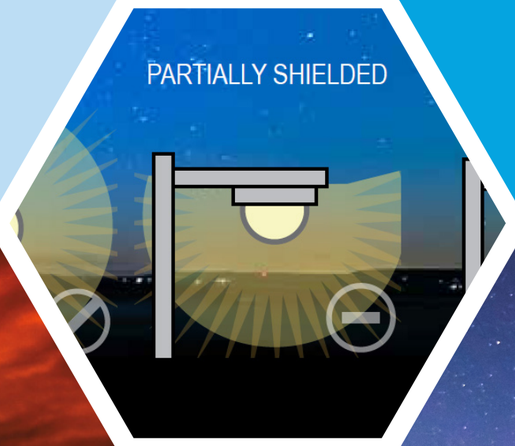
Protecting Peoria Skies: Drafting a Dark Sky Ordinance

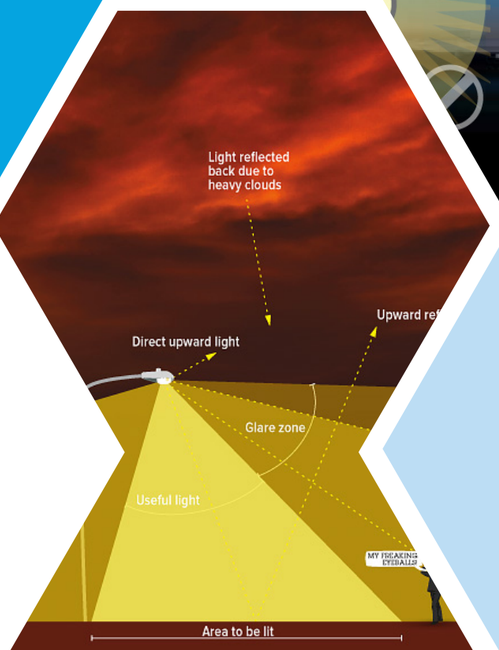
A Fall 2021
Collaborative Project with
Arizona State University's
Project Cities & the
City of Peoria

ASU
Sustainable Cities Network
Arizona State University

Project Cities

PEORIA ARIZONA





PART 1:

Project and Community Introduction

GET TO KNOW THE PROJECT

ABOUT ASU PROJECT CITIES

ABOUT THE CITY OF PEORIA

EXECUTIVE SUMMARY

KEY STUDENT RECOMMENDATIONS

SUSTAINABLE DEVELOPMENT GOALS

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This report represents original work prepared for the City of Peoria by students participating in courses aligned with Arizona State University's Project Cities program. Findings, information, and recommendations are those of students and are not necessarily of Arizona State University. Student reports are not peer reviewed for statistical or computational accuracy, or comprehensively fact-checked, in the same fashion as academic journal articles. Editor's notes are provided throughout the report to highlight instances where Project Cities staff, ASU faculty, municipal staff, or any other reviewer felt the need to further clarify information or comment on student conclusions. Project partners should use care when using student reports as justification for future actions. Text and images contained in this report may not be used without permission from Project Cities.

Cover images:

Project Cities, International Dark Sky Association, and ESRI

ACKNOWLEDGMENTS

City of Peoria

Cathy Carlat, Mayor

Jon Edwards, Vice Mayor

Bill Patena, Mayor Pro Tem

Michael Finn, City Councilmember

Vicki Hunt, City Councilmember

Bridget Binsbacher, City Councilmember

Denette Dunn, City Councilmember

Jeff Tyne, City Manager

Erik Strunk, Deputy City Manager

Katie Gregory, Deputy City Manager

Andrew Granger, Deputy City Manager

Arizona State University (ASU)

Julie Ann Wrigley Global Futures Laboratory

Peter Schlosser, Vice President, Global Futures Laboratory

Meredith Simpson, Director of Operations, Global Futures Laboratory

Dave White, Deputy Director, Global Institute of Sustainability and Innovation

Christopher Boone, Dean, College of Global Futures

Diane Pataki, Director, School of Sustainability

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 City of Peoria 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 Peoria's future livelihood and community well-being.

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To access the original student reports, additional materials, and resources, visit:
links.asu.edu/PCPeoriaDarkSkyOrdinance21F

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.*

PROJECT CITIES TEAM

Director

Anne Reichman
anne.reichman@asu.edu
480-965-2168

Program Manager

Julia Colbert
julia.k.colbert@asu.edu
602-543-1218

Graphic Design Specialist

Lindsey Sikorski
lasikors@asu.edu

SCN Program Assistants

Samuel Dent, Master of Sustainability Solutions

Kate Hartland, Master of Sustainability Solutions

Project Cities Program Assistant

Alison Almand, Master of Science in Community Resources and Development

ASU Sustainable Cities Network
Arizona State University

Project Cities

Sustainability through local action

ABOUT PEORIA

Ranked as the No. 1 place to live in Arizona by Money Magazine, the City of Peoria is currently home to over 191,000 residents. The City enjoys a reputation as a family-oriented, active community with an exceptional quality of life. Peoria entertainment and recreational amenities include attractions such as Lake Pleasant, trails, and community parks.

The City has also demonstrated a strong commitment to sustainability, as evidenced by its incorporation of LEED building design standards, a council-adopted Sustainability Action Plan, and the "Green Team" staff dedicated to managing organization-wide sustainability initiatives.

PEORIA TEAM

Project Cities Community Liaison

Sharon Roberson, Assistant to the City Manager, City Manager's Office

Peoria Project Leads

John Sefton Jr., Parks, Recreation, and Community Facilities Director

Jay Davies, Interim Public Works Director

Kristina Perez, Digital Media Manager

Sharon Roberson, Assistant to the City Manager, City Manager's Office

Cathy Colbath, Transit Manager

Chief Bobby Ruiz, Fire-Medical Department

Lorie Dever, Planning Manager

Aaron Redd, Solid Waste Manager

Cody Gleason, Principal Planner

Peoria is the place
World class ▪ Sustainable ▪ Future Ready

peoriaaz.gov

8401 West Monroe Street
Peoria, Arizona 85345
T 623.773.7300
F 623.773.7309

February 28, 2022

Dear Peoria community members,

On behalf of the City of Peoria, we would like to express our appreciation to all who have been involved with Arizona State University's (ASU) Project Cities program. Over the last year, our staff has had the opportunity to collaborate with faculty and students across several academic programs, benefitting from their insights, ingenuity, and diverse perspectives on a number of projects. Many of these entailed public participation, and you may have met some of these engaging students at a community event, or completed a community survey.

Project Cities is one of several partnerships we enjoy with ASU, and part of our ongoing strategy to connect with community partners to leverage our resources as we address the many challenges facing local governments. Working with students at an undergraduate, graduate and capstone project level brings a fresh perspective and resourcefulness to complex issues. This partnership has resulted in extensive research, recommendations, and deliverables that take several key initiatives to the next level. These include our efforts around increasing transit ridership, community engagement strategies, historic preservation and innovative recycling methods. Through this partnership, we have developed an understanding of the feasibility of each initiative much more quickly than we could have without their collaboration.

The results provided on each project position us to serve our community with cost-effective and innovative programs in the interest of continuous improvement. The city has already begun to incorporate the students' deliverables into next steps in advancing these projects. We look forward to continuing this work on additional projects in the coming year with such talented students and faculty.

The City of Peoria appreciates the ongoing and growing relationship with Arizona State University and the many ways in which the alliance provides mutual value.

Sincerely,

Cathy Carlat, Mayor

Jeff Tyne, City Manager

Peoria, Arizona

Rio Vista Recreation Center

Demographics

total population: **190,985**

median age: **35**

highly skilled and educated workforce of 85,252

11,997 veterans live in Peoria

78% of residents are homeowners

median property value: **$399,025**

33% of residents hold a Bachelor's degree or higher

median household income: **$79,700**

Schools

#3 of 131 Best School Districts for Athletes in Arizona

#5 of 40 Best School Districts in Phoenix Metro Area

#7 of 130 Best School Districts in Arizona

The Peoria Unified School District consistently receives high ratings and offers signature programs such as the Career and Technical Education programs. Deer Valley Unified School District has two highly-rated K-8 schools within the city, including an Academy of Arts.

Peoria is also home to Huntington University, a liberal arts college offering digital media education in animation, broadcasting, film, graphic design and other digital media arts.

Leading industries

Peoria, Arizona is not just a scenic suburb of Phoenix, but also a thriving economic development hub with an educated workforce and high-end residential living. There are over 4,000 employers and more than 75,000 people employed within Peoria. Leading industries include health care and social assistance, retail trade, and finance and insurance. Highest-paying industries include utilities, manufacturing and public administration. Beyond these industries, Peoria works actively to attract businesses from aerospace and defense, film and digital media, technology and innovation, hospitality and tourism, and research and development. Peoria is the place for business owners, developers and investors.

Health Care & Social Work
10,905 employees

Retail Trade
10,628 employees

Finance & Insurance
6,574 employees

History

Founded in 1886 by Midwestern settlers, Peoria is nestled in the Salt River Valley and extends North into the foothills around Lake Pleasant. Beginning as a small agricultural town, the economy received a major boost when a railroad spur line was built along Grand Avenue. The construction of the Roosevelt Dam in 1910 secured a reliable water supply, attracting more settlers to the area and business endeavors to the town center. Peoria's economy continued to have an agricultural focus for decades. Continually growing, Peoria assumed city status in 1971 with a population of 4,792. It has since grown into a city with a population over 190,000, and is renowned for its high quality of life and recreational amenities.

Sustainability

Peoria has demonstrated leadership in municipal sustainability efforts through a wide range of actions. Listed below are some of the City's sustainability accomplishments.

- Incorporation of LEED building design standards
- Appointment of a full-time city staff member who manages and coordinates sustainability initiatives
- Sustainable urban planning practices including open space planning and water management principles
- Sustain and Gain: Facebook page and brochures keep residents up to date on city sustainability efforts and ways to get involved
- Water Conservation Program: free public classes, public outreach at city events, and water rebate incentives for residents
- Council-Adopted Sustainability Action Plan: this strategic planning document, in its second iteration, ensures city departments are developing sustainability-oriented goals, tracking success metrics, and encouraging cross-communication in the preparation of Sustainability Update presentations made to the Peoria City Council on an annual basis
- Sustainable University: courses and workshops to empower residents to make small changes that make Peoria a better place to live; topics covered include residential solar, gardening, composting and recycling

Awards and recognition

- Number One City to Live, Work and Play in 2021 *(Ranking Arizona)*
- Received three Crescordia awards by Arizona Forward at the annual Environmental Excellence Awards in 2016
- 12th City for Green Space in the U.S. in 2019 *(Wallethub)*
- Top 15 Safest Cities in the U.S. 2017-2019 *(Wallethub)*
- 6th Wealthiest ZIP Code in 2020 *(Phoenix Business Journal)*
- Top 50 Hottest Hoods in 2018 *(Phoenix Business Journal)*
- 10th Best City to Raise a Family in 2018 *(Wallethub)*
- Top 100 Golf Course in U.S. 2017-2019 *(Golf Digest)*

Lake Pleasant

1886 — Peoria founded by William J. Murphy

1889 — First school district formed

1919 — Chamber of Commerce organized

1954 — Peoria incorporated

1971 — Assumed city status with a population of 4,792

1977 — Brewers spring training begins at Greenway Sports Complex

1986 — Centennial celebration

1994 — Peoria Sports Complex opened

2007 — Theater for the Performing Arts and Rio Vista Recreation Center opened

2012 — 20-year extension spring training agreement with San Diego Padres and Seattle Mariners

2017 — Selected as site of new $70M health clinic for Maricopa County Integrated Health System

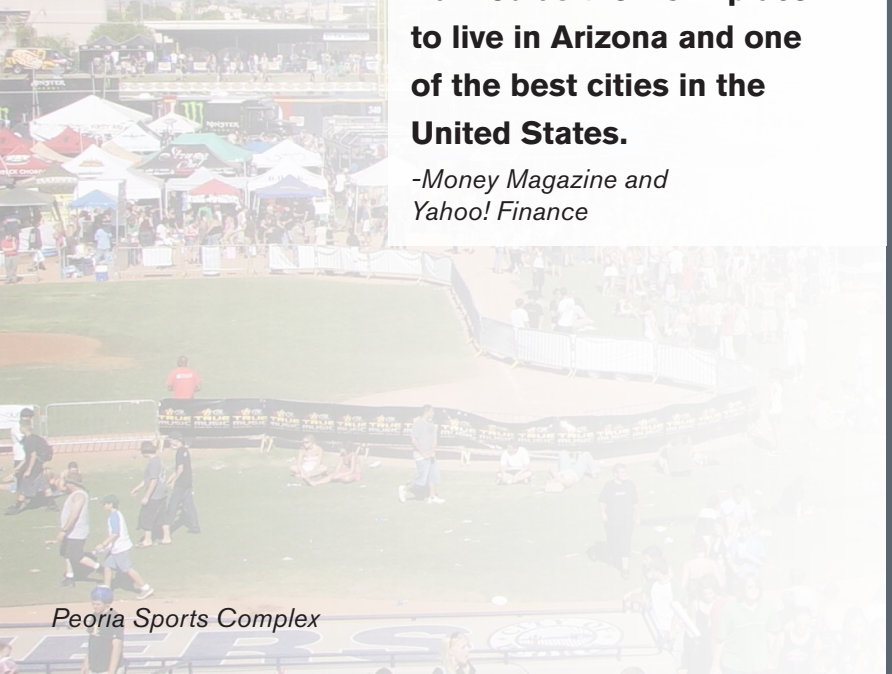
2020

Livability

Peoria is renowned as a great place to raise a family and start a career. A plethora of local amenities and attractions contribute to Peoria's livability. Beyond the tourist attractions of Spring Training and Lake Pleasant, the City offers many community facilities and recreational opportunities for all ages and interests such as an extensive public park system and annual community events. Peoria's dedication toward livability is also evident in the City's latest General Plan which addresses sustainable water use, housing, public services and more.

Ranked as the No. 1 place to live in Arizona and one of the best cities in the United States.

-Money Magazine and Yahoo! Finance



Peoria Sports Complex

Peoria strives to uphold these six major livability priorities in order to maintain an exceptional quality of life for its citizens:

- Arts, Cultural and Recreational Enrichment
- Economic Prosperity
- Smart Growth
- Superior Public Services
- Healthy Neighborhoods
- Integrated Transportation

Community Facilities

- Peoria Community Center
- Rio Vista Recreation Center
- Peoria Sports Complex
- Peoria Center for the Performing Arts
- 39 neighborhood parks
- 2 libraries
- 3 swimming pools
- 5 golf courses
- 9 lighted multi-purpose ball fields
- 15 tennis courts

Lake Pleasant

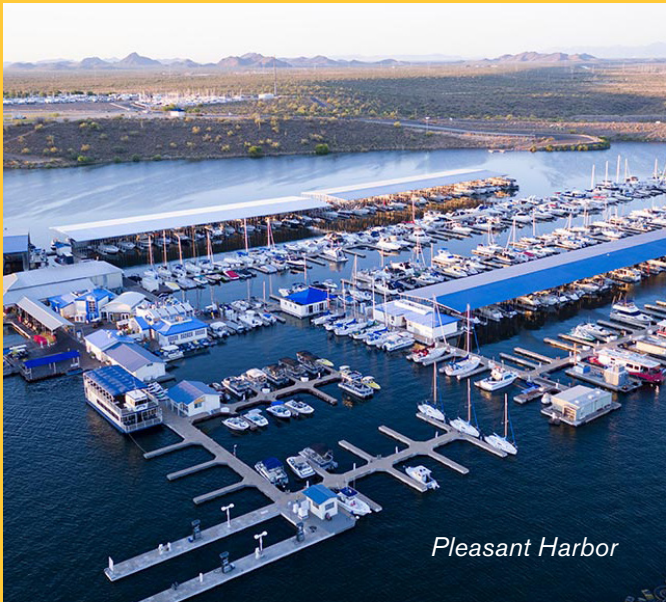
Urban ecology, ecotourism and recreation

Peoria is surrounded by the natural beauty of the Sonoran Desert and is home to Lake Pleasant, a 23,000-acre park and major recreational asset to the North Valley. The transient Agua Fria River and New River flow through Peoria, as do a multitude of washes and creeks. Most notable perhaps is Skunk Creek — known for the recreational trails running alongside it — which forges a connection between Peoria and Glendale. Northern Peoria is home to beautiful mountains and buttes including Sunrise Mountain, Calderwood Butte and Cholla Mountain.

Boasting over 300 days of sunshine annually, Peoria's ecotourism opportunities are a steady industry for residents and visitors. The City features over 60 miles of trails for walking, biking and horseback riding, as well as 570 total acres of accessible park land.

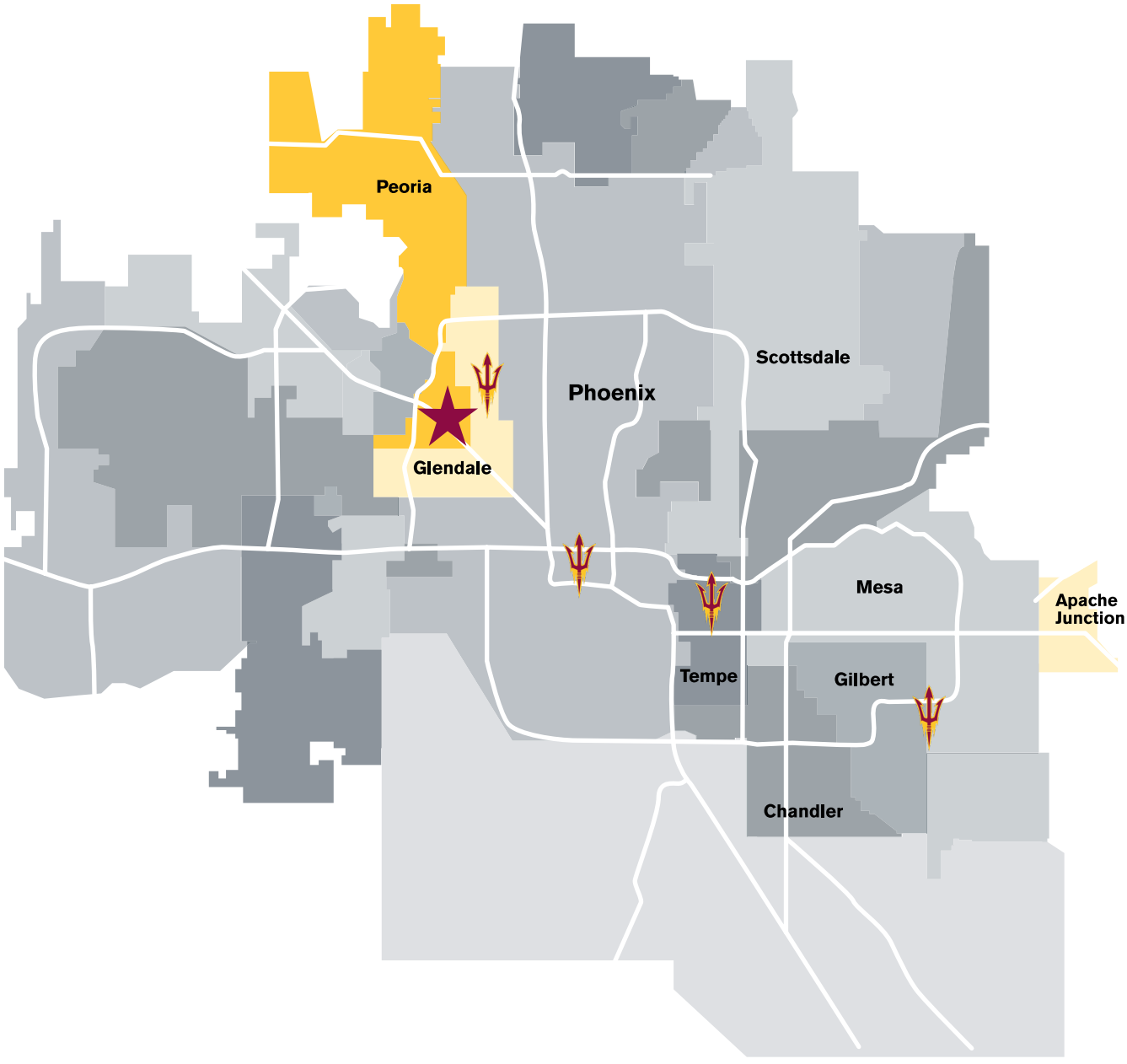
Lake Pleasant Regional Park contains a full-service marina, providing opportunities for water-oriented recreation such as kayaking, water skiing and even scuba diving. Visitors can also go horseback riding, take gliding lessons, hike, camp and more.

Skunk Creek



Pleasant Harbor

MAP OF PROJECT CITIES PARTNER COMMUNITIES IN THE GREATER PHOENIX METROPOLITAN AREA



Peoria City Hall

ASU campus

The following report summarizes and draws highlights from work and research conducted by students in SOS 498/594 Urban Sustainability Best Practices Application for the Fall 2021 partnership between ASU's Project Cities and the City of Peoria.

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

links.asu.edu/PCPeoriaDarkSkyOrdinance21F

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Sustainability through local action

EXECUTIVE SUMMARY

The City of Peoria, Arizona is located in Yavapai and Maricopa County, approximately thirty minutes from Downtown Phoenix in the Sonoran Desert. Originally founded as an agricultural community, Peoria has experienced an abundance of growth and urban development, causing an increase in artificial light and light pollution. Peoria is exploring possibilities to earn Dark Sky Designation with a Dark Sky Ordinance to enhance the City's sustainability and quality of life for all living beings. The City partnered with Arizona State University's **SOS 594/498: Urban Sustainability Best Practices Application** class, taught by Nalini Chhetri and Anne Reichman, to provide supporting information on the matter in the form of a report and an infographic summary. Two students worked together throughout the Fall 2021 semester to research the International Dark Sky Association (IDA), conduct literature reviews, hold subject-matter expert interviews, and compile their findings into a feasible set of recommendations for the City of Peoria to consider.

This report provides a background on benefits and requirements of Dark Sky protection and examines possible future measures. The research is built upon the IDA certification program for International Dark Sky Communities (IDSC) which defines six criteria essential to fighting light pollution. For each of these criteria possible measures are evaluated and recommendations specified. Lastly, the report contains a timeline of action, outlining Peoria's next steps if they choose to become a certified IDSC.

Figure 1 *Milky Way as seen from certified IDSC Flagstaff, Arizona*

This research is of interest for Peoria's community as a whole because light pollution affects local wildlife, human health, energy consumption, and other important factors. Pursuing Dark Sky designation can help the City continue functioning as a leader in sustainability, especially for communities in the Southwestern United States. Students intend for the information in this report to help city staff progress toward becoming a Dark Sky Community in an informed and straightforward manner.

KEY STUDENT RECOMMENDATIONS

General recommendations	Read more
Engage with the International Dark Sky Association and utilize its available resources.	pp.38-40, 42-46, 50-65
Work towards becoming a certified International Dark Sky Community through the IDA, by following the remaining specific recommendations in this report.	pp.37-39, 42-45, 50-67

Recommendations for drafting a Dark Sky Ordinance	Read more
Draft Peoria's Dark Sky Ordinance upon the Lighting Codes from Cottonwood and Sedona, and consider alterations and additions as specified in the adaptable lighting policies.	pp.42-46, 66-67
Introduce at least two different lighting zones (more protective in the North and more artificial light in the South) based on Flagstaff's approach.	pp.42-46
Work together with a Dark Sky representative.	pp.42-46
Give the community the opportunity to comment on the draft of the Ordinance and voice wishes and concerns.	pp.42-46

Recommendations for drafting a Dark Sky Ordinance	Read more
Assure support for the Dark Sky effort within the local government of Peoria, including the Mayor, members of the City Council, the Sustainability Consultant, as well as the Green Team.	pp.47-48, 51-53
Communicate Peoria's interest in protecting the Dark Sky early on to the community via Social Media, the City's website, flyers, and ads.	pp.47-49, 60
Include Dark Sky protection in Peoria's new *Sustainability Action Plan*.	pp.25, 49-50, 60
Compile a timeline for city compliance with the Dark Sky lighting regulations.	pp.49-50, 60-62
Outline an inventory of the current city-owned lighting.	pp.50-51, 61
Specify Phosphor Converted Amber (PCA) LEDs as the preferred standard for city-owned lighting.	pp.37, 50-51

KEY STUDENT RECOMMENDATIONS

Recommendations for fostering community engagement	Read more
Conduct a survey among all residents to assess the communities' needs, wishes and concerns.	pp.24, 46, 51-52, 61
Identify the most relevant stakeholders and include them in the Dark Sky protection efforts as early as possible.	pp.47, 51-54, 60-61

Recommendations for educational efforts	Read more
Start compiling, planning, and publishing Dark Sky Awareness documents as soon as possible.	pp.55-56
Aim to host one awareness event per month.	pp.38-39, 41, 55-56, 59-61

Recommendations for light pollution control	Read more
Review and adapt the already established due diligence process for new construction sites based on the Dark Sky Ordinance.	pp.6-57, 61-62
Raise awareness and transparently position and communicate the light pollution control process for construction applications.	pp.38-39, 41-42, 57, 61-62

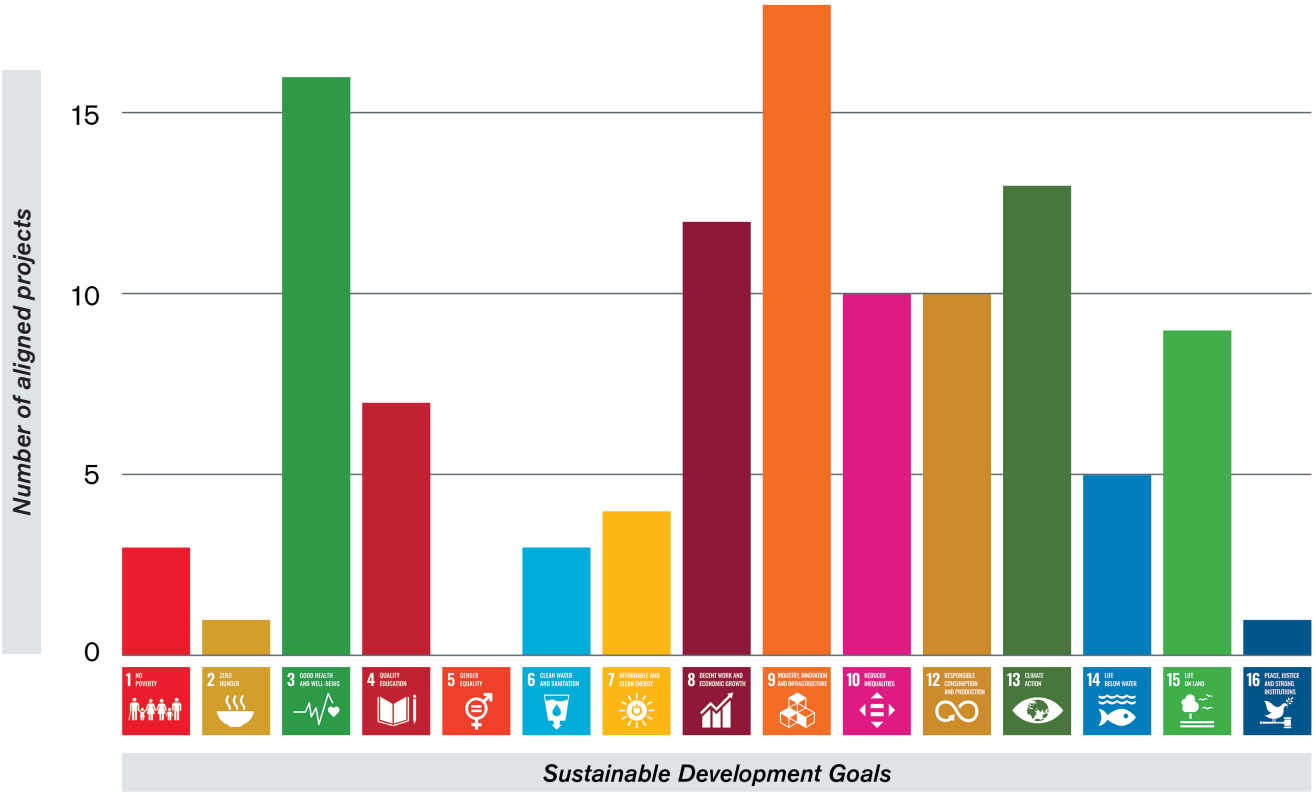
Recommendations for measuring sky brightness	Read more
Invest in at least one Sky Quality Meter device and complement the more qualitative assessment approaches with it.	pp.57-59
Conduct a sky brightness measurement together with the community as an educational activity.	pp.38-39, 41, 57, 59, 61

CITY OF PEORIA 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 City of Peoria's partnership with Project Cities, through the Fall 2021 semester.



TOP THREE GOALS ADDRESSED IN THE FOLLOWING REPORT

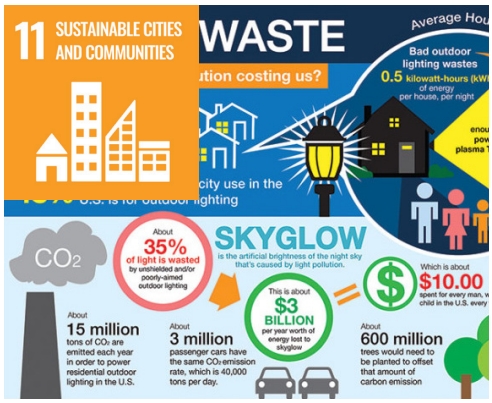
In this project, students outline key actions and recommendations the City of Peoria can take to work toward developing a Dark Sky Ordinance and becoming a certified International Dark Sky Community. The research aims to help Peoria move forward with a Dark Sky initiative as another contribution to local sustainability and quality of life.

Outdoor Lighting, Crime, and Safety

Goal 3: Good Health and Well-Being

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

Informed lighting decisions can affect physical health, environmental health, and contribute to increased outdoor safety.



Goal 11: Sustainable Cities and Communities

"Make cities and human settlements inclusive, safe, resilient and sustainable."

Excessive outdoor lighting can contribute to massive wastes of energy. By complying to Dark Sky guidelines, Peoria can reduce its energy usage and carbon footprint.

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."

Avoiding constant bright lighting can benefit local ecosystems including nocturnal animals and insects.

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PART 2:

Municipal Actions to Protect Peoria's Dark Skies

ORDINANCE DRAFTING SUGGESTIONS TO DECREASE LIGHT POLLUTION

SOS 498/594:
URBAN SUSTAINABILITY BEST PRACTICES APPLICATION

SCHOOL OF SUSTAINABILITY

FACULTY
NALINI CHHETRI & ANNE REICHMAN

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Faculty

Nalini Chhetri

Anne Reichman

Students

Devynn Glanz

Sophia Schröder

Editors

Alison Almand

Lindsey Sikorski

Julia Colbert

Anne Reichman

Peoria Staff Team

Lorie Dever

Cody Gleason

Sharon Roberson

PROJECT DESCRIPTION

The City of Peoria is exploring the opportunity of becoming a Dark Sky designated community with an aim to provide eco-friendly development standards while ensuring a high quality of life for Peoria residents. On this endeavor, Peoria is partnering with Arizona State University (ASU) and the Urban Sustainability Best Practices Application (SOS 498/594) class with sustainability science and urban planning students, through the Sustainable Cities Network and Project Cities program. Lorie Dever, Planning Manager, and Cody Gleason, Principal Planner, from Peoria's Zoning & Planning department are the city leads for this project.

The overall objective of this report is to provide Peoria with a solid basis of research to make an informed decision about more robust Dark Sky regulations and measures. The project does not only aim to support Peoria with advancing its Dark Sky Ordinance, but also focuses on fostering community engagement and education.

METHODS

To provide Peoria with a thorough assessment of possible measures to advance its Dark Sky efforts, this project follows four steps as described in Figure 1.

Dark Skies project plan

Step	*Details*
Step 1: Background	Building a common understanding through background information on: ▪ The City of Peoria ▪ Light pollution ▪ Benefits of Dark Skies ▪ Dark Sky protection ▪ Dark Sky efforts of the International Dark Sky Association (IDA)
Step 2: Gap assessment	Conducting a gap assessment of Peoria's current Dark Sky measures in relation to the requirements the IDA defines for a Dark Sky Community
Step 3: Measures and recommendations	Assessing possible measures to advance Peoria's Dark Sky efforts and specifying recommendations for Peoria
Step 4: Outlook	Providing an outlook and timeline of compliance for a possible application submission to become a certified International Dark Sky Community through the IDA

Figure 1 *Four-step project plan*

Editor's Note
Grey literature refers to information published outside of commercial publishers, such as conference proceedings, policy documents, or working papers.

Different sources were consulted for each step as outlined below:

- Scientific literature and journal articles
- **Grey literature**, Peoria's website, the International Dark Sky Association (IDA) website, and other Dark Sky advocate or Community websites
- Exchanges with Lorie Dever, planning manager for the City of Peoria, Cody Gleason, principal planner for the City of Peoria, and Marylou Stephens, arts and events planner
- Information from Victoria Caster, Peoria's Sustainability and Water Conservation Coordinator as shared in the Sustainable Cities Network Climate & Resilience Workgroup on 10/25/21
- An expert interview with Christian Luginbuhl, a retired astronomer from the U.S. Naval Observatory who is part of the Flagstaff Dark Skies Coalition (For the full list of interview questions, see Appendix A of the original student content at **links.asu.edu/PCPeoriaDarkSkyOrdinance21F**).

While the Omnibus survey of Peoria's residents conducted in October 2021 did contain questions about Dark Skies and light pollution, the results were not incorporated into this report due to a low number of participants (n=2). However, the questions are available in Appendix B in original student content (available at **links.asu.edu/PCPeoriaDarkSkyOrdinance21F**) as a resource for the City of Peoria to leverage for future resident surveys about Dark Skies and light pollution.

BACKGROUND

Peoria

The City of Peoria is located in Yavapai and Maricopa Counties in Arizona, approximately thirty minutes from Downtown Phoenix. The City is situated in the Sonoran Desert, which is home to diverse natural resources and wildlife. Originally established as an agricultural community in 1886, Peoria has been rapidly growing since its incorporation in 1995, expanding into the ninth largest city in Arizona. As of 2020, 191,000 people live in Peoria on approximately 179 square miles. Over the past few years, Peoria has received several awards and accolades, for example No. 1 city to live, work and play in Arizona in 2021, and top 15 safest cities in the United States (City of Peoria, n.d. a).

In addition to upholding and further improving the well-being of its citizens, Peoria is also committed to sustainability and wants to minimize its effect on the environment together with its citizens. Peoria is following a *Sustainability Action Plan* that was updated in 2016 to fulfill the sustainability mission statement:

"The City of Peoria will be the leader in developing, promoting and improving the quality of life in our community by balancing today's use of natural resources with the needs of tomorrow through environmental stewardship and sustainable practices" (City of Peoria, 2016, p.2).

This *Sustainability Action Plan* of 2016 does not contain any reference to light pollution or Dark Skies. However, a new version of the *Sustainability Action Plan* is currently in development. The formation of the new plan is community-driven and based on feedback from Peoria residents (Caster, 2021; City of Peoria, n.d. b).

Peoria's ambitions to advance its sustainability efforts manifests itself in the Peoria "Green Team" which is initiated and led by Victoria Caster, who holds the position of Sustainability and Water Conservation Consultant. The Green Team works on fostering city-wide ownership of sustainability and consists of staff from various departments within Peoria, including Community Health & Wellness, Parks, and Neighborhood Services. Meetings for this group usually take place once or twice per month (Caster, 2021).

The following Figure 2 shows characteristics of Peoria in comparison to the U.S. average.

Peoria demographic characteristics

Demographic	*Peoria*	*United States*
Median age	39.8	38.5
Median household income	$75,323	$65,712
Poverty rate	7.5%	12.3%
Median property value (2019)	$264,500	$240,500

Figure 2 *Demographic characteristics of Peoria in comparison to U.S. average, by Data USA, 2019*

As shown in Figure 3, Peoria is geographically widespread, with urban areas concentrated closer to Glendale and Phoenix in the south as well as areas up north, which include the Lake Pleasant Regional park.

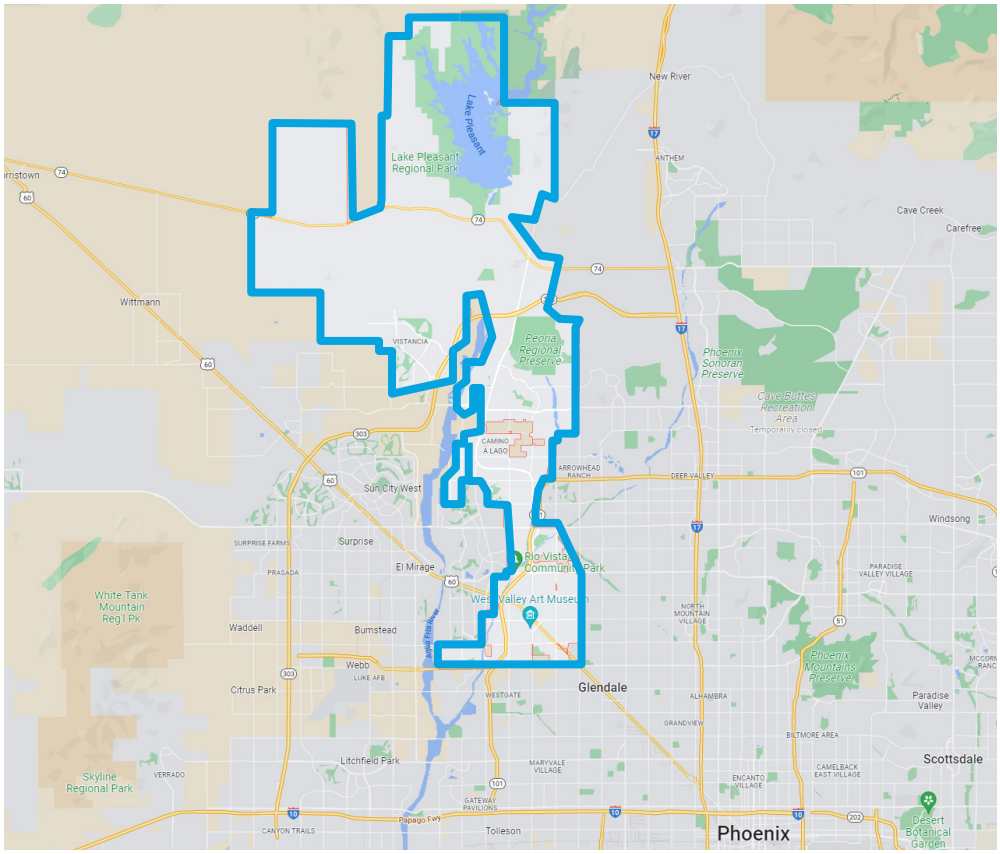


Figure 3 *City limits of Peoria, by Google Maps, 2021*

Light pollution

Ninety-nine percent of the U.S. and European populations are exposed to light pollution. Light pollution is defined as “the alternation of night natural lighting levels caused by anthropogenic sources of light” (Falchi et al., 2016, p.1). However, in this research, a more broad understanding will be utilized where light pollution refers to “inappropriate or excessive use of artificial light” (IDA, n.d. j). Light pollution is a widespread and rapidly increasing form of human interference with the environment, occurring synonymous with population growth, urbanization, and human development (Cinzano, Fachi, & Elvidge, 2001; Workforce Services & Colorado Plateau Dark Sky Cooperative [CPDSC], 2020). Being closely associated with modernity and security, the use of artificial light at night was seldom questioned (Meier, Pottharst, Krause, & Hasenöhrl, 2015) and has only recently gained more attention (Falchi et al., 2016).

As listed below and illustrated in Figures 4 and 5, light pollution has different components, including:

- **Light trespass:** Light falling where it is not intended or needed
- **Glare:** Excessive brightness causing visual discomfort
- **Clutter:** Bright, confusing and excessive groupings of light sources
- **Skyglow:** Brightening of the night sky over inhabited areas (IDA, n.d. j).

Thus, contrary to the common perception, light pollution entails much more than night visibility (Workforce Services & CPDSC, 2020).

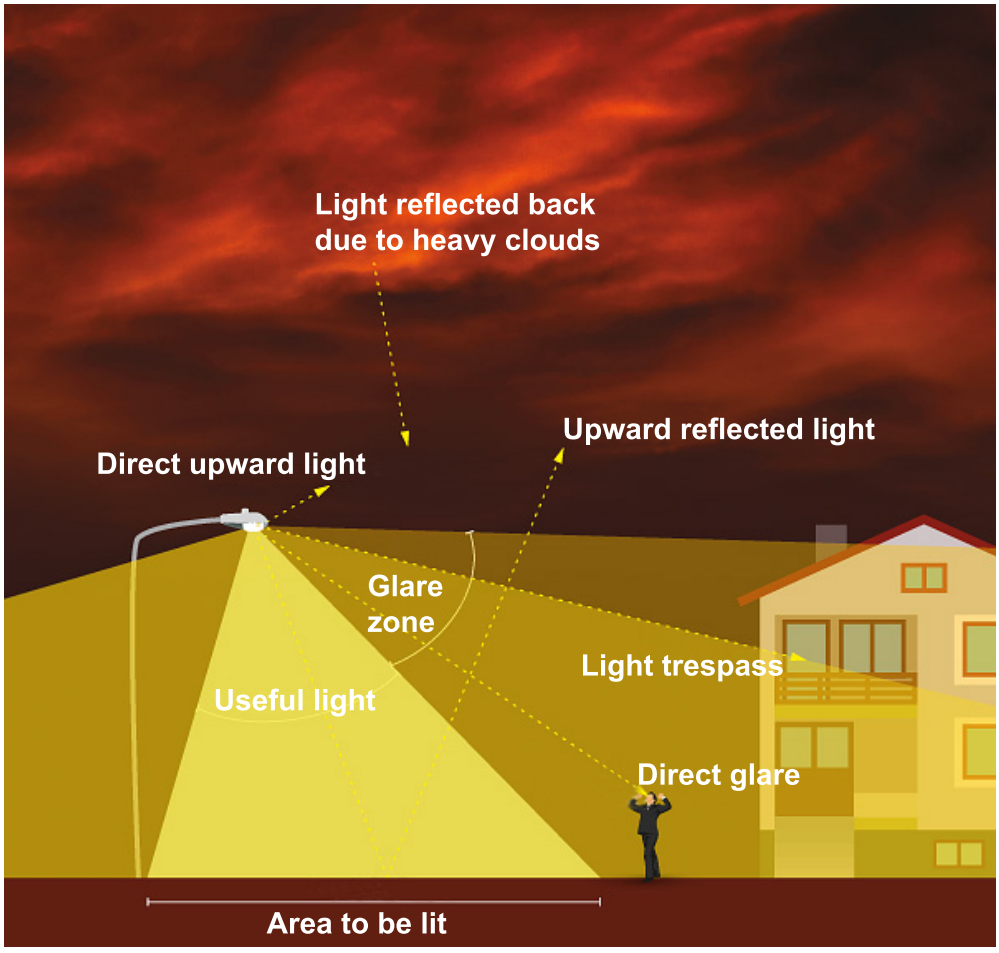


Figure 4 *Components of light pollution, by IDA, n.d. h*

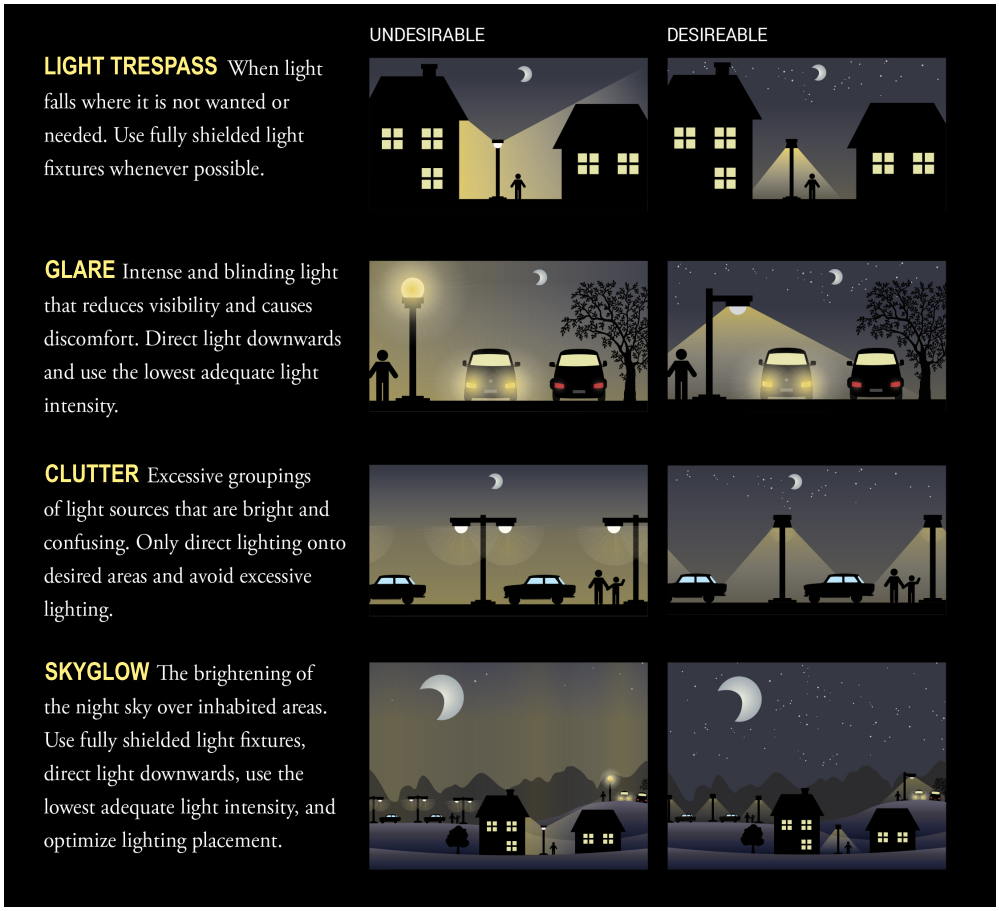


Figure 5 *Components of light pollution, including light trespass, glare, clutter, and skyglow, by Workforce Services and Colorado Plateau Dark Sky Cooperative, 2020*

As the main sources for light pollution are street lights, private housing, and commercial buildings and signs, light pollution is closely linked to urban spaces (Meier et al., 2014). Thus, towns and cities are the most important player in tackling light pollution and protecting the night sky. At the same time, more and more cities and towns are seeing the potential of adapting urban lighting in the context of "urban renewal, placemaking and city marketing" (Meier et al., 2014, p.2). As a growing metropolitan area Peoria can benefit from addressing light pollution, especially in its most urban areas. Figure 6 shows the level of light pollution in the Phoenix metropolitan area. The color of black stands for a natural Dark Sky (no artificial brightness). Areas colored in white represent where artificial brightness is so high that the human eye never adapts to the dark. Peoria (circled black on the map) is exposed to the second highest level of artificial brightness, which is 20.5-41% higher compared to natural darkness. Thus, the Milky Way is not visible at all in Peoria (Falchi et al., 2016).

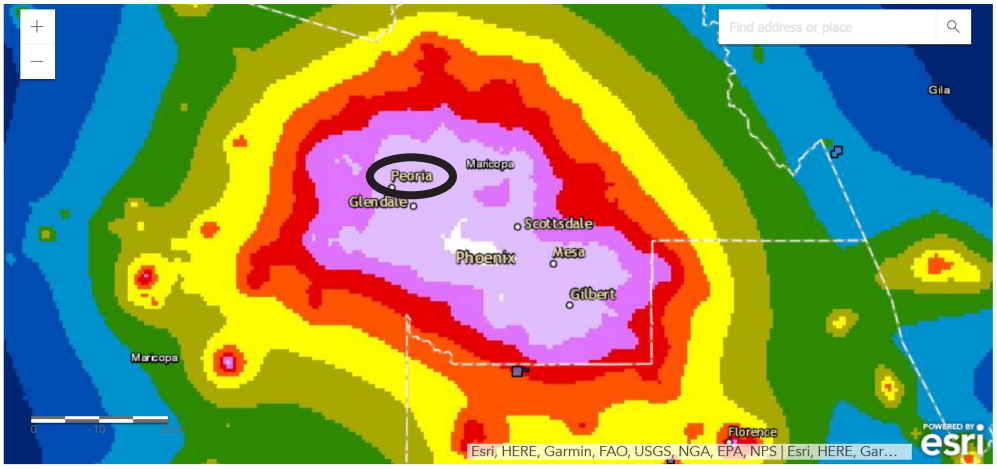


Figure 6 *Light pollution in the Phoenix metropolitan area with a focus on Peoria (circled), by CIRES, n.d., powered by ESRI, based on Falchi et al., 2016*

Light pollution map key

Ratio to natural brightness	*Artificial brightness (μcd/m²)*	*Approximate total brightness (μcd/m²)*	*Color name*	*Color swatch*
<0.01	<1.74	<0.176	Black	
0.01-0.02	1.74-3.48	0.176-0.177	Dark gray	
>0.02-0.04	>3.48-6.96	>0.177-0.181	Gray	
>0.04-0.08	>6.96-13.9	>0.181-0.202	Dark blue	
>0.08-0.16	>13.9-27.8	>0.188-0.202	Blue	
>0.16-0.32	>27.8-55.7	>0.202-0.230	Light blue	
>0.32-0.64	>55.7-111	>0.230-0.285	Dark green	
>0.64-1.28	>111-223	>0.285-0.397	Green	
>1.28-2.56	>223-445	>0.397-0.619	Yellow	
>2.56-5.12	>445-890	>0.619-1.065	Orange	
>5.12-10.2	>890-1780	1.07-1.96	Red	
>10.2-20.5	>1780-3560	>1.96-3.74	Magenta	
>20.5-41	>3560-7130	>3.74-7.30	Pink	
>41	>7130	>7.30	White	

Figure 7 *Light pollution map key, by CIRES, n.d., powered by ESRI, based on Falchi et al., 2016*

Why Dark Skies matter

While artificial light at night comes with a variety of benefits, its dispersion and excessive use is linked to various problems. Thus, effective protection of Dark Skies comes with benefits for human health and well-being, city development and economy, and the environment. Additionally, Dark Sky protection comes with an immense amount of educational opportunities, which can help advance Peoria's sustainability.

Fighting light pollution and protecting the night sky aligns with at least 3 of the 17 Sustainable Development Goals (SDGs):

- **Goal 3:** Good Health and Well-Being for All
- **Goal 11:** Sustainable Cities and Communities
- **Goal 15:** Life on Land

As the IDA quotes the American Medical Association Council on Science and Public Health (2012), "Many species (including humans) need darkness to survive and thrive" (IDA, n.d. o).

SDG 3: Good Health and Well-Being for All

Excessive use of artificial light at night, in particular bright and blue-rich lights, has a variety of negative effects on human health and well-being. Ultraviolet light has long-term effects on the human body, and contributes to premature skin-aging and skin cancer (European Commission, n.d.). Dark Sky protection can positively influence the following:

Improving vision

Artificial lighting, especially blue-rich lighting can impede and damage human vision (Chou, 2012). Limiting artificial lighting and using warm lighting reduces glare and improves vision for humans and animals. Providing alternative lighting fixtures under the ordinance will improve the safety of drivers and pedestrians. Blue light is also a cause of cataracts, which 17.1 million Americans were diagnosed with in 2010. An estimated 50 million are predicted to be affected by cataracts by 2050 if nothing is changed (U.S. Department of Health and Human Services, 2019).

Protecting the circadian rhythm and improving sleep

Artificial light causes hormone imbalances that can affect sleep. Ultimately, it disrupts the circadian rhythm, which regulates a multitude of hormones through a person's internal clock and environmental stimuli (Roberts, 2012). In a normal circadian cycle, blue light exposure in the morning triggers an increase in critical hormones including cortisol, serotonin, dopamine, and gamma amino butyric acid (Roberts, 2012). This hormonal activity helps regulate vital physical processes including impulse control, muscle coordination, stress response, and hunger (Roberts, 2012). Overall, following the patterns of the circadian rhythm increases the positive impacts on human health, well-being, and productivity (Roberts, 2012).

Other health benefits

Reducing excessive artificial light can lower blood pressure and improve metabolism repair with less affected growth hormones, which are produced solely in the dark or with red light (Roberts, 2012).

Individuals with a higher education are more likely to be concerned with their health and well-being (VCU Center on Society and Health, 2015). According to the U.S. Census Bureau, 92.6% of Peoria's population 25 years and older are high school graduates. Positive impacts on health and well-being can be assumed to be particularly relevant for Peoria residents (2019).

SDG 11: Sustainable Cities and Communities

Protecting Dark Skies fosters sustainable development due to the variety of economic benefits for Peoria which align with human and planetary health benefits:

Increasing Peoria's popularity for tourism, specifically astro-tourism

Light pollution negatively affects stargazing. Dark Sky protection holds the potential economic benefit of transforming Peoria into an astro-tourism destination (Welch & Dick, 2012). Astro-tourism is focused on viewing the universe, celestial objects, and space (Workforce Services & CPDSC, 2020). A study mentioned in the Dark Skies Planning guide indicates that one of the most important economic capabilities of astro-tourism is overnight stays. Those who stay overnight tend to spend more money in the community, whether in food, gas, or activities.

Many communities, such as in Utah and the Bryce Canyon area, have grown as tourist attractions due to Dark Skies (Workforce Services & CPDSC, 2020). According to the Dark Skies Planning guide, as of 2016, more than 5.5 million people visited an International Dark Skies park.

Additionally, Dark Sky events may further enhance Peoria's popularity as an astro-tourism destination. Peoria hosts a myriad of spring training games. Dark Sky friendly lighting can enhance the player and the audience view of the games with a reduction in white light glare and specific lighting directed onto the field. The sports complex also provides promotional opportunities for Dark Skies. Furthermore, promoting Dark Skies enables an increased appreciation of Peoria's cultural landscapes and historical landmarks after dark.

Increasing Peoria's popularity for citizens

Many of the aforementioned benefits which adhere to astro-tourism also hold the potential to satisfy and enhance the living quality of Peoria's residents as well as to attract new citizens.

Saving costs through minimizing energy consumption

The different aspects of responsible outdoor lighting hold the potential of reducing the use of energy by 60-70% (IDA, n.d. d). This may result not only from reducing the overall amount of light but also from shielding light fixtures. The IDA estimates that approximately 30 percent of all outdoor lighting in the U.S. is wasted due to poorly implemented or lack of shielded light, accounting for $3.3 billion in energy costs (IDA, n.d. d).

Overall, the implementation of proper light control with Dark Skies certified LED lighting could lessen energy cost by 70-90% (U.S. Office of Energy Efficiency and Renewable Energy, n.d.). Implementing Dark Sky lighting can save 60-70% of energy, saving Peoria billions of dollars (U.S. Office of Energy Efficiency and Renewable Energy, n.d.; IDA, n.d. n).

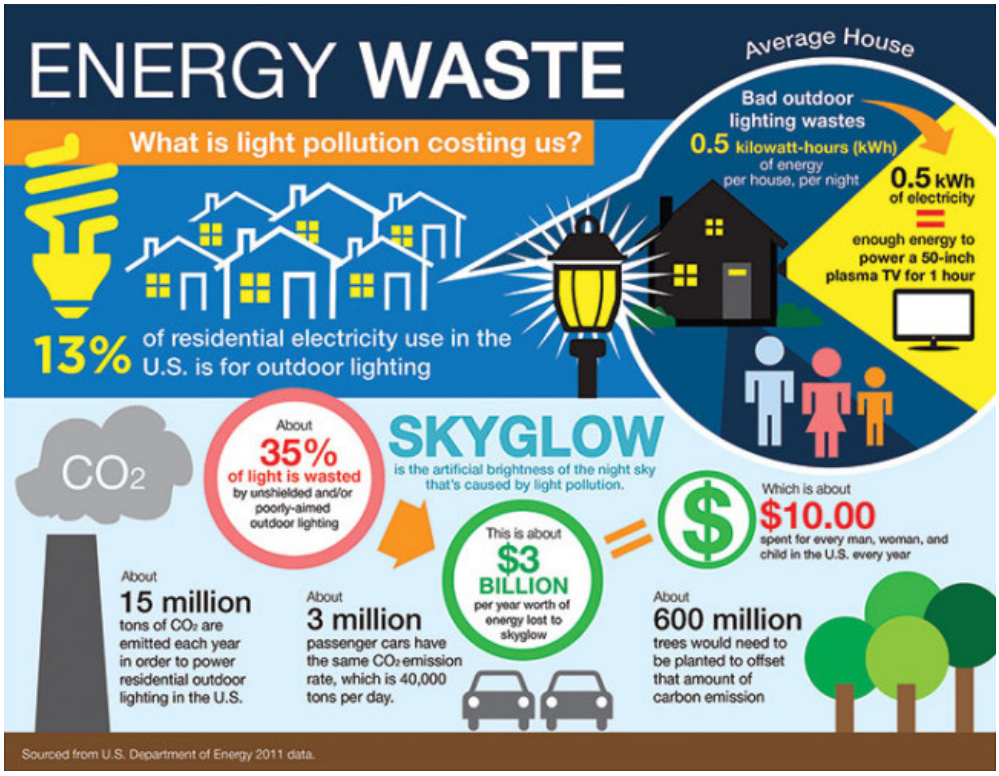


Figure 8 *Costs associated with energy waste and light pollution, by IDA, n.d. j*

RETURN ON INVESTMENT (ROI)

The benefits of using more energy efficient lighting such as Light Emitting Diodes (LEDs) and adaptive lighting can be assessed through a Return on Investment (ROI) analysis. The following is a general overview of a city's ROI when investing in more energy efficient lighting and controls.

$$\text{Simple ROI} = \frac{(\text{Gain} - \text{Cost})}{\text{Cost}} \times 100$$

Formula:

For an LED retrofit of 97,500 street lights we would assume the following to define the ROI:

Gain from Investment

1. Luminaire life will be 20 years
2. 50% reduction in power consumption: $3.25m x 20 years = $32.5m
3. Maintenance costs will be reduced by 60 percent as the majority of these costs are for re-lamping - $3.54m x 20 years = $35.5m
4. Total gain $32.5m + $35.5m = $68m plus a factor of 1.2 to include power cost rise and increase labor costs = $81.6M

Cost of Investment

1. Assume luminaire cost of $500
2. Assume installation of $60
3. Total cost $560 x 97,500 = $54.6m

$$\text{Simple ROI} = \frac{(\$81.6\text{m} - \$54.6\text{m})}{\$54.6\text{m}} \times 100 = 49.4\%$$

The simple ROI from an LED retrofit would be approximately 50 percent. These costs and ROI are approximate and would require extensive study and evaluation to define further. The ROI should be considered an order of magnitude at best and will need to be verified by individual cities.

Figure 9 *Return on investment from Dark Sky friendly and energy-efficient lighting, by Workforce Services and Colorado Plateau Dark Sky Cooperative, 2020*

Enhancing safety

Light provides safety by increasing environmental awareness, but too much artificial light causes vision impairment due to glare and sky glow. “Sky glow is light scattered and reflected off of air molecules and atmospheric aerosols” (Turina, n.d. p.188). Glare also obscures vision through shadows. This negatively affects human health as well as safety. As a result, increasing safety and security is not solely related to the amount of light on a scene, but is a function of how effectively the light provides information about your surroundings (Steinbach et al., 2015)

SDG 15: Life on Land

Lastly, reducing light pollution is connected to various environmental benefits which positively affect Life on Land (and in water, though this is less relevant for Peoria). As mentioned in the Dark Skies Planning Guide, “In Utah, state parks managers have found that changing to night sky-enhancing fixtures and bulbs brings significant benefits to their parks’ wildlife species, visitor experiences and revenue streams” (Workforce Services & CPDSC, 2020, p.17).

Reducing carbon emissions

As depicted in Figure 8, wasted energy from light pollution dispenses 15 million tons of carbon dioxide annually. Almost 600 million trees must be planted annually to compensate for this amount of carbon dioxide emissions (IDA, n.d. d).

Protecting ecosystems and wildlife

Artificial light can negatively affect ecosystems and wildlife. Artificial light not only disrupts photosynthesis, but affects insects and nocturnal animals. Nocturnal animals sleep during the day and are active at night while it is dark, so when it is light during the day and artificially lit at night, nocturnal animals’ sleep patterns are affected similarly to humans. Predators use light to hunt, while prey use the darkness to hide, so when there is light at night the prey are more vulnerable (IDA, n.d. g). Artificial light can negatively affect a myriad of wildlife. Nighthawks are a species of nocturnal birds in Arizona with migration and sleep patterns affected by artificial light. The bright lights can confuse the birds, causing them to stray from their migration route. Blue light can also endanger insects. A study of urban warming and artificial light outlines that artificial light interrupts the **diapause** of insects. Diapause protects insects from unfavorable environmental changes (Mukai et al., 2021).

Editor's Note
Diapause is a delay in development in response to environmental conditions.

Insects are a vital part of ecosystems, the “lever pullers of the world” (Worrall, 2021 vis MacNeal, 2017). In addition to wildlife and insects, light pollution also affects plants, which use light to gauge seasons and when to bloom. As days become longer and warmer, plants detect the spring season. “When light illuminates matter it can heat up,” contributing to the heat island effect (European Commission, n.d.). Due to artificial light, plants can bloom prematurely. Plants sprouting early can cause detrimental effects to the ecosystem. For example, moths usually hatch in the summer, and if moths hatch too early due to this disruption there will be no food as the plants are not yet in bloom. If the moths hatch on time, but after the plants have prematurely bloomed, the leaves of the plants are too mature and hard for the moths to eat. Hence, the moths die as well as the creatures that feed on moths, such as bats (Miller, 2016). Therefore, the mosquito population increases (Miller, 2016). The proper balance and survival of these creatures are all necessary for a thriving ecosystem.

Figure 10 *Yucca moths and lesser long-nosed bats, both nocturnal, are two critical pollinators in the Sonoran desert*

Dark Sky protection

The outlined benefits show the importance of protecting Dark Skies. Hereby, it is important to highlight that Dark Skies does not mean dark grounds (Hall 2020). Instead the aim is to assure responsible outdoor lighting, following the principle “smarter not brighter” (Night Sky Network, 2018). This entails three basic lighting design standards as listed below (Workforce Services & CPDSC, 2020):

Limiting the amount of light

First, lighting should solely be used “where it’s needed, when it’s needed, and only as bright as needed” (Workforce Services & CPDSC, 2020, p.11). This can be achieved by shining lights down and not up as well as directing lights only to where it is necessary. Furthermore, timers, motion sensors, dimmer switches, as well as turning off lights when not in use are key to reducing the amount of lighting. Lastly, the lowest adequate wattage of bulbs, examined later in the report, should be used to avoid overlight of an area.

Shielding light

With fully shielded lighting fixtures, no light is emitted above an angle of 90 degrees. Thus, the full shielding of fixtures directs light onto the desired areas, limits glare, and keeps unnecessary light from surrounding areas and the sky. The effects of fully shielded light in comparison to partially shielded lights is illustrated in Figure 11.

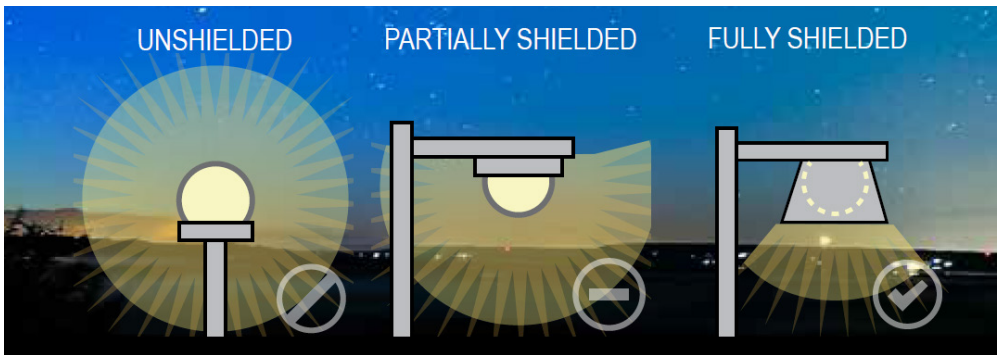


Figure 11 *Levels of shielding on outdoor lighting, by Workforce Services and Colorado Plateau Dark Sky Cooperative, 2020*

Using warm colored lighting

Lighting colors in the cool spectrum increase brightness of the night sky in comparison to those in the warm spectrum. Blue-rich lighting is also associated with negative impacts on human health and wildlife. This aspect of lighting is independent from the brightness of a lighting source and usually referred to as Correlated Color Temperature (CCT). CCT is indicated in the unit of Kelvin, with low values indicating warmer, and high values indicating cooler (more blue-rich) lighting (IDA, n.d. k). Thus, it is recommended to use amber lighting with a color temperature of 3000 Kelvin or less for outdoor lighting (IDA, n.d. k). The color spectrum of lighting in Kelvin is depicted in Figure 12.

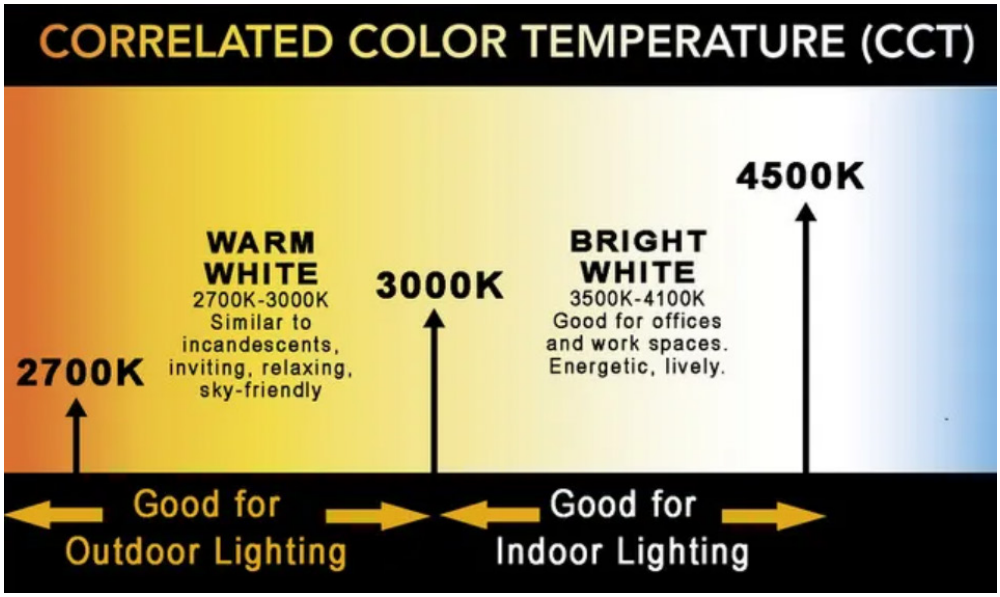


Figure 12 *Recommended color spectrum for lighting in Kelvin for outdoor and indoor lighting, by Fountain Hills Dark Sky Association, n.d.*

These required actions have been enacted in a multitude of communities for at least a decade (Falchi et al., 2011). Figure 13 shows how the regulation of these aspects may contribute to a reduced sky glow brightness.

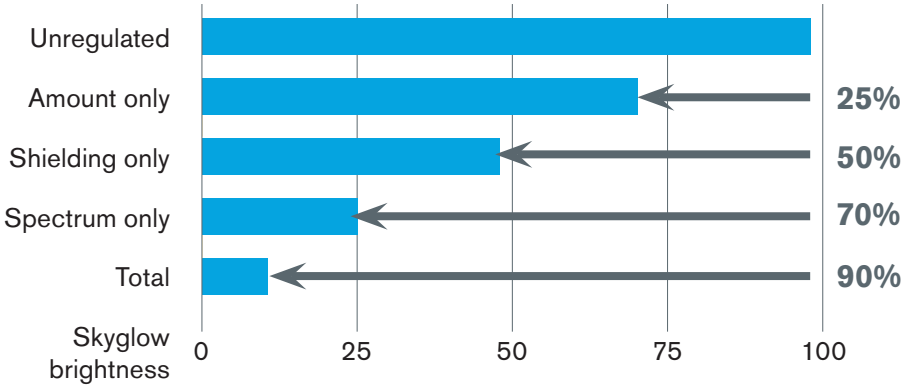


Figure 13 *Effect of different lighting regulations on sky glow brightness in percent, by Flagstaff Dark Skies Coalition, 2020*

International Dark Sky Association (IDA) efforts

The International Dark Sky Association (IDA) is an international non-profit organization, headquartered in Tucson, Arizona, that is dedicated to preserving night skies and fighting light pollution (IDA, n.d.). The IDA was founded in 1988 as a response to concerns among astronomers over the degradation of night skies above observatories and the impact of artificial light on night sky visibility (Welch & Dick, 2012). Ever since, the IDA has been working towards their vision of a "night sky filled with stars, [...] celebrated and protected around the world as a shared heritage benefitting all living things" (IDA, n.d. a).

The IDA provides leadership, tools, and resources concerning Dark Skies. One of these efforts is the International Dark Sky Places (IDSP) Program which certifies communities, parks, and protected areas around the world for their efforts to protect Dark Skies. As of August 2021 the IDA recognized approximately 180 Dark Sky Places worldwide (IDA, n.d. b). Among these are 32 cities and towns that are a certified International Dark Sky Community (IDSC), including 6 communities in Arizona, namely Big Park/Village of Oak Creek, Cottonwood, Flagstaff, Fountain Hills, Sedona, and Tucson (IDA, n.d. c). To earn this award, communities need to meet the following requirements (IDA, 2018):

Lighting policy

Communities need to adopt a quality comprehensive lighting policy with predefined minimum standards, e.g. shielding lighting.

Municipal commitment

The community needs to show its commitment through conforming with the adopted lighting policy and municipal support of Dark Skies.

Support by community organizations

Broad support is necessary from community organizations, e.g. chamber of commerce, police, lighting retailers, or homeowners associations.

Educational efforts

Dark Skies education needs to be incorporated into regular community Dark Sky awareness events (at least one per month), community informal documents, and schools and curricula.

Light pollution control

Communities need to show successful light pollution control through examples of construction projects fulfilling the policies, and through evidence and evaluation of successful light pollution control.

Sky brightness measurement program

Communities need to continuously measure their sky brightness.

IDSC visibility

Certified IDSCs' need to place a sign along roadway or footpath entrances.

Engaging with the IDA and, ultimately, becoming an International Dark Sky Community (IDSC) comes with several benefits. The IDA provides clear guidance and information on how to best protect the Dark Sky and, thus, how to achieve the associated benefits. These resources are not restricted to already certified communities, but are publicly available and can be accessed for free. Furthermore, the IDA and IDA staff closely work together with communities during the whole application and certification process to become an IDSC, which usually takes between one and three years (IDA, n.d. i).

General recommendations

Engage with the International Dark Sky Association and utilize the available resources

Considering the high ambition and variety of criteria IDSC's fulfill, receiving the certification highlights the magnitude of the efforts made by the community and its government, residents, and organizations. This prestigious certification does not only anchor the awareness of Dark Skies, but also serves as a great distinction criteria and unique selling proposition for the City as a high quality place to live and a great tourist destination (IDA, 2018).

Work towards becoming a certified International Dark Sky Community through the IDA

The following report sections are based upon these two primary recommendations and, thus, closely align with the International Dark Sky Community certification criteria. Subsequently, students assess Peoria's status quo on each of the IDA requirements and explore potential compliant measures. Additionally, a timeline of compliance to become a IDSC is provided. However, even if Peoria does not wish to pursue becoming a certified IDSC, Peoria can still utilize this report to select beneficial measures to be implemented.

PEORIA'S CURRENT DARK SKY MEASURES: GAP ASSESSMENT

In order to align the evaluation of measures and recommendations with Peoria's needs, students conducted a gap analysis. Herein, Peoria's currently implemented Dark Sky measures were mapped against the International Dark Sky Communities standards as defined by the IDA. In the gap analysis, it was distinguished between four different states of compliance for Dark Sky measures (see Figure 14):

1. **Measure implemented**
2. **Measure planned**
3. **Measure needs to be adapted**
4. **Measure needed**

This assessment is mainly based on the information publicly available on the website of the City of Peoria, as well as the interviews conducted with Cody Gleason and Lorie Dever from Peoria Planning & Zoning.

Gap assessment		
Measures IDS Communities need	***Peoria's current measures***	***Compliance***
Comprehensive lighting policy meeting 8 standards (e.g., shielding, color of lighting)	Outdated Dark Sky Ordinance from 1990 (see Zoning Code and City Code)	Needs to be adapted
Municipal commitment shown by (intended) compliance with policy and support (e.g., flyer, funding)	Existing code not fully enacted; no supporting materials or funding	Needed
Community support for Dark Skies from community organizations (e.g., HOAs, local business)	No specific Dark Sky dedicated organizations, limited awareness	Needed
Educational efforts such as community awareness events, informational material or school education	No formal events or education available	Needed
Light pollution control shown by examples of compliant construction projects or other evidence	Lighting is checked with construction requirements, though no focus on Dark Skies	Needs to be adapted
Sky brightness measurement either through the community, a public or a private entity	Sky brightness measurements have not been conducted thus far	Needed

Figure 14 *Gap assessment of Peoria's Dark Sky measures against IDA standards for International Dark Sky Communities*

As shown in Figure 14, Peoria has several opportunities to adapt its current measures and introduce new measures. Thus, Peoria can be considered at the beginning of their journey towards becoming an International Dark Sky Community.

EVALUATION OF MEASURES

For this project, every aforementioned area specified by the IDA for becoming an International Dark Sky Community is reviewed in the context of Peoria. For every indicator, the following will be stated:

- Background information on the importance of the topic
- Peoria's current status on the matter
- Possible measures to move forward for Peoria

Dark sky ordinance

Dark Sky Ordinances, also referred to as Outdoor Lighting Ordinances or Outdoor Lighting Codes, are legal documents that regulate lighting practices based on design standards as specified in the "Dark Sky protection" section. The focus lies upon limiting obtrusive aspects of lighting (IDA, 2002). By providing guidelines, outdoor lighting ordinances aim to not only limit light pollution, but also to realize the outlined benefits in the "Why Dark Skies matter" section. This goes beyond astronomical interests and includes conserving public funds and energy, increasing safety, and improving human well-being and environmental protection (IDA, n.d. e; Workforce Services & CPDSC, 2020). Thus, the adaptation of a comprehensive Dark Sky Ordinance is of relevance for all communities (IDA, 2000). Accordingly, to qualify for an International Dark Sky Community, a quality comprehensive lighting policy is required (IDA, 2018).

In general, lighting policies are often integrated in zoning or land-use codes. The standards are mainly applied to new construction projects, similar to a building or electrical code. However, lighting codes can also extend to bring already existing lighting into compliance either immediately or in the future (IDA, 2002).

Main elements of effective ordinances include the following:

- Definitions,
- Standards,
- Exemptions,
- Compliance methods,
- Enforcement,
- Actions in cases of violation.

Each of these elements are explained on the following page, including the requirements of the IDA to become an International Dark Sky Community (see IDA, 2018) for each of the components.

Definitions

To adopt any new code, definitions are a legal requirement which assures the correct interpretation of the ordinance and code. Since outside sources are rarely accepted, any unfamiliar term should be added to the adopted ordinance (IDA, 2011). Thus, definitions are needed even though the IDA requirements do not explicitly demand them.

Standards

The IDA defines five standards for a Dark Sky Ordinance to fulfill the requirements for an IDSC. This encompasses the following aspects:

- Full shielding of all lighting fixtures > 1,000 initial lamp lumens,
- Limiting the emission of short-wavelength light,
- Restricting the total amount of unshielded lighting,
- Regulating new installations of publicly-owned outdoor lighting,
- Restricting the installation and operation of illuminated signs.

Exemptions

According to the International Dark Sky Community Program Guidelines (IDA, 2018), outdoor recreational and/or athletic field lighting may be exempted from the strict shielding and wavelength standards under specific conditions (e.g., a curfew).

Compliance methods

The IDA requires all publicly and privately owned lighting to be compliant with the lighting policy in no more than 10 years.

Enforcement

The IDA requires the “implementation and enforcement of quality lighting policies” (IDA, 2018, p.3). However, there are no specific details regarding how this enforcement should appear.

Actions in case of violation

Likewise, the IDA does not specify how violations against the lighting policy should be punished.

Additional elements of lighting policies to be considered from other Dark Sky Communities' Ordinances include:

- Mission statement,
- Purpose and intent,
- Treatment of conflicting regulations,
- Applicability of the policy.

Furthermore, a variety of lighting policies distinguish Peoria's current lighting policy, a Dark Sky Ordinance, anchored in the City Code, Chapter 20 Planning and Development, Sections 60-67. This Ordinance was enacted on 11/03/1998. Further regulations concerning outdoor lighting can be found in the supplemental regulations 800 of the Zoning Ordinance that was adopted in 2018. Based on an analysis of the Outdoor Lighting Ordinances of other Dark Sky communities in Arizona, the following pitfalls in relation to the aforementioned crucial elements of a lighting policy were identified:

- Both documents, the Zoning Ordinance as well as the Dark Sky Ordinance in the City Code, contain a statement of purpose. However the stated purpose for both documents should highlight the same aspects. These should not be limited to astronomical observations (as in the Dark Sky Ordinance) but rather highlight the broad variety of benefits for all citizens as specified in the "Why Dark Skies matter" section.
- While Peoria's current Dark Sky Ordinance contains a definition section, there are six terms defined (Outdoor Light Fixtures, Fully Shielded, Partially Shielded, Filtered, Individual, and Installed). With technical advancements and an increasing complexity of a Lighting Code, more definitions become necessary. Which terms Peoria should define depends on the Ordinance that is enacted.
- Peoria's Zoning Ordinance as well as the Dark Sky Ordinance already touch upon some of the standards which the IDA requires, for example the shielding of lighting. However, the current definition of most of these standards is too generic. For example, instead of requiring shielding in a manner so that the light source is not visible from other properties (City of Peoria, 2018, Zoning Ordinance, 21-802, 5.), the standard could clearly state:

    - How the lighting should be shielded (fully vs. partially),
    - How bright the lighting is allowed to be (in initial lumens), and
    - If the lighting needs to fulfill certain color requirements.
    - Additionally, there are several standards the IDA requires which are not a part of Peoria's current lighting policy. For example, the lighting color (or wavelength of light) should be regulated.
- Regulations concerning outdoor lighting are designed in the Dark Sky Ordinance, the Building Code, the Electrical Code, and the Sign Code of Peoria. The lighting regulations should be as consistent and spread to as few documents as possible in order to reduce complexity and limit risk of conflicting regulations.

There are various resources which provide guidance for communities to draft their own lighting policy. This includes two different lighting guidelines/codes for interested communities to utilize and adapt according to their needs:

- **The Pattern Outdoor Lighting Code** (POLC) first published in 2000 by the IDA (2000), and
- **The Model Lighting Ordinance** (MLO) written by the IDA in cooperation with the Illuminating Engineering Society of North America (IES) in 2011 (IDA & IES. 2011).

While no lighting codes were identified based on the MLO, the POLC served as a basis for various lighting codes particularly in Northern Arizona (Luginbuhl, 2013). An analysis of the two adaptable guidelines suggests the adoption of a lighting policy based on the POLC reduces light pollution more effectively compared to the MLO. One example is the missing regulation of the wavelength (color) of lighting in the MLO (IDA & IES, 2011; Luginbuhl, 2013).

The Flagstaff Dark Sky Coalition highlights the Lighting Codes of Flagstaff, Cottonwood, and Sedona as excellent examples of lighting policies. While Cottonwood and Sedona lighting codes resemble each other, Flagstaff's lighting code additionally distinguishes three different Lighting Zones based on their location within the city, mainly their proximity to the observatory. This is a very important aspect which allows communities to vary the stringency of their lighting policy based on the intent and sensitivity of different areas.

Alternative approaches may involve: a land-use zoning approach where the lighting code is tied to different zoning categories (e.g., commercial vs. residential) (Workforce Services & CPDSC, 2020). Peoria can make use of the broad variety of available resources and base its Dark Sky Ordinance on the work that has already been done.

Dark Sky Ordinance recommendations

Recommendation 1: Base Peoria's Dark Sky Ordinance upon the Lighting Codes from Cottonwood and Sedona, and consider alterations and additions as specified in the adaptable lighting policies.

Due to the proximity of Northern Peoria to Lake Pleasant Regional Park and the urban characteristics of Southern Peoria, closer to the City of Phoenix, Peoria should additionally consider the introduction of different lighting zones. In particular:

Recommendation 2: Introduce at least two different lighting zones (more protective in the North, more artificial light at night in the South) based on Flagstaff's approach.

Section 8: Resources contains an outline for a possible Dark Sky Ordinance which follows this example. Even though this may be a valuable starting point, given the complexity of a Dark Sky Ordinance, Peoria can draw upon the available online resources and directly engage with Dark Sky experts on the matter.

Recommendation 3: Work together with a Dark Sky representative.

This may be staff from the IDA or from another Dark Sky Organization, such as the Flagstaff Dark Sky Coalition or the Fountain Hills Dark Sky Association. Since these coalitions already successfully guided their communities through the International Dark Sky Community certification process of implementing an effective lighting policy, their insights will be of great value to Peoria. For example, Fountain Hills updated their Outdoor Lighting Ordinance with guidance from the IDA Program Manager Dr. John Barentine (Fountain Hills & Fountain Hills Dark Sky Coalition, 2017).

Recommendation 4: Give the community the opportunity to comment on a draft of the Ordinance and to voice wishes and concerns.

Municipal commitment

Action from leaders, citizens and other stakeholders is needed in order for communities to gain momentum and to implement the necessary municipal policies to protect the Dark Sky. Herein, the first step is to gain support of the local government. Their commitment translates into making Dark Sky protection a priority for the community and to be actively involved in doing so (Workforce Services & CPDSC, 2020).

Accordingly, municipal commitment (or in the IDA guidelines referred to as community commitment), is one of the IDA requirements to become an International Dark Sky Community. This requirement consists of the following two main focuses.

- The community demonstrates its commitment towards Dark Skies through public outreach (e.g., public service announcements)
- The community complies with their own lighting policy (IDA, 2018)

However, as a first step, this requires internal support within the municipal government as emphasized by Luginbuhl (2021). According to Lorie Dever and Cody Gleason, Peoria's government, including the City Council, is supportive of sustainability efforts in general. This becomes evident considering Peoria's dedication for the new sustainability plan as well as the existence of the Green Team. Since Dark Skies and light pollution are fairly recent topics for Peoria and its government, it is still crucial to get explicit and immediate support and commitment to the cause.

Municipal commitment recommendations

Recommendation 5: Assure support for the Dark Sky effort within the local government of Peoria, including the Mayor, Cathy Carlat, the members of the City Council, the Sustainability Consultant, Victoria Caster, as well as the Green Team.

By gaining Victoria Caster's support early, the Dark Sky project will accrue an ally who contains expert knowledge in the area of sustainability and who is familiar with Peoria's processes and procedures necessary to anchor and realize a better protection of the night sky. Thus, students propose the following plan of action:

1. Gather Victoria Caster's support,
2. Present the Dark Sky project to the Green Team with the help of Victoria Caster to exchange feedback, related ideas and concerns, and identify Dark Sky efforts and regulations in relation to addressing and including the different departments,
3. Build a working group responsible for the Dark Sky project, and build upon the original plan and the Green Team's feedback,
4. Present the Dark Sky project to the Mayor and City Council and get their support.

The benefits of Dark Sky protection should be emphasized to accrue support within the City of Peoria and from the aforementioned individuals. This particularly includes benefits for the quality of life for Peoria's residents, safety improvements, as well as the potential for astro-tourism. Once Peoria's government is supportive of the project, Peoria can start working on the two formal IDA requirements.

Public commitment towards Dark Skies

A communities' support towards Dark Sky measures can be demonstrated by, for example, city publications, flyers, public service announcements, or funding of lighting upgrades (IDA, 2018). Currently, there are no statements of public commitment towards Dark Skies in Peoria. Even though this means Peoria must build something from scratch, there are several measures which other IDSC's utilized and which can be implemented with a reasonable effort. The following measures are important to consider:

- Publishing a statement or news release highlighting Peoria's commitment towards Dark Sky protection on the city website.
- Communicating Peoria's commitment via the already existing and utilized social media channels.
- Compiling, printing, and distributing a rack card which entails Peoria's vision of a Dark Sky, a guideline for the community on how they can support Dark Sky measures, as well as smart lighting concepts. One great example is provided by the Town of Fountain Hills and its Dark Sky Coalition (Figure 15) (Fountain Hills, 2017).

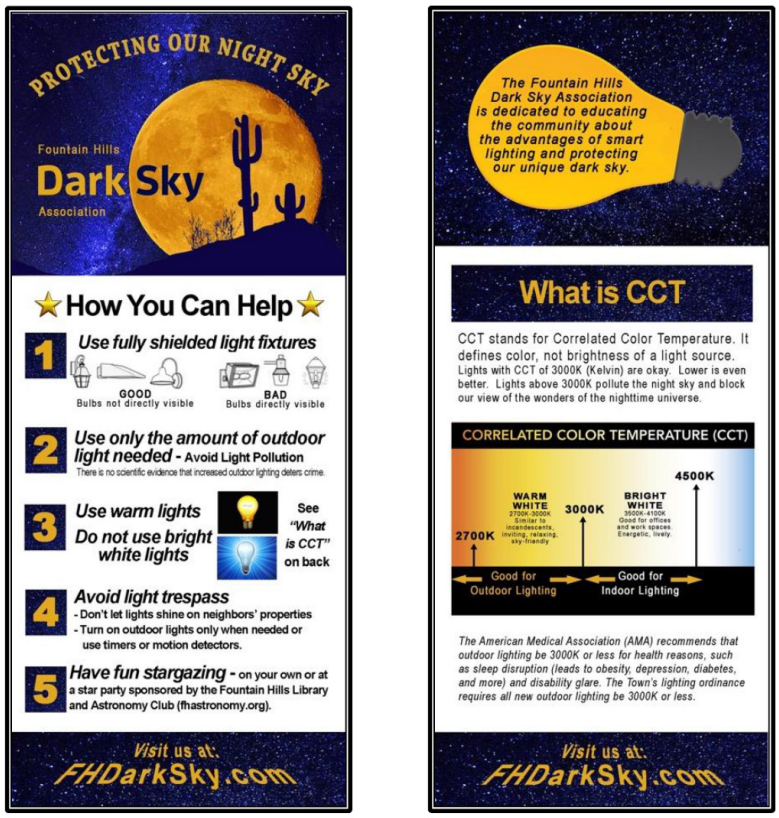


Figure 15 *Fountain Hills Dark Sky Association rack card*

Recommendation 6: Communicate Peoria's interest in protecting the Dark Sky early on to the community via social media and the city website.

This can be achieved with little additional costs since these platforms are used independently from the Dark Sky project. Additionally, this is a way to inform and engage Peoria's community early in the process and to obtain residents' feedback.

Recommendation 7: Include Dark Sky protection in Peoria's new Sustainability Action Plan.

Compliance with the lighting policy

Closely tied to updating Peoria's Dark Sky Ordinance is the City's compliance with this ordinance. Since city-owned lighting, for example streetlights, contribute considerably to light pollution, adapting the public lighting infrastructure is crucial to protect the Dark Sky, to assure optimal lighting conditions, and to enhance safety and bring other benefits as highlighted in the "Why Dark Skies matter" section. Peoria can only expect its residents to adhere to the Dark Sky Ordinance if the City leads by example.

However, since updating the public lighting infrastructure is a major task which involves a lot of planning and requires funds to do so, the IDA requirement to become an International Dark Sky Community can also be fulfilled by demonstrating commitment to conform with the lighting policy. This requires a detailed plan with a timeline for completion in five years or less.

Recommendation 8: Compile a timeline for municipal compliance with Dark Sky lighting regulations.

For a possible IDSC application, Peoria needs to show its commitment by means of a timeline of compliance. This process can begin before the finalized Dark Sky Ordinance is passed. The basic requirements for protecting Dark Skies, as outlined under the "Dark Sky protection" section, are uncontested. This timeline depends on the extent of the need for adaption.

Recommendation 9: Create an inventory of the current city-owned lighting.

An inventory of all existing lighting should be compiled in order to estimate the required efforts and financial obligations for the updated city lighting. This inventory should specify at minimum:

- The number of lighting fixtures,
- The type of lighting (e.g. High Pressure Sodium, LED),
- The current level of shielding,
- The brightness of each fixture in lumens,
- The correlated color temperature in Kelvin.

One valuable tool that can be used to outline the inventory is the Dark Sky Assessment Guide, a 20-page document containing valuable background information on important lighting criteria, and an inventory template and questionnaire (IDA, 2019).

Instigating a plan for Peoria to adopt Dark Sky-friendly lighting fixtures also includes deciphering specific lighting the city should utilize in the future. Similar to other communities, Peoria is utilizing Light Emitting Diode (LED) units for their lighting system due to higher efficiency (Hall, 2020; Peoria, 2016).

Accordingly, as of 2016 Peoria has converted more than 2,200 lights to LEDs (City of Peoria, 2016). While this lighting saves more than 1 million kWh per year, regular white LEDs are estimated to increase sky glow by a factor of two or three in comparison to the usual High Pressure Sodium. Thus, it is of utmost importance to utilize amber colored LEDs. This can either be Narrow Band Amber (NBA) LEDs or Phosphor Converted Amber (PCA) LEDs. Due to an efficiency that is almost as effective as white LEDs and a reasonable additional expense for a tremendously lower Dark Sky impact, PCA LEDs should be utilized (Hall, 2020).

Recommendation 10: Specify Phosphor Converted Amber (PCA) LEDs as the preferred standard for city-owned lighting.

The following further defines Dark Sky friendly lighting as specified by the IDA (2020, p.3-4):

- Always choose fully shielded fixtures that emit no light upward.
- Use "warm-white" or filtered LEDs (CCT ≤ 3000 K; S/P ratio ≤ 1.2) to minimize blue light emission.
- Look for products that are capable of accepting 7-pin controls that can enable the use of dimmers, timers, motion sensors, and networking.
- Consider dimming or turning off lights during overnight hours.
- Avoid the temptation to over-light because of the higher luminous efficiency of LEDs.
- Only light the exact space and the amount required for particular tasks.
- Select fixtures that have aftermarket shields available if light trespass is an issue.
- Give the community a voice towards the lighting they will be experiencing for generations, with test installations for soliciting public input and feedback.

Community engagement

Drafting a Dark Sky Ordinance itself is an important first step, which can only be achieved with municipal support. Though, the real aim and challenge is to have an Ordinance that is acted upon. For this reason, involving the community in Dark Sky efforts is the biggest factor for successful Dark Sky protection (Luginbuhl, 2021).

Accordingly, the IDA requires International Dark Sky Communities to have broad community support for Dark Skies from a variety of organizations, such as local electrical utilities, businesses, chambers of commerce, lighting retailers, and Homeowners Associations (HOAs). Aside from the aforementioned organizations, Luginbuhl (2021) highlights the importance of working closely together with city representatives and obtaining government support. He also references focusing on the police and fire departments to prove that the Dark Sky's lighting is safer.

Every member of Peoria's community is a stakeholder when pursuing the International Dark Sky Community Certification. Different community members will be receptive to different arguments and benefits of Dark Sky protection. Each of the mentioned benefits of Dark Sky protection in the "Why Dark Skies matter" section may be a valuable argument and help to gain broad community support. In order to better understand the residents' needs, wishes, and concerns in relation to Dark Sky measures, Peoria should reach out to as many of their citizens as possible.

Community engagement recommendations

Recommendation 11: Conduct a survey among all residents to assess community needs, wishes and concerns.

As highlighted in Section 2, possible survey questions can be found in Appendix C in the original student content at **links.asu.edu/PCPeoriaDarkSkyOrdinance21F**. These questions may be adapted and complemented as Peoria sees fit. The survey should be accessible to as much of the community as possible. Therefore, the survey should be distributed both online and in-person.

Among Peoria residents, the following groups were identified as particularly relevant community stakeholders (Dark Sky Planning guide n.d.; Luginbuhl, 2021).

Local government

Representatives in the local government are influential stakeholders as they are not only important community members, but they also have crucial influence on the success of Dark Sky efforts, specifically when it comes to supporting Dark Sky protection within the municipal government or voting to pass the ordinance. For more details on the involvement of the local government and obtaining municipal support, see the "Municipal commitment" section.

The Police and Fire Department

The main concern of the Police and Fire Departments is community safety. Thus, these departments must be involved in Dark Sky efforts early on to assure the implemented measures enhance residents' safety, and to support and trust the implementation of measures within the community. One way to foster support is by showcasing evidence of how lighting regulations improve safety in other Dark Sky Communities. A multitude of information on this topic can be found on the IDA website, such as a public outreach brochure focused on the relation of outdoor lighting and safety (Figure 16) (IDA, 2021).

Figure 16 *International Dark Sky Association lighting and safety brochure*

Homeowners Associations (HOA)

Between 2015 and 2019, 74.2% of Peoria's residents are homeowners (U.S. Census Bureau, 2019). Therefore, the HOAs are important stakeholders for the Dark Skies implementation process. Receiving HOA support will influence the ease of converting lighting practices in residential areas and on private property. In order to gain their support, emphasizing the potential increase in home values due to Dark Skies is critical. For example, Sedona and Colorado mention Dark Skies as a resource for increasing property values (Dark Sky Planning n.d.). Sedona also mentions the view of the night sky in their property descriptions.

Educators

Gaining educators' (teachers, principals) support holds the potential to integrate Dark Sky related topics, such as astronomy, into the school curriculum and school groups and programs. Having educators who are willing to engage in Dark Sky events as volunteers and/or may also contribute significantly to Dark Sky advancements is valuable. Particularly reaching out to educators who may be interested in astronomy due to their involvement with STEM subjects may be a promising approach.

Schoolchildren and students

Focusing on children as a stakeholder for Dark Skies represents future thinking to sustain the implementation of Dark Skies for generations to come. Children and the youth are the future leaders. Thus, by appealing to the younger generation, Peoria can anchor the interest for Dark Skies in their community and may be more successful in sustaining their efforts. Their engagement and support can be enhanced through adding astronomy into the curriculum of the Peoria Unified School District, as well as, introducing clubs and extracurricular activities which can be hosted in schools, libraries, and community centers.

Businesses, utilities, and lighting companies

These entities are essential stakeholders to recruit and influence the integration of Dark Sky designated lighting. Emphasizing the reduced cost of lighting and electricity for both utility companies and businesses are effective arguments to rally support.

Healthcare workers

Finally, Healthcare workers can be very important Dark Sky allies to emphasize the importance of reducing light pollution for human health (see the "Why Dark Skies matter" section).

Recommendation 12: Identify the most relevant stakeholders and include them into the Dark Sky protection efforts as early as possible by direct approaches, such as holding and exchanging presentations.

One very successful way to engage the overall community is hosting awareness and education events. Since this is categorized, per IDA requirements, in the area of education, different event possibilities are explored in the following "Education" section.

Education

Community support is essential to implement an acted upon lighting policy. In order to do so, the residents and stakeholders in Peoria must be educated and appreciative of Dark Skies. Therefore, the IDA specifies the requirement for an International Dark Sky Community to show at least one of the following three educational measures (IDA, 2018):

- Plan and execute at least one Dark Sky awareness event per month,
- Publish Dark Sky awareness documents (e.g., brochures, infographics),
- Integrate Dark Sky education in community schools and curricula.

Educational staff (specifically STEM), community center organizers, librarians, students, and volunteers can be utilized to promote and lead events. In the expert interview, Christian Luginbuhl (2021) referred to various community events in Flagstaff, such as a "Star Party." This occurs monthly and resulted in broad community support. Flagstaff also has a Dark Sky Brewery and Dark Skies Aerial dance group.

Further examples of successful Dark Sky promotion events can be taken from Utah and Colorado. Peoria may find the following helpful to consider:

- The Peoria Regional Preserve hosts a "Milky Way Race" to run at night
- Lake Pleasant hosts "Starry Night Boating" at night
- The public pool can host "Starry Night Swims"
- Sunset Ranch HOA Park: "Milky Way Viewing" and "Starry Night Hikes"
- Different community centers and libraries can host a myriad of educational "Starry Night Events" with telescopes and a sampling of Dark Sky friendly lighting
- Hosting "Starry Night Bar Crawls" to cater towards the adult population
- Adopt mascots in relation to Dark Skies (astronaut, alien, etc) for some elementary and middle schools
- Host Dark Sky information conferences with Dark Sky representatives, such as Christian Luginbuhl or the IDA Director of Conversation, John Barentine.

Based on the estimated duration of 14 months to plan such an event, it is in Peoria's best interest to begin the planning process as early as possible.

Figure 17 *Popular Dark Sky events include Grand Canyon Star Parties, Stockholm's annual Midnight Run, and telescope teaching workshops*

Education recommendations

Recommendation 13: Start planning, compiling, and publishing Dark Sky Awareness documents as soon as possible.

Documents can be found on the IDA website and adapted to best fit Peoria. Peoria can also design its own documents to publish.

Recommendation 14: Aim to host one awareness event per month.

When first hosting events, plan for once per month. This may include any combination of the previously listed events (starry night runs, starry night hikes, etc.), but also presentations and exchanges with the identified stakeholder groups. In order to minimize the organizational effort, previous resources and engagement techniques can be reused.

Light pollution control

Replacing existing lighting fixtures with Dark Sky-friendly ones can cause some hesitancy, so assurance of a cost effective and comparatively simple solution is essential. Due to the importance of this aspect, the IDA requires potential IDSCs to show effective light pollution control. This is demonstrated by examples of a number of construction projects appropriate to the Community population and amount of new construction and renovation activity, built under the lighting policy to demonstrate its effective application (IDA, 2018).

Peoria already has a process in place where applications for a building permit require evidence that lighting is in compliance with city standards for new construction projects, additions, alterations, or changes to construction permits. However, this process is currently not focused on Dark Sky protection.

Recommendations for light pollution control

Recommendation 15: Review and adapt the established due diligence process for new construction sites based on the Dark Sky Ordinance.

To intervene with as few applications as possible, HOAs, homeowners, and construction businesses should be made aware of the Dark Sky Ordinance requirements prior to starting the construction process.

Recommendation 16: Raise awareness and transparently communicate light pollution control for construction applications.

Sky brightness measurements

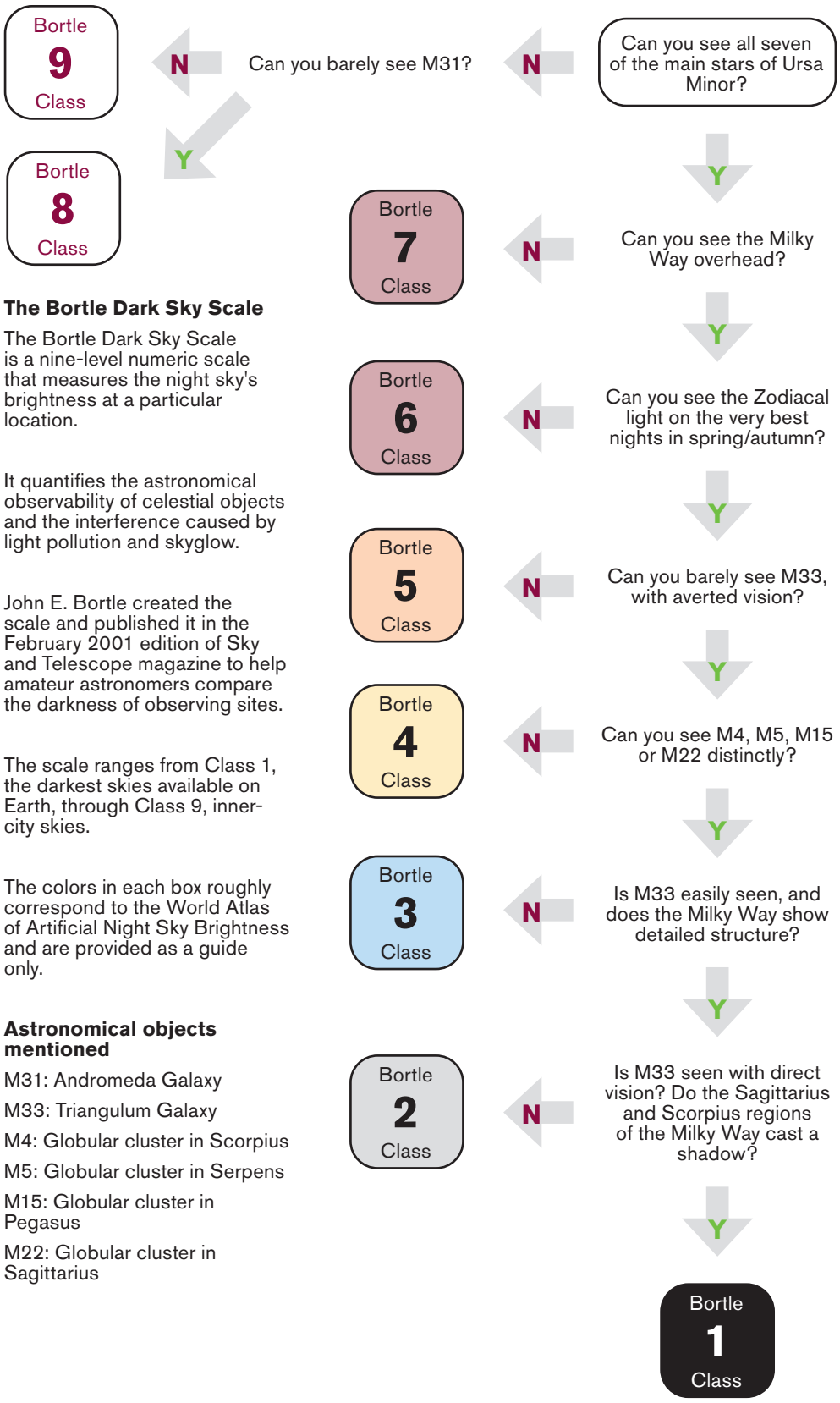
Lastly, the IDA requires that communities monitor progress on their Dark Sky efforts by implementing a sky brightness measurement program. This program can be conducted through a public or a private identity, including but not limited to universities, research centers, IDA chapters, or astronomy clubs. Though measuring the brightness of the sky is a challenging task (Falchi et al., 2016), there are a multitude of possibilities accessible to communities.

Sky Quality Meter survey

The Sky Quality Meter is an easy-to-handle device that measures the brightness of the night sky in magnitudes per square arcsecond. It allows a quantitative sky brightness assessment for an affordable price of $119.99 (IDA, n.d. m; Sky Quality Meter, n.d.).

Bortle Scale Interpretation (BSI)

The Bortle Scale is a more qualitative approach to measuring sky brightness compared to the Sky Quality Meter. The BSI does not rely on a device, but rather on a flow chart in which the assessment is conducted through assessing pre-defined criteria (IDA, n.d. m). The flow chart which can be used is depicted in Figure 18. In order to identify astronomical objects, applications such as SkyView or Star Walk can be used.



The Bortle Dark Sky Scale

The Bortle Dark Sky Scale is a nine-level numeric scale that measures the night sky's brightness at a particular location.

It quantifies the astronomical observability of celestial objects and the interference caused by light pollution and skyglow.

John E. Bortle created the scale and published it in the February 2001 edition of Sky and Telescope magazine to help amateur astronomers compare the darkness of observing sites.

The scale ranges from Class 1, the darkest skies available on Earth, through Class 9, inner-city skies.

The colors in each box roughly correspond to the World Atlas of Artificial Night Sky Brightness and are provided as a guide only.

Astronomical objects mentioned

M31: Andromeda Galaxy

M33: Triangulum Galaxy

M4: Globular cluster in Scorpius

M5: Globular cluster in Serpens

M15: Globular cluster in Pegasus

M22: Globular cluster in Sagittarius

Figure 18 *Bortle Scale flow chart, by Owens, 2012*

Photographic evidence

This is a great possibility to get photographic evidence while engaging the community in a citizen science inspired approach. Citizens are encouraged to take pictures and/or measure the brightness of the sky with their smartphone. Two tools that can be utilized are the Dark Sky Meter app or the Loss of the Night app (IDA, n.d. l).

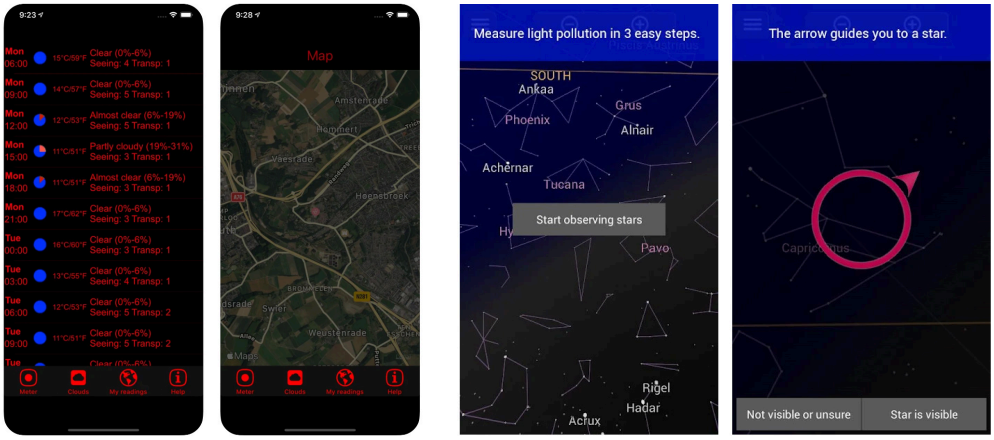


Figure 19 *Dark Sky Meter app (left) and Loss of the Night app (right)*

Sky brightness measurement recommendations

Recommendation 17: Invest in at least one Sky Quality Meter device and complement the more qualitative assessment approaches with it.

Additionally, sky brightness measurements are a great opportunity to involve the community in Dark Sky efforts and educate them about the presence of different types of light pollution as well as their impact.

Recommendation 18: Conduct a sky brightness measurement together with the community as an educational activity.

OUTLOOK

Though pursuing certification as an International Dark Sky Community can be a lengthy process of one to four years, it provides a variety of potential benefits, guidance, and resources. Thus, Recommendation 2, pursuing the IDSC certification is a central recommendation based on which a timeline of compliance shall be provided. This timeline can be used to sort out the next steps for a possible application submission.

In general, the process consists of three phases:

1. Initial Inquiry (45 days on average),
2. Formal Application (1-3 years on average), and
3. Certification (90-150 days on average).

To account for the myriad of tasks and Peoria's current status as a city striving to start its journey of Dark Sky protection, a five-year timeline is suggested (Figure 20).

Year 1

Gaining support within the City and working towards community awareness

- Review the provided report and decide whether Peoria wants to aim to become a IDSC certified city (based on Recommendations 1 and 2) over six months.
- Specify a plan of action (based on this timeline of compliance).
- Identify who needs to be involved within the local government of Peoria and pitch the project internally (based on Recommendation 6).
- Make sure Dark Sky protection is included in the new *Sustainability Action Plan* (based on Recommendation 8)
- Build a Dark Sky Task Force within the city government which focuses on the project. If city personnel are not available, prioritize searching for engaged and interested members of the community to pursue the project as a Dark Sky Advocate group.
- Identify the most important community stakeholders and reach out to them as early as possible, as the researchers have identified (based on Recommendation 13).
- Plan at least 15 Dark Sky awareness events for year 2, such as stakeholder presentations, community events, and advertising booths (based on Recommendation 14).
- Apply for funding towards community events.

Figure 20A *Dark Sky task timeline*

Year 2

Gaining community support, assessing the current status, and drafting the Ordinance

- Communicate Peoria's interest in pursuing Dark Sky protection measures on the city website, social media, and through hosting community events (this should focus on highlighting the most important benefits for the City of Peoria as outlined in the "Why Dark Skies matter" section). Connect this outreach with a community survey (based on Recommendations 7 and 12)
- Host at least one Dark Sky awareness event per month, as outlined in year 1, to engage the community. Invite Dark Sky experts to these events (based on Recommendation 14).
- Continuously engage with the identified stakeholders.
- If not already completed in year 1, foster a Dark Sky Advocate group within the community.
- Collaborate with the IDA on drafting an ordinance (based on Recommendations 3 and 4).
- Create an inventory of current city-owned lighting (based on Recommendation 10).
- Apply funding to substitute lighting that is not conformant with Dark Sky friendly lighting.

Year 3

Finalizing the Dark Sky Ordinance and continue community support

- Continue building community awareness and support with presentations and events. Focus on local organizations' involvement.
- Conduct a Sky Brightness Measurement with the community (based on Recommendations 17 and 18).
- Finalize the draft of the Dark Sky Ordinance and make it available for public and community feedback (based on Recommendations 3, 4 and 5).
- Adapt the Dark Sky Ordinance draft accordingly, present it to the City Council and, ideally, vote the ordinance into action (based on Recommendations 3, 4 and 5).
- Plan an improved due diligence process for construction projects based on the new Dark Sky Ordinance in collaboration with the respective departments. Assess to what extent current construction projects already adhere to these requirements (based on Recommendation 15).
- Create an inventory of current city-owned lighting. Identify to what extent the inventory is compliant with the Dark Sky Ordinance, and compile a plan for city compliance with the regulations (based on Recommendations 9, 10 and 11).

Figure 20B *Dark Sky task timeline continued*

Year 4

Begin conversion to Dark Sky lighting based on the finalized Dark Skies Ordinance

- Continue the community support efforts, and specifically target schools and educators in order to eventually integrate Dark Sky protection and astronomy into school curricula.
- Implement the new due diligence process for Dark Sky compliance of new construction projects, raise awareness, and communicate the enhanced due diligence process for new construction sites and compliance with the lighting policy. Document compliant construction projects (based on Recommendation 15).
- Enforce the process and gather evidence for successfully compliant construction projects.

Year 5

Applying to become an International Dark Sky Community

- Continue the work from years 1-4
- Gather all necessary documents for the IDSC application (steps outlined in Figure 18).

Figure 20C *Dark Sky task timeline continued*

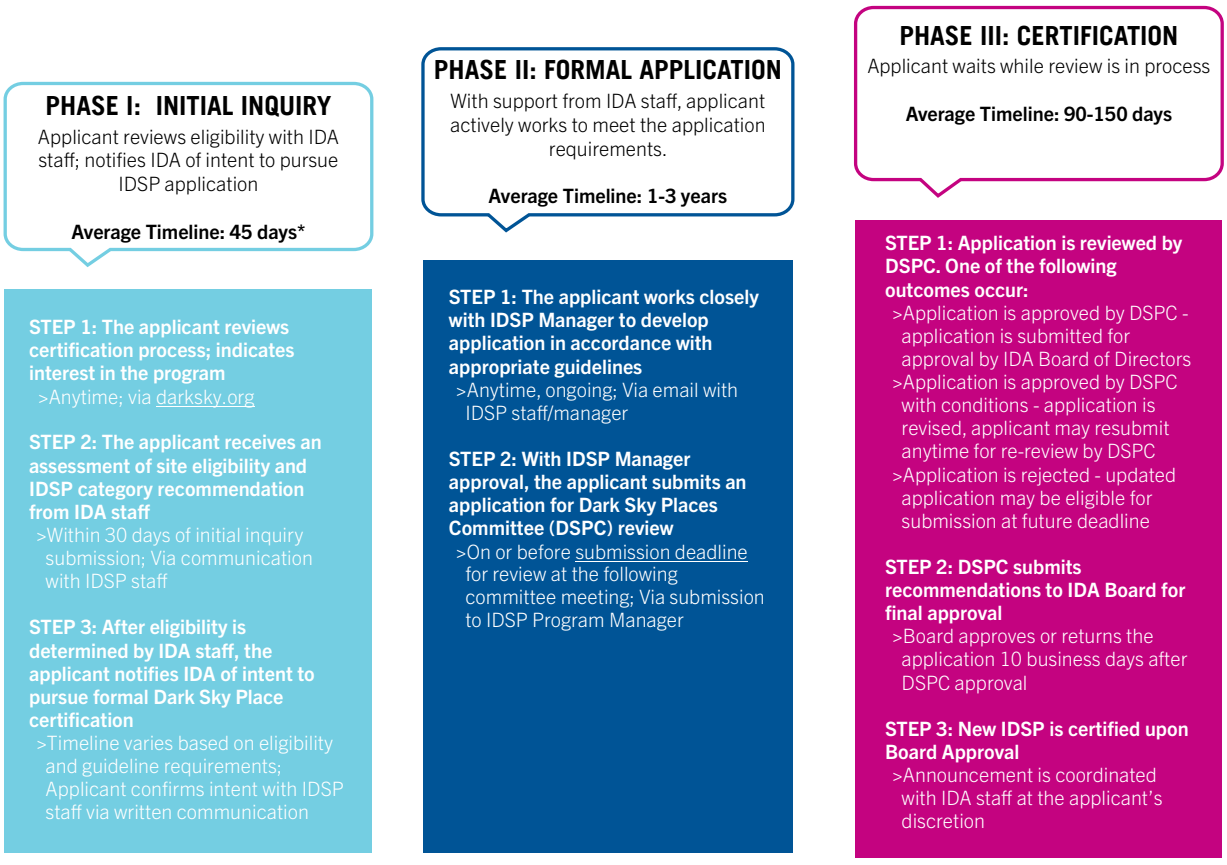


Figure 21 *Application process to become an International Dark Sky Community, by IDA, n.d. p*

Infographic

Students developed the following infographic as a summation of the project needs, context, key points, recommendations, and timeline.

Figure 22A *Student Dark Sky Ordinance infographic, page 1*

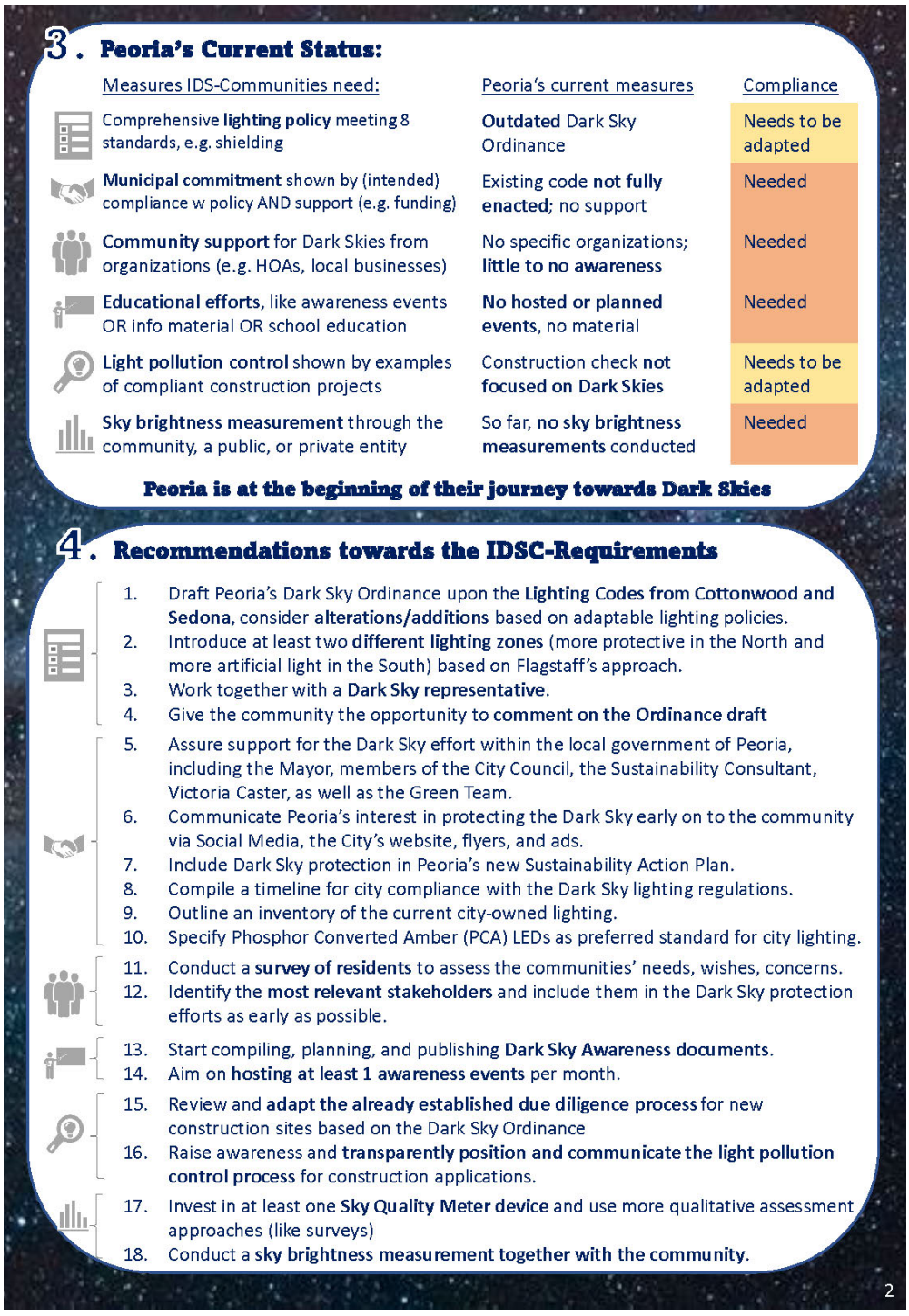


Figure 22B *Student Dark Sky Ordinance infographic, page 2*

Figure 22C *Student Dark Sky Ordinance infographic, page 3*

RESOURCES

As frequently mentioned throughout this report, there are various sources freely available which Peoria can consult in order to advance their Dark Sky measures. Students compiled the following toolkit and process outline to assist Peoria leadership in their Dark Sky efforts.

Dark Skies Toolkit

- Dark Sky Assessment Guide: **http://ruralplanning.org/assets/dark-sky-assessment-guide---web.pdf**
- Dark Sky Planning Guideline: **https://www.planning.nsw.gov.au/-/media/Files/DPE/Guidelines/dark-sky-planning-guideline-2016-06.pdf**
- Flagstaff Dark Skies Coalition: **http://www.flagstaffdarkskies.org/**
- Fountain Hills Dark Sky Association: **http://fhdarksky.com/**
    - In particular their application to become an IDSC: **http://fhdarksky.com/wp-content/uploads/2017/11/IDA-APPLICATION-Fountain-Hills-09-14-2017.pdf**
- International Dark Sky Association: **https://www.darksky.org/**
- Royal Astronomical Society of Canada: **https://www.rasc.ca/classroom-activities**

Exemplary outline for Peoria's Dark Sky Ordinance

(Based on IDA recommended Cottonwood and Sedona Lighting Codes)

1. Mission Statement
2. Purpose and Intent
3. Definitions
4. Applicability
5. Administration
    - Requirements
        - Shielding code, lamp type, warm lighting, lighting controls
    - Prohibitions
    - Exemptions

6. Evaluation of Compliance
    - Business lighting, street lighting, residential lighting, parking lighting, airport lighting, sports complex lighting
7. Installation and Maintenance
8. Permits

CONCLUSION

This project demonstrates that Dark Skies are valuable for many reasons, including human health, tourism growth, educational opportunities, and more. Students believe Peoria is well-positioned to begin efforts toward establishing itself as a certified Dark Sky Community. The research outlined in this report is intended to provide a guiding framework to catalyze the often intimidating process of making municipal-led changes toward Dark Sky practices. As Peoria continues to grow, continuing to advance its existing sustainable practices, as well as pursuing new practices such as those presented in this project, will be important in maintaining the City's exceptional standard of living. The student team hopes the provided array of information can assist Peoria decision-makers in transforming Peoria into a certified Dark Sky Community while providing enriching experiences for the community as a whole.

Figure 23 *The Milky Way visible above Cathedral Rock in Sedona, Arizona*

REFERENCES

Bullough, J. D. (2012). Lighting in the roadway environment: Aims, advances, and alternatives. *Journal of The Royal Astronomical Society of Canada*, Special Report Dec. 2012, 15-17. **https://www.rasc.ca/sites/default/files/publications/JRASC-LPA-Special-Issue-lr.pdf**

Caster, V. (2021 October 25). *SCN Climate & Resilience Workgroup Meeting*. YouTube. **https://youtu.be/gyhOVK6EcnE**

Chou, B. R. (2012). The eye and visual system: A brief introduction. *Journal of The Royal Astronomical Society of Canada*, Special Report Dec. 2012, 3-6. **https://www.rasc.ca/sites/default/files/publications/JRASC-LPA-Special-Issue-lr.pdf**

Cinzano, P., Fachi, F., & Elvidge, C. D. (2001). The first world atlas of the artificial night sky brightness. *Monthly Notices of the Royal Astronomical Society, 328*(3), 689-707. **https://doi.org/10.1046/j.1365-8711.2001.04882.x**

City of Cottonwood. (2018). *Outdoor lighting requirements, Section 408*. **https://cottonwoodaz.gov/DocumentCenter/View/644/Section-408-Outdoor-Lighting-Requirements-PDF?bidId=**

City of Peoria. (n.d. a). About Peoria, Arizona. **https://www.peoriaaz.gov/residents/about-peoria [retrieved 11/12/2021].**

City of Peoria. (n.d. b). *Sustainability.* **https://www.peoriaaz.gov/government/departments/water-services/sustainability-water-conservation/sustainability**

City of Peoria. (2016). *Sustainability Action Plan 2.0. Renewing our Commitment to Peoria's Future.* **https://www.peoriaaz.gov/home/showpublisheddocument/4282/637370709867570000**

City of Sedona. (n.d.). *Exterior building lighting: Sedona land development code.* **https://sedona.municipal.codes/SLDC/5.8.I**

Coetzee, B. (2019). *Light pollution: The dark side of keeping the lights on.* Phys.org. **https://phys.org/news/2019-04-pollution-dark-side.html**

Cooperative Institute for Research in Environmental Sciences [CIRES]. (n.d.). *The new world atlas of artificial sky brightness.* University of Colorado Boulder. Retrieved November 8, 2021, from **https://cires.colorado.edu/artificial-sky**

Data USA. (2019). *Peoria, AZ.* Retrieved October 5, 2021, from **https://datausa.io/profile/geo/peoria-az**

Dick, R. (2012). LEDs in outdoor lighting. *Journal of The Royal Astronomical Society of Canada*, Special Report Dec. 2012, 18-21. **https://www.rasc.ca/sites/default/files/publications/JRASC-LPA-Special-Issue-lr.pdf**

Edson, S. (2020, December 20). *Tips for telescope buying.* National Air and Space Museum. **https://airandspace.si.edu/stories/editorial/tips-telescope-buying**

European Commission (n.d.). *Health effects of artificial light.* Scientific Committee on Emerging and Newly Identified Health Risks. **https://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_035.pdf**

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. D., Baugh, K., Portnov, B. A., Rybnikova, N. A., & Furgoni, R. (2016). The new world atlas of artificial night sky brightness. *Science Advances*, *2*(6). **https://doi.org/10.1126/sciadv.1600377**

Flagstaff Dark Skies Coalition. (2016). *LC Benefits.* Retrieved November 19, 2021, from **https://www.flagstaffdarkskies.org/dark-sky-solutions/dark-sky-solutions-2/outdoor-lighting-codes/2015-02-campverde-c/**

Flagstaff Dark Sky Coalition (2020). *Outdoor lighting codes: The why and how of lighting regulation.* Retrieved November 20, 2021, from **https://www.flagstaffdarkskies.org/dark-sky-solutions/dark-sky-solutions-2/outdoor-lighting-codes/**

Fountain Hills Dark Sky Association. (2018). *What is shielding?* **https://fhdarksky.com/information/what-is-shielding/**

Fountain Hills Dark Sky Coalition (n.d.). *What is correlated color temperature (CCT)?* **http://fhdarksky.com/information/what-is-corregated-color-temperature-cct/**

Fountain Hills & Fountain Hills Dark Sky Coalition (2017). *Application for International Dark Sky Community Designation for Fountain Hills, Arizona, USA.* **http://fhdarksky.com/wp-content/uploads/2017/11/IDA-APPLICATION-Fountain-Hills-09-14-2017.pdf**

Gallaway, T., Olsen, R. N., & Mitchell, D. M. (2010) The economics of global light pollution. *Ecological Economics*, *69*(3), 658-665. **https://doi.org/10.1016/j.ecolecon.2009.10.003**

Hall, J. C. (2020). *Flagstaff's dark sky heritage.* Poster for the 235th meeting of the American Astronomical Society, Honolulu, Hawai'i, January 4-8, 2020. **https://aas235-aas.ipostersessions.com/?s=48-F2-E3-B1-A4-B4-6A-39-50-D2-56-DA-E1-C5-E7-69**

Harrington, P. (2019). *How to care for your telescope.* Astronomy. **https://astronomy.com/magazine/2019/08/how-to-care-for-your-telescope**

Hyde, E; Frank, S.; Barentine, J. C.; Kuechly, H.; & Kyba, C. M. (2019). Testing for changes in light emissions from certified International Dark Sky places. *International Journal of Sustainable Lighting, 21*(1), 11-19. **https://doi.org/10.26607/ijsl.v21i1.92**

International Dark Sky Association [IDA]. (2002). *Outdoor Lighting Code Handbook Version 1.14.* Dark Sky Society. **https://www.darkskysociety.org/handouts/idacodehandbook.pdf**

International Dark Sky Association [IDA]. (2012). *Fighting light pollution: Smart lighting solutions for individuals and communities.* Stackpole Books.

International Dark Sky Association [IDA]. (2018). *International Dark Sky Community Program Guidelines.* **https://www.darksky.org/wp-content/uploads/bsk-pdf-manager/2021/05/IDSC-Final-May-2021.pdf**

International Dark Sky Association [IDA]. (2019). *Dark Sky Assessment Guide.* **https://www.darksky.org/wp-content/uploads/bsk-pdf-manager/2019/06/Dark-Sky-Assessment-Guide-Update-6-11-19.pdf**

International Dark Sky Association [IDA]. (2019). *Nights over Tucson: How the Tucson, Arizona, LED conversion improved the quality of the night.* **https://www.darksky.org/nights-over-tucson/**

International Dark Sky Association [IDA]. (2020). *The promise and challenge of LED lighting: A practical guide.* **https://www.darksky.org/wp-content/uploads/bsk-pdf-manager/2020/10/IDA_LED_handout_rev201016.pdf**

International Dark Sky Association [IDA]. (2021). *Outdoor lighting, crime, and safety.* **https://www.darksky.org/wp-content/uploads/2021/01/Outdoor-Lighting-Crime-and-Safety-English.pdf**

International Dark Sky Association [IDA]. (n.d. a). *Who we are.* **https://www.darksky.org/about/**

International Dark Sky Association [IDA]. (n.d. b). *International Dark Sky Places.* **https://www.darksky.org/our-work/conservation/idsp/**

International Dark Sky Association [IDA]. (n.d. c). *International Dark Sky Communities.* **https://www.darksky.org/our-work/conservation/idsp/communities/**

International Dark Sky Association [IDA]. (n.d. d). *Light pollution wastes energy and money.* **https://www.darksky.org/light-pollution/energy-waste/**

International Dark Sky Association [IDA]. (n.d. e). *Lighting ordinances.* **https://www.darksky.org/our-work/lighting/public-policy/lighting-ordinances/**

International Dark Sky Association [IDA]. (n.d. f). *Five principles for responsible outdoor lighting.* **https://www.darksky.org/our-work/lighting/lighting-principles/**

International Dark Sky Association [IDA]. (n.d. g). *Light pollution effects on wildlife and ecosystems.* **https://www.darksky.org/light-pollution/wildlife/**

International Dark Sky Association [IDA]. (n.d. h). *Materials for educators.* **https://www.darksky.org/our-work/grassroots-advocacy/resources/educators/**

International Dark Sky Association [IDA]. (n.d. i). *How to become an International Dark Sky Place.* **https://www.darksky.org/our-work/conservation/idsp/become-a-dark-sky-place/**

International Dark Sky Association [IDA]. (n.d. j). *Light pollution.* **https://www.darksky.org/light-pollution/**

International Dark Sky Association [IDA]. (n.d. k). *Outdoor lighting basics.* **https://www.darksky.org/our-work/lighting/lighting-for-citizens/lighting-basics/**

International Dark Sky Association [IDA]. (n.d. l). *Measuring light pollution.* **https://www.darksky.org/light-pollution/measuring-light-pollution/**

International Dark Sky Association [IDA]. (n.d. m). *How to conduct a sky quality survey.* **https://www.darksky.org/our-work/conservation/idsp/become-a-dark-sky-place/sky-quality-survey/**

International Dark Sky Association [IDA]. (n.d. n). *Light pollution wastes energy and money*. **https://www.darksky.org/light-pollution/energy-waste/**

International Dark Sky Association [IDA]. (n.d. o). *Human Health.* **https://www.darksky.org/light-pollution/human-health/**

International Dark Sky Association [IDA]. (n.d. p). *International Dark Sky Place (IDSP) application process.* **https://www.darksky.org/wp-content/uploads/bsk-pdf-manager/2019/12/IDA-IDSP-ApplicationProcess.pdf**

LED Hut. (2015). *The difference between warm white, daylight & cool white LED bulbs.* **https://ledhut.co.uk/blogs/news/the-difference-between-warm-white-daylight-and-cool-white-led-bulbs**

Luginbuhl, C. B. (2010). *Pattern Outdoor Lighting Code.* Flagstaff Dark Skies Coalition. **http://www.flagstaffdarkskies.org/wp-content/uploads/2015/10/CBL-POLC-standard-v2.0.pdf**

Luginbuhl, C. B. (2013). *Light pollution and lighting codes.* Flagstaff Dark Skies Coalition. **http://www.flagstaffdarkskies.org/wp-content/uploads/2013/02/Lighting-Codes-and-LP-Luginbuhl-130115.pdf**

Materese, R. (2021). *Kelvin: Introduction.* NIST. **https://www.nist.gov/si-redefinition/kelvin-introduction**

Meier, J., Pottharst, M., Krause, K., & Hasenöhrl, U. (2014). The new visibility of lighting: An introduction. In J. Meier, J., Hasenöhrl, U. Krause, K., & M. Pottharst (Eds.), *Urban lighting, light pollution and society* (pp.1-6). Routledge. **https://doi.org/10.4324/9781315747811**

Miller, M. (2016). *Light pollution may cause early spring in cities.* Slate Science. **https://slate.com/technology/2016/07/light-pollution-is-the-main-culprit-behind-early-spring-in-cities-worldwide.html**

Mukai, A., Yamaguchi, K., & Goto, S.G. (2021). Urban warming and artificial light alter dormancy in the flesh fly. *Royal Society Open Science, 8*(7). **https://doi.org/10.1098/rsos.210866**

NASA Night Sky Network. (2018). *How can you help curb light pollution?* **https://nightsky.jpl.nasa.gov/news-display.cfm?News_ID=745**

New South Wales Department of Planning and Environment. (2016). *Dark sky planning guidelines.* **https://www.planning.nsw.gov.au/-/media/Files/DPE/Guidelines/dark-sky-planning-guideline-2016-06.pdf?la=en**

Oracle State Park. (2021). *About dark skies.* Arizona State Parks. **https://azstateparks.com/oracle/dark-skies/about-dark-skies**

Owens, S. (2012). *The Bortle Scale: A flow chart.* Dark Sky Diary. **https://darkskydiary.wordpress.com/2012/01/19/the-bortle-scale-a-flow-chart/**

Rich, C., & Longcore, T. (2006). *Ecological consequences of artificial night lighting.* Island Press.

Riemersma-van der Lek, R.F, Swaab, D.F., Twisk, J., Hol, E.M., Hoogendijk, W.J., & Van Someren, E.J. (2008). Effect of bright light and melatonin on cognitive and noncognitive function in elderly residents of group care facilities: a randomized controlled trial. *JAMA*, *299*(22), 2642-55. **https://doi.org/10.1001/jama.299.22.2642**

Roberts, J. E. (2012). Light and Dark and Human Health. *Journal of The Royal Astronomical Society of Canada*, Special Report Dec. 2012, 11-14. **https://www.rasc.ca/sites/default/files/publications/JRASC-LPA-Special-Issue-lr.pdf**

Royal Astronomical Society of Canada. (n.d.). *Lesson plans and classroom activities.* Retrieved November 9, 2021, from **https://www.rasc.ca/classroom-activities**

Rural Planning. (n.d.). *Dark sky assessment guide.* **http://www.ruralplanning.org/assets/dark-sky-assessment-guide---web.pdf**

Sky Quality Meter. (n.d.). *Sky quality meter.* Unihedron. **http://unihedron.com/projects/darksky/**

Steinbach, R., Perkins, C., & Tompson, L. (2015). The effect of reduced street lighting on road casualties and crime in England and Wales: Controlled interrupted time series analysis. *Journal of Epidemiol Community Health*, *69*(11), 1118-1124. **https://doi.org/10.1136/jech-2015-206012**

Turina, F. (1970). Protecting night skies and naturally dark conditions in national parks. In Gobster, P. H. & Smardon, R. C. (Eds.), *Visual resource stewardship conference proceedings: Landscape and seascape management in a time of change.* Gen. Tech. Rep. NRS-P-183. U.S. Department of Agriculture, Forest Service, Northern Research Station, 186-200. **https://www.srs.fs.usda.gov/pubs/57546**

U.S. Census Bureau. (2019). *Quickfacts: Peoria City, Arizona.* Retrieved September 15, 2021, from **https://www.census.gov/quickfacts/peoriacityarizona**

U.S. Department of Energy. (n.d.). *Lumens and the lighting facts label.* **https://www.energy.gov/energysaver/lumens-and-lighting-facts-label**

U.S. Department of Health and Human Services. (2019). *Cataract data and statistics.* National Eye Institute. Retrieved November 22, 2021, from **https://www.nei.nih.gov/learn-about-eye-health/outreach-campaigns-and-resources/eye-health-data-and-statistics/cataract-data-and-statistics**

U.S. Office of Energy Efficiency and Renewable Energy. (n.d.). *Outdoor lighting.* U.S. Department of Energy. **https://www.energy.gov/eere/slsc/outdoor-lighting**

VCU Center on Society and Health (2015). *Why education matters to health: Exploring the causes.* **https://societyhealth.vcu.edu/work/the-projects/why-education-matters-to-health-exploring-the-causes.html#:~:text=Education%20can%20create%20opportunities%20for,affect%20both%20health%20and%20education**

Welch, D. & Dick, R. (2012). International Dark Sky Efforts. *Journal of the Royal Astronomical Society of Canada,* Special Report Dec. 2012, 22-25. **https://www.rasc.ca/sites/default/files/publications/JRASC-LPA-Special-Issue-lr.pdf**

Wilson, B., & Schnee, A. (2020). *A dark night sky in Los Angeles*. Outside History Blog Series: A Call for A Dark Night Sky, Colorado State University. **https://publiclands.colostate.edu/plhc-blog/outside-history-blog-series-dark-night-sky/#_ftnref1**

Workforce Services & Colorado Plateau Dark Sky Cooperative [CPDSC]. (2020). *Dark sky planning. An introduction for local leaders.* **https://assets.simpleviewinc.com/simpleview/image/upload/v1/clients/newmexico/Dark_Sky_Planning_Guide_8f996430-e8a2-468e-94c4-29332777ee12.pdf**

Worrall, S. (2021). Without bugs, we might all be dead. *National Geographic.* **https://www.nationalgeographic.com/animals/article/insect-bug-medicine-food-macneal**

Wright, S. (2021). *Astrotourism is looking up.* Visit Tucson. **https://www.visittucson.org/blog/post/astrotourism-is-looking-up/**

Zhao, Z.-C., Zhou, Y., Tan, G., & Li, J. (2018). Research progress about the effect and prevention of blue light on eyes. *International Journal of Ophthalmology, 11*(12). **https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6288536/**

Zielinska-Dabkowska, K. M.; Xavia, K.; & Bobkowska, K. (2020). Assessment of citizens' actions against light pollution with guidelines for future initiatives. *Sustainability, 12*(12). **https://doi.org/10.3390/su12124997**

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