thedailygardener.com/flow-through-worm-bin**

The Daily Gardener. (2020b, December 3). *3 Bin Compost System: Everything you need to know!* **https://www.thedailygardener.com/3-bin-compost-system**

Dickson, N., Richard T., and Kozlowski, R. (1991). *Composting to reduce the waste stream.* Northeast Regional Agricultural Engineering Service. **https://ecommons.cornell.edu/handle/1813/44736**

Dripworks. (n.d.). *Vital Tea Brewer.* Retrieved December 08, 2020, from **https://www.dripworks.com/vital-tea-brewer?gclid=CjwKCAiAkan9BRAqEiwAP9X6UdXYgL7HXPV7BumGR8q5kyfFp6zHHhVg6ZbN3sRLcwICGiKhodTzsxoC2I0QAvD_BwE**

DuPoldt, C., Garber, L., Isaacs, B., Lapp, J., Murphy, T., & Rider, G. (n.d.). *A Handbook of Constructed Wetlands.* U.S. Environmental Protection Agency. **https://www.epa.gov/sites/production/files/2015-10/documents/constructed-wetlands-handbook.pdf**

Dupraz, C., Marrou, H., Talbot,G., Dufour, L., Nogien, A., & Ferad, Y. (2011, October). *Combining solar photovoltaic panels and food crops for optimising land use: Towards new agrivoltaic schemes.* Science Direct. **https://www.sciencedirect.com/science/article/pii/S0960148111001194**

Earl, M. (n.d.). *Temperature: An Essential Ingredient for any Quality Compost Pile.* ThermoWorks. Retrieved December 08, 2020, from **https://blog.thermoworks.com/thermometer/temperature-essential-ingredient-quality-compost-pile/**

EarthWorm Technologies. (n.d.). *What Are The Benefits of Worm Castings in Your Home & Garden?* **https://earthwormtechnologies.com/blogs/organic-gardening-plant-flower-care/what-are-benefits-of-worm-castings-in-home-garden**

Enervolt. (n.d.). *ENERVOLT Solar Golf Cart Kit.* Retrieved February 1, 2021 from **https://enervolt.energy/enervolt-solar-golf-cart-kit-universal-180-watt-180w-48v-solar-panel-battery-charger-kit-for-golf-cart-charge-while-driving-save-electricity-bill-for-lead-acid-golf-carts-or-lithium-golf-carts/**

Fang, K., Agrawal, A., Steele, J., Hunter, J. J., & Hooper, A. M. (2018). *Where Do Riders Park Dockless, Shared Electric Scooters?* San Jose State University Scholarworks. **https://scholarworks.sjsu.edu/cgi/viewcontent.cgi?article=1250&context=mti_publications**

Farm Service Agency. (n.d.). *USDA Announces Grants for Urban Agriculture and Innovative Production.* **https://www.fsa.usda.gov/news-room/news-releases/2020/usda-announces-grants-for-urban-agriculture-and-innovative-production**

Farmtek. (n.d.). *GrowSpan Round Premium Corrugated Greenhouses.* **https://www.farmtek.com/farm/supplies/prod1;ft_greenhouses-ft_professional_greenhouses;pg104933.html**

Fearnley, N. (2020). Micromobility – Regulatory Challenges and Opportunities. *Shaping Smart Mobility Futures: Governance and Policy Instruments in times of Sustainability Transitions*, Emerald Publishing Limited, Bingley, pp. 169-186. **https://doi.org/10.1108/978-1-83982-650-420201010**

Federal Transit Administration (FTA). (n.d.). *Grant Programs.* Retrieved February 2, 2021 from **https://www.transit.dot.gov/grants**

Filatoff, N. (2019, October 14). 90% increased biomass under solar panels: Agrivoltaics hold productive promise. *PV Magazine Australia.* **https://www.pv-magazine-australia.com/2019/10/14/90-increased-biomass-under-solar-panels-agrivoltaics-hold-productive-promise/**

Friends of the Verde River. (2019). *Rain Garden: Stormwater management.* **https://verderiver.org/stormwater-management/**

GAIACA. (2020, May 12). *How to Dispose of Hydroponic Nutrients Safely & Legally.* **https://www.gaiaca.com/dispose-hydroponic-nutrients/**

Gelt, J. (1997, March). *Constructed Wetlands: Using Human Ingenuity, Natural Processes to Treat Water, Build Habitat.* University of Arizona Water Resources Research Center. **https://wrrc.arizona.edu/publications/arroyo-newsletter/constructed-wetlands-using-human-ingenuity-natural-processes-treat-wa**

Georgetown Climate Center. (2020). *Green Infrastructure Toolkit.* **https://www.georgetownclimate.org/adaptation/toolkits/green-infrastructure-toolkit/state-funding.html**

Giacomelli, G.A. (1996). *Designing the greenhouse to fit the needs of the plant, in Proceedings of the Greenhouse Tomato Seminar.* ASHS Press, pp. 7-12.

Goldowitz Jimenez, I. (2020, August 23). *Composting Fruit And Vegetable Waste – Should You Cut Up Compost Scraps.* Gardening Know How. **https://www.gardeningknowhow.com/composting/basics/cutting-up-compost-scraps.htm**

Government of New South Wales. (2007, June 12). *Light in greenhouses.* **https://www.dpi.nsw.gov.au/agriculture/horticulture/greenhouse/structures-and-technology/light**

Green Building Alliance. (2016). *Permeable Pavement.* **https://www.go-gba.org/resources/green-building-methods/permeable-pavements/**

Grogan, J. (2020). (Rep.). America's Legacy Cities: Building An Equitable Renaissance. *Lincoln Institute of Land Policy.* **http://www.jstor.org/stable/resrep24401**

Halverson, N. (2004). *Review of Constructed Subsurface Flow vs. Surface Flow Wetlands.* Westinghouse Savannah River Company Savannah River Site. **https://digital.library.unt.edu/ark:/67531/metadc782197/m2/1/high_res_d/835229.pdf**

Hamdan, H. (2018, October 19). *Hydroponic Systems - Different Types and How They Work.* Trees.com. Retrieved October 2, 2020, from **https://www.trees.com/hydroponic-systems**

Hopkins, H. (2018). *The Brockwood Worm Sifter.* Worm Sifter. Retrieved December 8, 2020, from **https://www.wormsifter.com/**

Irfan, U. (2018). *Electric scooters' sudden invasion of American cities, explained.* Vox. **https://www.vox.com/2018/8/27/17676670/electric-scooter-rental-bird-lime-skip-spin-cities**

Kennedy, B. (2020, August 14). *Americans strongly favor expanding solar power.* Pew Research. **https://www.pewresearch.org/fact-tank/2016/10/05/americans-strongly-favor-expanding-solar-power-to-help-address-costs-and-environmental-concerns/**

The Kratky Method - Grow food the passive Hydroponic Way. (2021, February 01). Trees.com. **https://www.trees.com/gardening-and-landscaping/the-gratky-method**

Li, H., Harvey, J., Holland, T., & Kayhanian, M. (2013). The use of reflective and permeable pavements as a potential practice for heat island mitigation and stormwater management. *Environmental Research Letters, 8*(1). **https://doi.org/10.1088/1748-9326/8/1/015023**

Lime. (2020, January 2). *All About Charging Tasks.* **https://help.li.me/hc/en-us/articles/360015604694-All-About-Charging-Tasks**

Live Green Howard. (2020, April). *Agrivoltaics at CEI Freetown Farm.* **https://livegreenhoward.com/news/agrivoltaics-at-cei-freetown-farm/**

Madsen, R., Richardson, J., & Powney, D. (2020, November 11). *How to Make Perfect Worm Bedding for Thriving Worms.* Worm Farm Guru. **https://wormfarmguru.com/worm-bin-bedding/**

Majumdar, D., & Pasqualettim, M. J. (2018). Dual use of agricultural land: Introducing 'agrivoltaics' in Phoenix Metropolitan Statistical Area, USA. *Landscape and Urban Planning, 170.,* 150-168. **https://doi.org/10.1016/j.landurbplan.2017.10.011**

Mariano, M. (2016). Chapter 5 - Syngas. *Industrial Chemical Process Analysis and Design*, Elsevier. 199-297. **https://doi.org/10.1016/B978-0-08-101093-8.00005-7**

McDonald, L. (2019, August 9). *PV and produce combine-benefits of agrivoltaics.* The American Ceramic Society. **https://ceramics.org/ceramic-tech-today/energy-1/pv-and-produce-combine-benefits-of-agrivoltaics**

McDowell, C. F. (2008). *The Carbon: Nitrogen Ratio (C:N).* Home Composting Made Easy. **http://homecompostingmadeeasy.com/carbonnitrogenratio.html**

Michigan SoilWorks. (n.d.). *Continuous Flow Vermicomposter.* Retrieved December 8, 2020, from **https://michigansoilworks.com/**

Mitchell, R., & Says, S. (2019, August 26). *Turning Compost by Temperature.* Rodale Institute. **https://rodaleinstitute.org/science/articles/turning-compost-by-temperature/**

Nace, T. (2017, July 28). *China just built A 250-Acre solar farm shaped like a giant panda.* Forbes. **https://www.forbes.com/sites/trevornace/2017/07/25/china-just-built-250-acre-solar-farm-shaped-giant-panda/?sh=7d3e3b4b4685**

National Association of City Transportation Officials (NACTO). (2018). *Shared Micromobility in the U.S.: 2018.* **https://nacto.org/shared-micromobility-2018/**

National Association of City Transportation Officials (NACTO). (2020). *Urban Street Stormwater Guide.* **https://nacto.org/publication/urban-street-stormwater-guide/stormwater-elements/green-stormwater-elements/permeable-pavement/**

National Energy Technology Laboratory (NETL). (n.d.). *Gasification Introduction.* **https://www.netl.doe.gov/research/Coal/energy-systems/gasification/gasifipedia/intro-to-gasification**

National Energy Technology Laboratory (NETL). (n.d.). *Plasma Gasification.* **https://www.netl.doe.gov/research/Coal/energy-systems/gasification/gasifipedia/westinghouse**

National Farm to School Network (n.d.) *Resources.* Retrieved November 16, 2020 from **http://www.farmtoschool.org/resources**

National Institute of Food and Agriculture. (n.d.) *Agriculture and Food Research Initiative Competitive Grants Program.* **https://nifa.usda.gov/sites/default/files/rfa/FY2020-AFRI-Foundational-and-Applied-Science-RFA.pdf**

National Institute of Food and Agriculture. (2020, July 17). *Agriculture and Food Research Initiative - Foundational and Applied Science Program.* **https://nifa.usda.gov/funding-opportunity/agriculture-and-food-research-initiative-foundational-applied-science-program**

Natural Resources Conservation Service. (2020). *Conservation Innovation Grants.* Retrieved November 16, 2020, from **https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/**

Ottensmann, J., & Lindsey, G. (2008). A use-based measure of accessibility to linear features to predict urban trail use. *Journal of Transport and Land Use, 1*(1), 41-63. **http://www.jstor.org/stable/26201608**

Oyama, N. (2008). *Hydroponic System for Wastewater Treatment and Reuse in Horticulture* [Unpublished master's thesis]. Murdoch University, Western Australia.

Parkinson, S. & Hunt, J. D. (2020, June). Economic Potential for Rainfed Agrivoltaics in Ground-water Stressed Regions. *Environmental Science and Technology* 7(7), 525-531. **https://doi.org/10.1021/acs.estlett.0c00349**

Pearce, J. M. (2016, February). The Potential of Agrivoltaic Systems. *Renewable and Sustainable Energy Reviews 54*, 299-308. **https://doi.org/10.1016/j.rser.2015.10.024**

Perraki, V., & Megas, L. (2014). *Single Axis Tracker Versus Fixed Tilt PV: Experimental and simulated results.* Researchgate. **https://www.researchgate.net/publication/289941949_SINGLE_AXIS_TRACKER_VERSUS_FIXED_TILT_PV_EXPERIMENTAL_AND_SIMULATED_RESULTS**

Pigott, S. (2019, September 2). *Agrivoltaics Proves Mutually Beneficial Across Food, Water, Energy Nexus.* University of Arizona News. **https://news.arizona.edu/story/agrivoltaics-proves-mutually-beneficial-across-food-water-energy-nexus**

Planet Natural Research Center. (2019, August 29). *Troubleshooting.* **https://www.planetnatural.com/composting-101/making/problems/**

Pueblo County. (2019). *Pueblo County, Colorado Comprehensive Annual Financial Report.* **https://county.pueblo.org/sites/default/files/2020-10/Pueblo_County_Colorado_2019_CAFR.pdf**

Roberts, W. (2004, January 18). *Choosing a Greenhouse.* University of Arizona Controlled Environment Agriculture Center. **https://ceac.arizona.edu/sites/default/files/Choosing%20Your%20First.pdf**

Rollet, C. (2020). *A good year for solar: Agrivoltaics in vineyards.* PV Magazine. **https://www.pv-magazine.com/2020/03/31/a-good-year-for-solar-agrivoltaics-in-vineyards/**

Rosen, S. (2020). *Sample Golf Cart and Utility Vehicle Prices from BuyerZone Buyers.* BuyerZone. **https://www.buyerzone.com/residential/golf-cars/ar-prices-golf-carts/#:~:text=The%20average%20golf%20cart%20%2D%20electric,for%20between%20%242%2C500%20and%20%245%2C000.**

Sawyer, S. (2020, March 19). *Gas Works Park (Seattle).* History Link. **https://www.historylink.org/File/20978**

Schindele, S., Trommsdorff, M., Schlaak, A., Obergfell, T., Bopp, G., Reise, C., ... & Goetzberger, A. (2020, May 1). Implementation of agrophotovoltaics: Techno-economic analysis of the price-performance ratio and its policy implications. *Applied Energy, 265*, 114737. **https://doi.org/10.1016/j.apenergy.2020.114737**

Seed Savers Exchange. (2020). *Cool Season Crops.* **https://www.seedsavers.org/cool-season-crops**

Smart Garden Guide. (2019, September 26). *What Is The Best pH For Hydroponics*? **https://smartgardenguide.com/best-ph-for-hydroponics/**

Solar Energy Industries Association (SEIA). (2020). *Solar Industry Research Data.* **https://www.seia.org/solar-industry-research-data#:~:text=Growth%20in%20Solar%20is%20Led,history%20across%20all%20market%20segments**

The Solar Foundation (2020, February) *National Solar Jobs Census 2019.* **http://www.SolarJobsCensus.org**

Sustainable Cities Network. (2019). *Greater Phoenix Metro Green Infrastructure & LID Handbook.* Arizona State University Global Institute of Sustainability. **https://static.sustainability.asu.edu/giosMS-uploads/sites/22/2019/04/LID2018-Book-04-11-19.pdf**

SolarGreenCompany. (2013). *Solar Powered Golf Carts*. **http://www.solargreencompany.com/Solar_Golf_Cart.php**

Stauffer, B., & Spuhler, D. (2019, June 10). *Hybrid Constructed Wetland.* Sustainable Sanitation and Water Management. **https://sswm.info/water-nutrient-cycle/wastewater-treatment/hardwares/semi-centralised-wastewater-treatments/hybrid-constructed-wetland**

Stewart, R. (2016). T*echnical Aspects of Wetlands, Wetlands as Bird Habitat.* United States Geological Survey. **https://water.usgs.gov/nwsum/WSP2425/birdhabitat.html**

Stowell, H. (2020, January 31). *Making Micromobility Equitable for All.* Transportation Research Board. **https://trid.trb.org/view/1692556**

Sweetser, R. (2019, February 8). *What is Hydroponics?: The Basics of Hydroponic Systems.* The Old Farmer's Almanac. **https://www.almanac.com/news/gardening/gardening-advice/what-hydroponics-basics-hydroponics**

Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., & Zurbrügg, C. (2014, January). *Compendium of Sanitation Systems and Technologies: 2nd revised edition.* Swiss Federal Institute of Aquatic Science and Technology (Eawag). **https://doc.rero.ch/record/309484/files/12-13._Compendium_2nd_Ed_Lowres_EN.pdf**

Tip of the Mitt Watershed Council. (2020). *Permeable Pavers.* **https://www.watershedcouncil.org/permeable-pavers.html.**

Town of Clarkdale. (2010, January 19). *Proposal for the Clarkdale Sustainability Park.* **https://docs.google.com/document/d/1PKJ9Wug_K2DOAuvIM0gFMAovPNJJbLZ0Mi5OP0VgdIU/edit**

Town of Clarkdale. (2011, June 1). *A Comprehensive Economic Development Strategy for Clarkdale.* **https://docs.google.com/document/d/1-Z-Qlr1Ox4p_T4qHgbSog9TWAzy9glkh/edit**

Town of Clarkdale. (2018, October 9). *Sustainable Development Guidelines.* **https://www.clarkdale.az.gov/Town%20Departments/Community%20Development/Sustainable%20Clarkdale/Sustainable%20Development%20Guidelines,%20Adopted.pdf**

Town of Clarkdale. (2018). *2018-2109 Economic Development Plan.* **https://www.clarkdale.az.gov/document_center/PLANS/Community%20Development/2018-19%20Economic%20Development%20Plan%20draft%20with%20public%20comments%20and%20fixes.pdf**

Union of Concerned Scientists. (2011, July 11). *The Hidden Costs of Industrial Agriculture.* **https://www.ucsusa.org/resources/hidden-costs-industrial-agriculture**

University of Arizona College of Social and Behavioral Sciences. (2019, April 18). *UA Agrivoltaics Project Named As a 2018 World Changing Idea.* **https://sbs.arizona.edu/news/ua-agrivoltaics-project-named-2018-world-changing-idea**

University of California Cooperative Extensions (UCCE). (n.d.). *Procedure For Managing the Three-Bin Composting System.* University of California Master Gardeners of Nevada County. **http://ncmg.ucanr.org/files/118303.PDF**

Urban Climate Lab. (2016). *The Benefits of Green Infrastructure for Heat Mitigation and Emissions Reduction in Cities.* The Trust for Public Land. **https://www.tpl.org/sites/default/files/Benefits%20of%20GI%20for%20heat%20mitigation%20and%20emissions%20reductions%20in%20cities.pdf**

U.S. Department of Agriculture. (2009). *Trail and Walkway Design Aid.* **https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=27584.wba**

U.S. Department of Agriculture Rural Development. (2016, September). *Funding for Food Waste Reduction Projects.* **https://www.usda.gov/sites/default/files/documents/RD_Food_Loss_and_Waste_Guide.pdf**

U.S. Energy Information Adminstration (EIA). (2018, March 21). *Solar photovoltaic costs are declining, but estimates vary across sources.* **https://www.eia.gov/todayinenergy/detail.php?id=35432**

U.S. Energy Information Administration (EIA). (2019, October 2). *EIA projects that renewables will provide nearly half of world electricity by 2050.* **https://www.eia.gov/todayinenergy/detail.php?id=41533#**

U.S. Environmental Protection Agency. (2008). *Green Infrastructure Approaches to Managing Wet Weather with Clean Water State Revolving Funds.* **https://www.epa.gov/sites/production/files/2015-10/documents/gi_in_cwsrf.pdf**

U.S. Environmental Protection Agency. (2015). *Clarkesville Green Infrastructure Implementation Strategy.* **https://www.epa.gov/sites/production/files/2015-10/documents/clarkesville_strategy.pdf**

U.S. Environmental Protection Agency (EPA). (2016, March 29). *Municipal solid waste.* EPA Web Archive. **https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/**

U.S. Environmental Protection Agency. (2019). *Green Streets, Green Jobs, Green Towns (G3) Funding Opportunities.* **https://www.epa.gov/G3/green-streets-green-jobs-green-towns-g3-funding-opportunities**

U.S. Environmental Protection Agency. (2020a). *Phoenix and South Tucson to Receive $1.7 Million from EPA for Revitalization of Contaminated Lands.* **https://www.epa.gov/newsreleases/phoenix-and-south-tucson-receive-17-million-epa-revitalization-contaminated-lands**

U.S. Environmental Protection Agency. (2020b). *What is Green Infrastructure*? **https://www.epa.gov/green-infrastructure/what-green-infrastructure**

Wakefield, M., & Hassan, A. (2017). *Pueblo County Cannabis Impact Study.* CSU Pueblo. **https://mountainscholar.org/handle/10217/192586**

Warner Companies. (n.d.). *Sustainable Gardening in Northern Arizona.* **https://warnercompanies.com/wp-content/uploads/2012/04/Sustainable-Gardening-in-Northern-Arizona.pdf**

Water Infrastructure Finance Authority of Arizona. (2020). *Clean Water SRF.* **https://www.azwifa.gov/programs/funding-type/cwsrf.**

Westbrook, A. (2016, February 26). *A-Frame vs. Curved.* Grower Talks. **https://www.growertalks.com/Article/?articleid=22121**

White, C. (2014, July 10). *Agrivoltaics: Farming food and fuel, side by side.* University of Washington Conservation Magazine. **https://www.conservationmagazine.org/2014/07/agrivoltaics/**

Working Worms. (n.d.). *Introduction to Worm Farming.*

http://working-worms.com/

World Population Review. (2020). *Clarkdale, Arizona Population 2020.* **https://worldpopulationreview.com/us-cities/clarkdale-az-population**

Yfantidou, G., & Anthopoulos, P. (2017). Designing of outdoor green recreational parks. *Theoretical and Empirical Researches in Urban Management, 12*(2), 5-18. **http://www.jstor.org/stable/26332367**

To access the original student reports, additional materials, and resources, visit:

links.asu.edu/PCClarkdaleSustainability20F

APPENDIX A

Scope of work

Scope of Work: Sustainable Park

Town of Clarkdale and School of Sustainability

November 06, 2020

Background and objectives

The Town of Clarkdale, in collaboration with Arizona State University's School of Sustainability (SOS), is looking for constructive suggestions on how best to create a sustainability park on a 100-acre plot of land. The School will provide ideas and suggestions on varying projects that can promote sustainability and tourism within the Town.

Design of the sustainability park

The Sustainability Park will be an integrated, interconnected public space that is highly adaptable, and one which promotes community engagement for all ages and provides an immersive experience, through park amenities, facilities, and services.

SOS commitment

Through the Urban Sustainability Class of Fall 2020, SOS will work in four thematic areas. Each thematic area will be interconnected with the other to ensure a synergistic approach. The final product will be a detailed report that includes the theme area with illustrations, followed by cases of similar facilities, and a simple analysis. Prior to the finalization of the full report there will be mid-term check-ins with the leadership of the Town of Clarkdale to ensure that the class is on the right track. The project will function in conjunction with Project Cities.

Town of Clarkdale commitments and responsibilities

Clarkdale will provide support in form of reports and related resources pertaining to the Sustainability Park that include Clarkdale residents and, where possible, allow interaction with leaders to ensure relevant feedback.

Sustainable park design

Integrating sustainable energy systems

Energy will be a prominent feature of the sustainability park. One of these features is the agrivoltaic structure. We will be creating an agrivoltaics structure above the urban garden. We will provide information on solar: tracking vs. fixed, bifacial solar panels, and different types of agrivoltaics available to allow the Mayor and Town Council to make an educated decision. Explain what bifacial panels are and the purpose they can serve in the high-albedo areas of the park. Include alternative solar panels locations such as parking structures, tourist facilities, and restrooms. Present information on Solar Stirling engines which can also provide electrical power.

This would include conducting a cost-benefit analysis, extensive document reviews, and we would also make recommendations on what we think is the best option for the sustainability park. We would also include information on applying for APS's Solar Communities Program, which could help finance the project. Incorporating native plants below the panels to attract wildlife, and possibly provide another tourism feature. A variety of funding mechanisms is provided to help Clarkdale cover the costs of the agrivoltaics.

Another feature is the plasma gasification/conversion facility. The benefits and costs of different sized facilities, and the potential partnerships with the surrounding communities will be analyzed. The opportunities for integration with other systems in place such as composting, wastewater treatment, and solar panels will be explored and evaluated. Surrounding communities could help fund the initial construction in return for cheaper services down the line. Sending municipal waste to a more centralized location in the valley will have significant environmental and financial benefits for not just Clarkdale but the entire Verde Valley.

Urban gardening, hydroponics, and composting

Urban gardening is a growing trend in cities as people are turning to healthier lifestyles and lower carbon diets. This initiative will bring together different members of the town, students, and provide internship and community grant opportunities such as EPA Brownfield Multipurpose, Assessment, or Cleanup (MAC) and grants provided by Arizona State University.

Create a community hydroponic and agrivoltaic garden with a vermicomposting center

The garden and composting project advocates for sustainable cities and communities through partnerships constructed by a cooperative community garden. Through sponsorship of local NGOs it could allow income through sale of produce at farmer's markets and attracting visitors from Jerome by art installations/collaborations. Lifted gardens beds limit interaction from polluted soil while bioremediation processes (composting) help revitalize unhealthy soil quality, this allows for seasonal vegetables to be grown and cold season crops as well.

The vermicompost center could offer visitors an immersive, hands-on learning experience on the value and process of maintaining a vermicompost. Information on different vermicomposting methods and the environmental benefits will be presented. In the report, the process of collecting compostables from the park's compost bins in partnership with the walkability team will be discussed.

Information will be compiled on hydroponic gardening where crops can be grown and be used to both increase the sustainability of local agriculture and the profitability of the local economy. Different methods of hydroponic growth, greenhouse design, crops, and community involvement will be discussed. Existing examples and literature to provide relevant information to Clarkdale will be reviewed. Hydroponic facilities can be the way for Clarkdale to become a tourist and sustainability destination and gain access to the economic boost from Jerome and Sedona tourism.

Creating sustainable infrastructure, education, and tourism

Designing a park that is both sustainable and provides for the revitalization of the town of Clarkdale is the focus of this initiative. The park will provide unique educational and recreational opportunities for visitors and will be an inclusive environment for all ages so that everyone may enjoy all the provided amenities that this park has to offer.

We will focus on creating pathways for community integration allowing this to come to fruition through a report, infographics, and design on what a future industrial park can look like.

It is imperative that these pathways make the park environmentally regenerative where all systems are conducive to the wellbeing of the ecosystem.

Human comfort will be the main focus of the pathways and trails throughout the park. Strategic placement of trees and green infrastructure will be necessary to create shade and reduce the impacts of the desert environment.

Implementing best practices for controlling storm runoff and reducing soil erosion through the installation of green infrastructure will be addressed. These practices will be highlighted by illustrations that will educate park visitors and explain the sustainable practices at work. Furthering the educational focus of the park, placards with QR technology will be used to make learning interactive and easy.

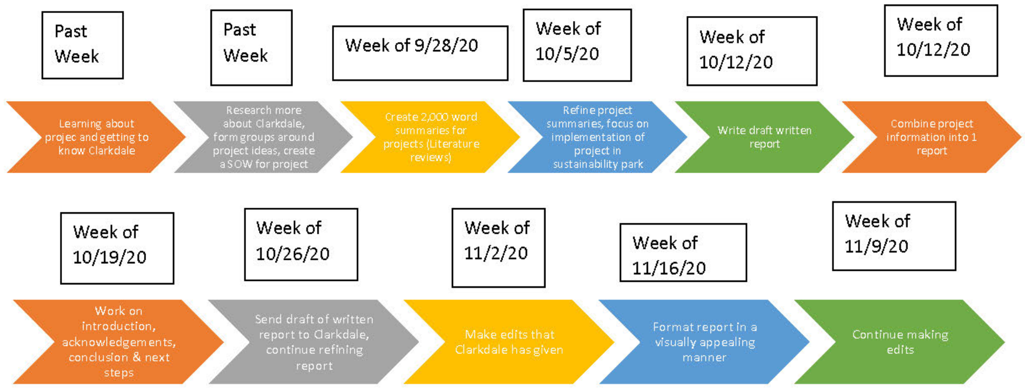
Sustainable development aims to make visitor's experiences as convenient and comfortable as possible. The usability and accessibility of the park will be increased by offering multiple modes of mobility for visitors. The use of e-scooters and solar-powered golf carts will provide visitors with sustainable mobility options. Utilizing solar energy from the park to charge these modes of transport is key in the focus for sustainable practices.

General deliverables

The deliverables will be a **final report with illustrations** showing sustainability features of the park, a 20-25 minutes final presentation at the end of the fall semester recommended future actions and performance goals that are aligned with the SDGs, and a midterm check-in with the leadership of Clarkdale to ensure that the project is on track.

Timeline of deliverables

- Draft presentation and draft report to be submitted by mid November 2020
- Responses and reviews of drafts from the Town of Clarkdale by the end of November 2020
- Final presentation and report at the end of the semester through Project Cities



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Disclaimer

This Scope of Work is solely for the use of the SOS 498/594 class and not a binding legal document between the class and the Town of Clarkdale.

APPENDIX B

Topical subcategory SWOT tables

Community accessibility SWOT analysis	
Strengths	***Weaknesses***
Allows all abilities to enjoy the park's features Incentivizes exercising, good health and well-being Suitable conditions for disabled populations Safety and security	Determining "how accessible" a trail must be Accordance with ADA guidelines and municipal expectations Trail conditions must be maintained and updated on a consistent basis to ensure suitability
Opportunities	***Threats***
Increasing accessibility for older and disabled demographics Aesthetic appeal for the park Incentivize walkability for the whole town Creates centralized hubs around the park More inclusive design in the future such as sensory and auditory design	Trail maintenance Upfront costs Funding for materials

Green infrastructure SWOT analysis	
Strengths	***Weaknesses***
Provides erosion control Provides stormwater management Permeable pavement replenishes aquifers Bioswales include native vegetation Adds beauty and interest to the park	Permeable pavement requires maintenance for peak efficiency Vegetation requires additional inputs (i.e., water, maintenance) Upfront installation cost Limited capacity to offset flood risk
Opportunities	***Threats***
Partnerships with educational institutions Future retail development options Government grants for sustainable initiatives	Climate change impacts green space Stakeholder resistance Funding Limited competition for product offerings

Micromobility SWOT analysis

Strengths	***Weaknesses***
Increases accessibility to those who cannot walk the entire park Adds a fun attraction to the park Provides convenient transportation to visitors Suitable for warmer days where people do not want to walk as much Keeps people in the park for longer periods	May not be suitable for all ages Cannot provide enough e-scooters and golf carts for every visitor Maintenance to make sure vehicles are charges and can run properly Have to give a percentage of profits made to renting company
Opportunities	***Threats***
E-scooters and golf carts can create an attraction point for the park. Generates an additional source of income for Clarkdale Can allow possibilities for more attractions to be placed in the park	May cause injuries if not used safely If mismanaged, there can be property damage Providing funding for e-scooters and golf carts

Composting SWOT analysis

Strengths	***Weaknesses***
Cost savings of waste disposal from hauling Sustainable organic waste management Low operating costs	Upfront capital costs Requires daily monitoring and labor Risk of improper composting methods resulting in contaminated compost, pests, and odor
Opportunities	***Threats***
Expansion into residential composting service for community Increase in job and intern opportunities for students and young adults Retail opportunities for vermicompost products	Could become less economically viable due to private competition Food waste collection contamination and bin placement Labor shortage Stigmatization of composting

Hydroponics SWOT analysis

Strengths	***Weaknesses***
Low resource use Economically viable Low environmental impact Versatile, can grow nearly any crop New industry with high economic potential	High amount of attention and expertise needed to be done effectively Requires construction of greenhouses Used water needs to be disposed of Reliance on electricity and water from Clarkdale
Opportunities	***Threats***
Prop. 207 and cannabis industry Provide cheaper fruits and vegetables for the Town Contributes to Clarkdale's reputation as a sustainability leader and tourism destination	Could become less economically viable due to private competition Power outages or water shortages could jeopardize crops

Constructed wetland SWOT analysis

Strengths	***Weaknesses***
Wastewater treatment Wildlife habitat Flood control	Maintenance Large land area requirements Clogging/undesired odors
Opportunities	***Threats***
Community engagement Bird watching trail Revitalize recreational Pecks Lake area	Contaminants in ground Budget

Agrivoltaic and solar array SWOT analysis

Strengths	***Weaknesses***
New source of clean energy, diversifies Clarkdale's energy portfolio	High initial capital cost
Modular and can easily be moved if necessary	Maintenance
Can be integrated into different parts of the park	Difficulty connecting to electrical grid
Artistic and tourism value	Funding challenges
Conserves resources	Land disturbance
Agrivoltaics increase solar panel efficiency, conserve water, and encourage sustainable food production	Dust build up reduces electricity generation
	Limited produce can be grown via agrivoltaics
	Installing an agrivoltaic garden is more costly than regular solar panels
Opportunities	***Threats***
Local Job opportunities	Weather damage
Solar PV and agrivoltaic education	Legal approval/constraints from the utility
Displays a positive sustainable message	Local and public acceptance or interest
NGO sponsorship	Events that would trip the solar array offline
Community engagement	Funding
Foster connections with Jerome and Cottonwood	Economic leakage
Income opportunity through selling produce grown via agrivoltaics	Slow development

Plasma gasification SWOT analysis

Strengths	***Weaknesses***
Produces energy from waste	High capital cost
Community approval/anticipation	Poor odor from waste input
Works in conjunction with solar panels	Frequent traffic of waste input trucks to and from the site
Opportunities	***Threats***
Contributes to local energy independence	Funding
Can sell electricity at a profit	Changing public opinion
Produce materials/goods for sale	
Local job opportunities	

Agrivoltaics and solar array SWOT analysis

Strengths and opportunities

The primary strength in the solar array and agrivoltaics project is that it provides a valuable source of energy, which is especially valuable for a town with a growing population. It aligns with the Clarkdale sustainability park proposal, which states the importance of having a diverse array of energy sources. Diversifying Clarkdale's energy portfolio makes the grid more resilient and decreases the chances of an energy blackout. In the face of climate change, the choice to incorporate solar panels into the park provides a carbon free energy source, thus helping mitigate the effects of climate change. The only GHG emissions associated with the creation of solar panels are those in the manufacturing phase, but the use phase has zero GHG emissions. Another major benefit of solar is that it is modular and can easily be moved if necessary. This prevents large land disturbance and allows the park to easily adapt to changing needs. Furthermore, both agrivoltaics and the solar array can easily be integrated into different parts of the park. Agrivoltaics demonstrates the food-energy-water nexus, and easily combines with the agriculture and tourism aspects of the park. The solar array targets the tourism aspect of the park and provides artistic value. Agrivoltaics helps conserve water where growing crops, and helps extend the life of the solar panels.

Weaknesses

The main weakness of agrivoltaics and the solar array are their high initial capital cost; this may provide some obstacles to its implementation. The estimated costs for installing agrivoltaics is about $280,000. There may also be funding challenges associated with the two projects. Small solar panels also require annual maintenance. There are also some technical challenges, such as difficulty in having panels connected to the grid. With agrivoltaics, there is an inability to grow all types of crops. There are also challenges in transporting solar panels to the hillside.

Threats

A main threat to solar panels and subsequently an agrivoltaics installation is damage from imminent weather. The various weather events that can impact the systems can include high winds, dust, wildfires, and thunderstorms. Wind can dislodge solar panels from their brackets, possibly requiring panels and wiring to be replaced. Dust in the Arizona climate is a common event, which can cover the panels and lower electrical output. Cleaning panels costs time and water resources.

Oftentimes, it is not financially viable to wash the panels unless there is extreme buildup, which also poses the slight risk of damaging or scratching the panels if not done correctly. It is often best to wait for a rain shower to clean the panels. Other barriers include legal approval and grid connections with APS, the local utility. Substation details and a Power purchase agreement would need to be approved by both parties. Along with the utility acceptance, the public would also need to be aware and accepting of the project since it will be “in their backyard." Lastly, obtaining funding is an obstacle to the solar and agrivoltaic project because if you cannot finance the parts, equipment, and construction, the project cannot get implemented.

Sustainable food system park components

There are many strengths associated with the proposal of a community garden, constructed wetland, composting area, and hydroponic facility within the sustainability park. With the opening of the park comes the potential for an increase in both sustainability and economic development for the town. Focusing on sustainable food systems will be an increasingly important aspect of sustainability in the near future, and it is considered responsible, proactive planning for communities to plan their sustainable food system futures.

Strengths

The primary strengths associated with the selected park elements include new sources of food production with lower resource input. By growing crops hydroponically, Clarkdale can produce food in a quick and inexpensive way as opposed to traditional agriculture. Growing plants in water in a greenhouse reduces the need for space, irrigation, herbicides and pesticides, and equipment. The harvests can go to the residents or tourists through farmers markets or other means. Similarly, the agrivoltaic community garden can generate electricity through the use of solar panels and foster a sense of community without the use of resources associated with typical community gardening. The functionality of a constructed wetland delivers wastewater treatment and wildlife habitat in an Important Bird Area that encourages a bird watching trail as well. Finally, composting can decrease food waste and organic waste hauling fees. Composting also offers the possibility of producing organic fertilizers that could be used throughout the park, garden, and hydroponic center. These three projects in conjunction with one another can greatly increase awareness of the importance of sustainable food systems.

Weaknesses

While there are many strengths that come with the park suggestions, certain weaknesses also need to be taken into consideration. Hydroponic operations of larger size require time, attention, and expertise to be successful. Water and electricity would still need to be used for growth and temperature regulation. Constructing a greenhouse could cost thousands of dollars, as could the solar panels for the agrivoltaic community garden. Growing crops under solar panels requires plants that can tolerate shade, and dust buildup on the panels must be cleaned regularly. A constructed wetland in addition to mimicking a conventional treatment plant if properly built and maintained can demand a substantial amount of land and maintenance to ensure proper performance. The different flows incorporated in a constructed wetland could lead to clogging or unwanted odors, therefore collaboration with educated professionals is critical to build a constructed wetland that successfully functions at its full capacity. Composting can often be seen as unpleasant and can take many months to show benefits. Placing composting bins at the right places in the park will be imperative: too far apart, and the food could be littered or thrown in the regular trash. Too short, and it could create too much work for those who have to empty the bins and create more plastic bag waste. Ensuring residents and visitors compost the right items and continue to participate in the program can also be a challenge.

Opportunities and threats

External opportunities and threats also need to be considered for each of the installations. Low community or tourist interest could affect all four projects. Similar projects could also be implemented in the cities and towns of the surrounding area and reduce tourism to Clarkdale and the town's reputation as a sustainable tourism destination. Private companies could also affect the economic viability of a hydroponic or composting business based in Clarkdale. Despite these threats, many opportunities are still available. The passing of Proposition 207 legalizing recreational cannabis could attract a hydroponic operation that grows cannabis to Clarkdale, turning the town into a destination for this industry in the Verde Valley. While there is a cannabis industry in nearby towns like Cottonwood and Camp Verde, Clarkdale could potentially capture some of this business for themselves. The community garden could foster a connection between Jerome and Sedona and potentially attract Non-Governmental Organization (NGO) involvement in the area. Although Pecks Lake is experiencing eutrophication and is heavily contaminated with heavy metals, dredging the lake and constructing a wetland provides the town of Clarkdale a unique opportunity to revitalize Pecks Lake Area.

Vermicompost products could be sold in the park or possibly to other towns or businesses and have a positive economic impact. Though there are many obstacles to overcome with this project, there is real potential for Clarkdale to become a sustainability destination while economically developing.