Rooftop Solar Photovoltaic Feasibility Study

for the Mesa Fire Department

Scott Somers, Ph.D.

City of Mesa Fire Dept, Mesa, Arizona

Certification Statement

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

Signed: ____

Abstract

Climate change and particulate pollution represent critically important issues with a wide array of potential environmental disasters threatening public health and safety. Volatility in energy markets and newly-imposed environmental regulations have increased the cost of energy and the cost of using energy, placing a fiscal strain on municipal budgets. The Mesa Fire Department (MFD) is exploring the efficacy of installing rooftop solar photovoltaic systems on several of its facilities to partially obviate the need for grid-supplied electricity. Rooftop-mounted solar photovoltaic systems offer a clean, alternative-energy source that can abate energy-related emissions from department facilities and reduce budget expenses for electricity. The problem is that conducting a detailed solar-site analysis on each of over 20 MFD facilities is neither practical nor economical. The purpose of this applied-research project is to design a method to quickly and economically evaluate fire department facilities for rooftop solar-energy potential. Descriptive and evaluative-research methods were employed to answer the following questions: (a) how might converting to solar photovoltaic-generated power contribute to accomplishing the Mesa Fire Department's mission and strategic plan; (b) which financing mechanism will likely offer the most favorable internal rate of return to the city; (c) what rooftop layout factors or design guidelines should be considered in order to identify rooftop space suitable for solar panel placement; and (d) which fire department facility rooftops have a higher potential for PV installation? The results of the study demonstrate that solar photovoltaic systems are both financially and technologically feasible for the MFD. It is recommended that the MFD consider two facilities for a solar-pilot project, financed through a Power Purchase Agreement.

Table of Contents

Introduction

The City of Mesa, Arizona has made efforts to identify energy conservation measures that will help the city reduce energy consumption, lessen the need for capital improvements, reduce operating expenses, and ease the maintenance requirements for city buildings and infrastructure. The mayor, city council, management and staff are all committed to protecting the environment and providing a sustainable future for city residents. In a comprehensive effort to go "green," steps are being taken to obtain Leadership through Energy and Environmental Design (LEED) certification on certain buildings, and deploy clean-energy solutions such as solar photovoltaic (PV). PV technology has demonstrated to be an economical and technologically feasible approach to supplying sustainable energy in buildings under certain conditions (Burlage, 2009; Pearce, 2002). There is a broad portfolio of clean-energy opportunities that are being evaluated as part of a detailed energy study for the city. The objective is to develop and implement a seamless energy-efficiency program that meets the city's financial and operational needs, and environmental sustainability goals.

Prompted by concerns over continuing budget shortfalls, as well as a commitment to the city's sustainability efforts, the United Mesa Fire Fighters approached the fire department administration, city manager's office, and city council members in late 2010 with a preliminary proposal to install rooftop solar PV systems on fire stations as a way of reducing operation and maintenance costs related to energy consumption. The problem is that conducting a detailed solar-site analysis on over 20 Mesa Fire Department facilities is neither practical nor economical.

The purpose of this applied-research project is to design a method to quickly and economically evaluate fire department facilities for rooftop solar-energy potential. From this assessment, appropriate facilities can be targeted for more detailed engineering analyses. This project was completed as part of the National Fire Academy Executive Fire Officer Program Course R123: Executive Development, and examined the feasibility of installing rooftop solar technology on Mesa Fire Department facilities in terms of environmental issues, financial considerations, and technical factors. Descriptive and evaluative research methods were employed to answer the following questions:

1. How might converting to solar photovoltaic-generated power contribute to accomplishing the Mesa Fire Department's mission and strategic plan?
2. Which financing mechanism will likely offer the most favorable internal rate of return to the City?
3. What rooftop layout factors or design guidelines should be considered in order to identify roof space suitable for solar panel placement
4. Which fire department facility rooftops have a higher potential for PV installation?

Background and Significance

The city of Mesa is the third largest community in the State of Arizona and is located 16 miles east of Phoenix, within the county of Maricopa, one of the fastest growing metropolitan areas in the nation. Today, the city's population is 439,041 (U.S. Census Bureau, 2010), within an incorporated area of 137 square miles. The city provides a full range of municipal services, including police and fire protection; parks and recreation; library services; streets and transportation; health and certain social services; energy generation, transmission and distribution; water, sewer, natural gas, and sanitation services; and general administration. Currently, there are over 200 city buildings with more than 3 million square feet of space. Mesa's utility bills for FY08/09 were $13 million for the generation of 140 million kilowatt hours (kWh) of energy (City of Mesa, 2008).

The Mesa Fire Department (MFD) has a fairly sizeable facility portfolio. The department maintains 18 strategically-located fire stations-with two additional fire stations in various phases of construction-as well as a joint-operated public safety training facility and communications center, administrative buildings, and a service center. Electricity expenses for all fire-department facilities in the Salt River Project (SRP) service area for FY09/10 totaled $222,540.35 (Appendix A). This applied research project explores the efficacy of rooftop solar photovoltaic (PV) panels for fire stations and related facilities, in an effort to further improve fire department facilities, reduce operating expenses, and create a more sustainable infrastructure.

A key factor in the decision pursue this project was the city's continuing budgetary constraints, which are exacerbated, in part, by fluctuating energy costs. The previous years have been difficult economically for the City of Mesa. The decline in the national economy has been felt directly by the city, with a dramatic decrease in local sales tax revenues, and is shared throughout the State through declines in State shared revenue receipts. The extent of the budget reductions, necessitated by revenue declines, was significant. Ultimately, the approved FY08/09 budget was reduced by $29 million, and $60 million of anticipated expenditures was eliminated from the FY09/10 budget (City of Mesa, 2009). As the 2009-2010 fiscal year progressed, a variety of continuing economic impacts was recognized. General-fund projections were forecasted to decrease another $16 million, with additional reductions of over $3 million anticipated for FY10/11 (City of Mesa, 2010). City management continues to explore better, more efficient ways of providing services. This includes identify energy conservation measures that help reduce energy consumption, decrease operating expenses, and ease the maintenance requirements for city buildings.

Volatility in energy markets and new environmental regulations has increased the cost of energy and the cost of using energy. Clean, renewable energy sources – such as solar, wind, hydro, geothermal and biomass – account for only six percent of the total electricity generated in Arizona (Valley Forward Association, 2011). Most of the rest is produced by large electric plants, fueled by non-renewable sources including coal, natural gas, and oil, as well as nuclear energy. In 2006, the state's public utility regulator, the Arizona Corporation Commission (ACC), adopted the Renewable Energy Standard and Tariff (RES), requiring a dramatic increase in renewable energy sources. The long-term renewable energy requirement of the RES is for 15% of retail energy sales from ACC-regulated electric utilities to come from renewable energy sources by 2025 (Holbert, 2007). It further requires that in years 2012 and beyond, 30% of that power be from "distributed generation," which means it must be produced on site by systems such as rooftop solar photovoltaic, to reduce loads on transmission lines and power lost in transit (Arizona Corporation Commission, 2006).

The city of Mesa has continuously elevated its leadership role in stewardship of the environment by leading and participating in regional and local initiatives. The city is an organizing member of the Sustainable Cities Network (SCN). SCN is a regional initiative of Arizona State University (ASU), city, county and tribal leaders for sharing knowledge and coordinating efforts to understand and solve problems related to front-line challenges of municipal sustainability. Scott Bouchie, Deputy Director of Environmental and Sustainability, serves as chair of the SCN Solar Committee. In 2009, Mesa Mayor Scott Smith became the 1,000th signatory to the U.S. Conference of Mayors' Climate Protection Agreement. The agreement aligns with Kyoto Protocol standards, which call for a reduction in carbon emissions by 7% below 1990 levels (U.S. Conference of Mayors, 2009). Five Mesa City Council Strategic

Initiatives provide a framework for the city strategic plan. These initiatives call for regional leadership that "… partners to find common solutions to regional challenges that are innovative and sustainable," and seek to address quality-of-life issues in a manner that is "… sustainable and environmentally friendly." Toward these goals, the city has participated in several local sustainability projects including a public-private partnership with SolFocus® to install concentrated solar photovoltaic (CPV) technologies at the city's Central Arizona Project Water Treatment Plant. They have also partnered with ASU to integrate research of solar and other alternative energy resources with Mesa's electric distribution utility. The transportation department has installed PV panels to provide lighting for bus shelters to obviate the need for electrical service, and the fire department is seeking LEED certification for fire stations 219 and 220.

This applied-research project is significant to the Mesa Fire Department in three ways. First, it supports the department's *Strategic Plan 2006*, a component of which focuses on neighborhood and environmental vitality and stresses the promotion of "environmental awareness" (p. 33). Second, the use of alternative energy sources acknowledges an ongoing commitment by the MFD to integrate the *Strategic Plan 2006* with the city strategic and general plans, and Council Strategic Initiatives. Third, the research can serve as a framework to evaluate the feasibility of installing rooftop PV on other municipal buildings.

This research project is related to the National Fire Academy's (NFA) Executive Development (ED) course, which "…is intended to prepare the fire service executive for the 21st century", and identifies a leader as "…one who can anticipate future trends" (USFA, 2010a, p. iii). Clearly, as Arizona continues to grow, there will be increasing demands for energy. Environmental regulations, enacted to reduce GHG emissions, will increase the cost of energy generated from non-renewable sources, which will place continued pressure on municipal budgets. While some federal standards, such as the U.S. Energy Independence and Security Act of 2007 (EISA), do not apply to local governments, it is foreseeable that future federal grants may come with renewable energy requirements for all new or renovated buildings. Indeed, the 2009 Station Construction Grant (SCG) included sustainability benchmarks used to evaluate applications (US Department of Homeland Security, 2009). With the ACC-adopted RES, requiring greater use of distributed generation, solar power will likely play an important role in Arizona's energy future.

Finally, this research project addresses one of the U.S. Fire Administration's (2010b) strategic plan goals to "reduce risk at the local level through prevention and mitigation" (p. 13). The objective of this goal is to "[e]ncourage State, local, and tribal adoption of risk reduction, prevention, mitigation, and safety strategies" (p. 18). In the ED pre-course reading *Leadership on the Line: Staying Alive through the Dangers of Leading*, Heifetz and Linsky (2002) use the metaphor of the balcony - alternatively being on the balcony and on the dance floor - to illustrate the need for leaders to see the big picture by distancing themselves from the fray, but also engage in actions that make an impact. Fire service leaders can better enact proactive local mitigation measures if they more fully understand the global nature of problems. Climate change represents a critically important issue for the safety, health and welfare of America's citizens, "with a wide array of potentially disastrous effects threatening the nation's cities" (National League of Cities, 2010, p. 60). Increasing threats related to climate change that fire departments will be called upon to deal with include, but are not limited to, thermal extremes of heat and cold, hurricanes, floods, and wildfires (NLC, 2010). The burning of fossil fuels produces particulate matter and GHG emissions that exacerbate respiratory symptoms in patients with chronic obstructive pulmonary diseases, such as asthma, and those with allergies and heart disease (American Lung Association, 2006). There are complex linkages of technology and infrastructure that affect climate change (Gamble, Ebi, Grambsch, Sussman, & Wilbanks, 2008). For example, Torcellini, Pless, Deru, and Crawley (2006) observe that buildings "have a significant impact on energy use and the environment" (p. 1). In Arizona, electricity use accounts for 40% of the state's gross greenhouse gas (GHG) emissions (Arizona Climate Change Advisory Group, 2006). Installing PV panels on fire department facilities may provide an opportunity for the MFD to demonstrate environmental leadership and proactively mitigate the adverse public health and safety effects of climate change, while reducing energy costs.

Literature Review

A literature review was conducted as part of this applied research project to accumulate background information on environmental trends and solar photovoltaic energy systems. Sources of information included academic journals, as well as professional and trade magazines, books, government and non-governmental organization (NGO) publications, technical reports, newspaper articles and press releases, and Internet sites. This review provided valuable insight into key issues and concepts, especially as they related to some of the more technical aspects of the project. Particularly important to this research was the identification of factors that influence solar feasibility and guidelines for evaluating solar ready roof surfaces. This section reports on the existing body of knowledge related to the environmental, financial, and technical feasibility of rooftop solar PV installations.

Environmental Issues

One benefit of solar power is the improvement in air quality it will contribute to over time. According to a Morrison Institute (2008) report, the Phoenix-Tucson corridor – of which

Mesa is a part – is poised to double in population from 5 million to 10 million residents by 2050. The region will grapple with the environmental challenges of rapid urbanization in a unique, sensitive and diverse ecosystem. Securing an adequate water supply, mitigating the heat island effect, and ensuring air quality are some of the big challenges ahead. Global climate change will likely further impact the region as atmospheric concentrations of GHG rise and temperatures increase, creating serious public health and environmental problems. The advancement of solar energy in Arizona is thus intrinsically interrelated with concerns about the sustainability of the region.

Maricopa County Air Quality. Once renowned for its clean air, Arizona was a destination for patients suffering from chronic lung diseases or environmental allergies. Today, however, the Phoenix area is known for its “brown cloud” and much of the State struggles to attain acceptable air quality standards. Metropolitan Phoenix is located in a valley surrounded by mountains, predisposing the area to frequent temperature inversions, particularly during the winter months. “An inversion is an atmospheric condition caused by increasing temperature with elevation, resulting in a layer of warm air preventing the rise of cooler air trapped beneath” (Maricopa County Air Quality Department, 2011). During the day, as the desert floor heats up, trapped polluted air spreads and particulate matter rises creating a visible haze (Eastwood, 2006).

The Phoenix-Mesa-Scottsdale region appears on all three lists for most polluted cities in the American Lung Association *State of the air: 2011 report*. *State of the air* is a national air quality “report card” that assigns letter grades to counties across the country and ranks cities and counties on three measures of the most widespread air pollutants – ozone and particle pollution. Ozone is a colorless, highly reactive gas that is the principle component of smog (Fierro, 1999). Particle pollution, also known as particulate matter or PM, “is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, soil or dust particles" (US Environmental Protection Agency, 2011. para. 1). The region ranked 19th for ozone, 2nd for year-round particle pollution, and 24th for short-term particle pollution. Four Arizona counties received a grade of "F" for the number of high ozone days.

As a whole, Maricopa County does better with particle pollution receiving a "B" grade in the *State of the Air* report. However, the Phoenix-Mesa-Scottsdale area, where the bulk of the Maricopa County population is concentrated, does not fare as well. In a January 25, 2011 press release, the Arizona Department of Environmental Quality (ADEQ) announced that the State had withdrawn its particulate matter air quality plan for Maricopa County to avoid a finding on non-compliance by the US EPA. The Plan calls for significant reductions in particle matter of 10 microns or less, commonly known as PM_{10} (ADEQ, 2011, January 25).

The American Lung Association (2011) estimates that over 4 million "at-risk groups" are exposed to air pollution in Maricopa County. The Maricopa County Environmental Services Department (MCESD) high air pollution advisories contain a warning of the health effects of particle pollution:

> When inhaled, particulate matter invades the respiratory system's natural defenses and lodges deep in the bronchial tubes. Normal body defenses (coughing and sneezing) do not remove these harmful pollutants. Particulate matter can increase the number and severity of asthma attacks, cause or aggravate bronchitis and other lung diseases, and reduce the body's ability to fight infections. (MCESD, 2000, para. 4)

Particle pollution increases the risk of premature death, heart attack, and stroke, and is known to affect the development and function of children's lungs (American Lung Association, 2010).

Ozone exposure results in several pathophysiologic processes that significantly affect human health (Fierro, 1999). The oxidant pollutant primarily impacts the respiratory system causing wheezing, coughing, and triggering asthma attacks. There is evidence that ozone pollution can shorten lives (National Research Council, 2008). "Four groups of people are particularly sensitive to ozone when they are active outdoors: children, healthy adults doing outdoor exercise, people with preexisting respiratory disease, and the elderly" (Fierro, 1999, p. 2). Arizona's climate plays a role in ozone pollution. High ambient temperatures influence the chemical and physical process involved in the formation of ozone, increasing concentrations during the summer months (McKinnon, 2010).

Epidemiological studies conducted in Arizona have established a strong correlation between air quality and public health, particularly among at-risk populations. Mar, Norris, Koenig, and Larson (2000) evaluated the association between mortality outcomes in the elderly and PM. Cardiovascular mortality was found to be significantly associated with carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), $PM_{2.5}$, PM_{10}, and ozone levels in atmosphere. A 2006 study by ADEQ in collaboration with the Arizona Department of Health Services (ADHS) and ASU Center for Health Information Research examined the connection between PM_{10} and incidence of asthma among children. It found that the asthma events among children aged 5-18 years increased 13.7% when the daily average of PM_{10} rose to the 75^{th} percentile. Neighborhoods with lower socioeconomic status, higher populations of Latino immigrants, and higher proportions of renters have been found to have greater exposure to air pollutants (Grineski, Bolin, & Boone, 2007).

In other studies, the World Health Organization estimates that the global burden of disease due to outdoor air pollution, in terms of particulate air pollution ($PM_{2.5}$), results in 800,000 deaths and 6.4 million years of life lost annually, worldwide (Romieu et al., 2005). Meta-analyses involving hundreds of studies have consistently shown that short- and long-term exposure to PM and ozone affect morbidity and mortality, hospitalizations and emergency department visits, asthma and bronchitis, days of work lost, restricted-activity days, and varying levels of pulmonary function loss in children and adults (US EPA 2004, 2006). Furthermore, these results may be caused by lower levels of air pollution than previously thought (Medina-Ramon, Zanobetti, & Schwartz, 2006; Meng, Rull, Wilhelm, Lomardi, & Ritz, 2010).

Global Climate Change. Global climate change has the potential to exacerbate pollution-related problems in Arizona and has been recognized by scientists as a serious public health and environmental concern. As atmospheric concentrations of GHG rise, global temperatures are increasing. The Intergovernmental Panel on Climate Change (Parry, Canziani, Palutikof, van der Linden, & Hanson, 2007) predicts that climate change may lead to more extremes of heat and cold; increase the prevalence of climate-sensitive diseases including malaria, dengue fever, yellow fever, and encephalitis; and diminish air quality directly as hotter days facilitate ozone formation and indirectly affect the concentration of PM in the air by affecting natural sources of PM such as wildfires and dust from dry soils. A report entitled *Analysis of the Effects of Global Climate Change on Human Health and Welfare and Human Systems* by the U.S. Climate Change Science Program concludes that the anticipated impact of global warming on the Intermountain West will include early snowmelt, degraded air quality, more intense urban heat island effect, wildfires, heat waves, and drought (Gamble et al., 2008).

The Arizona Climate Change Advisory Group (ACCAG, 2006) observes that, over the past 50 years, the climate in the western United States has warmed, on average, 1.4 degrees Fahrenheit. It cites IPCC climate models that predict that annual mean temperatures in the American southwest could increase by as much as 14 degrees Fahrenheit before the end of the century. The National Weather Service Forecast Office in Phoenix reports that high and low temperatures have been trending warmer since records began in 1896. "This warming is attributable to a combination of local warming (urban heat island effect) and regional climate change" (National Oceanic and Atmospheric Administration, 2010, para. 6). Arizona GHG emissions are rising faster than the national average. An ACCAG survey of Arizona GHG emissions documented an increase of 51% from 1990 to 2000, compared to only 23% nationally during this period (Bailie et al., 2006). The effects of global warming on Arizona are expected to be severe and include an impact on the state's water supply as high temperatures increase evaporation off reservoirs; warmer temperatures may intensify the urban heat island effect, especially in the metropolitan Phoenix and Tucson areas, worsening Arizona's air pollution problems; stronger summer storms and earlier mountain snowmelt could contribute to greater flash flooding; and hotter, drier temperatures may produce larger, more intense wildfires and a longer wildfire season (Owens, 2009).

A study by scientists at the University of Arizona and the University of California-San Diego (Westerling, Hidalgo, Cayan, & Swetnam, 2006) observed that, since 1987, the wildfire season in the Western states had become 2 ½ months longer due to climate changes brought about by global warming. The paper analyzed 1,166 large forest fires in excess of 1,000 acres from 1970 to 2004 and noted that, in the second half of that period, there were four times as many wildfires, and 6 ½ times as much acreage burned.[1] A search of the Disaster Information database on the FEMA website logged 70 disaster declarations in Arizona since 1966. Forty-seven wildfire events are recorded, all occurring after 1987. In fact, after a decade of drought and warmer temperatures, the Arizona wildfire season had its earliest start on record in February 2006, and the state's two largest wildfires, the 2002 Rodeo-Chediski Fire and the 2005 Cave Creek Complex Fire, collectively consumed over 750,000 acres (ACCAG, 2006; Owens, 2009).

Wildfires are themselves producers of GHG emissions (Bonnicksen, 2008). Smoke produced by wildfires contains gasses and PM that contribute to local and regional haze in Arizona, and increase the frequency and intensity of asthma attacks (Arizona Department of Environmental Quality, 2011). Teruyuki Kobayashi (2008), former Fire Chief of the Tokyo, Japan Fire Department, feels that the fire service can make a contribution to reducing the effects of GHG and improving its carbon footprint by seeking firefighting efficiency that minimize the emission of smoke and fire gasses, taking steps to conserve energy and monitoring departmental environmental protection initiatives, and reducing fuel consumption. Indeed, local government agencies can make meaningful contributions to reducing GHG as they "have considerable authority over land-use planning, and waste management and can play an important role on transportation issues and energy consumption" (Betsill, 2001, p. 394).[2]

Data from the *Final Arizona Greenhouse Gas Inventory and Reference Case Projections, 1990-2020* shows that electricity use accounts for nearly 40% of the state's gross GHG emissions, "slightly higher than the national share of emissions from electricity production" (Bailie, 2006, D-8). Coal is the largest source of electricity in Arizona, accounting for 35.5% of production, or 40 million (MM) megawatt hours (MWh), followed by natural gas (31.1%, 36MM MWh), and nuclear (27.4%, 30MM MWh); oil accounts for 0.1% of Arizona energy production (Considine & McLaren, 2008; Valley Forward Association, 2011). Emissions from coal-fired power plants contain 84 of 187 hazardous air pollutants identified by the US EPA as posing a threat to human health and the environment and are a major source of sulfur dioxide, oxides from nitrogen, and PM (MacIntosh & Spengler, 2011).

Table 1.

Life-Cycle Greenhouse Gas Emission Estimates for Selected Energy Sources

Energy Source	Direct Emissions	Cumulative Emissions
Coal	800-1,000	950-1,250
Natural Gas	360-575	440-780
Oil-fired	<800	500-1,200
Nuclear	<1.5	2.8-24
Hydro		1-35
Photovoltaic		43-73

Source: Weisser, D. (2007). A Guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies, *Energy*, *37*: 1543-1559.

Table 1 describes GHG direct and cumulative GHG emissions from various energy sources measured in grams of CO_2 per kWh.[3]

While the ACCAG (Bailie, 2006) GHG inventory raises concerns over GHG emissions, there is a positive trend worth noting:

> During the 1990s, Arizona electricity demand grew at a rate of 4.0% per year, while electricity emissions grew 3.3% annually, reflecting a decline in emissions per kWh. This decline was due largely to the rapid growth of new natural gas generation, and to a lesser extent increases in nuclear generation. (p. D-8)

Since natural gas and nuclear energy are “cleaner” than other forms of fossil fuels, this finding suggests that an increased use of renewable energy sources may not only retard the growth of GHG emissions per kilowatt hour, but actually decrease gross GHG emissions in the state.

Mesa Solar Climate. Mesa’s climate and location at latitude create an opportunity for the fire department to install solar PV, assuming the availability of suitable rooftop space.

Table 2.

Mesa Area Weather Information

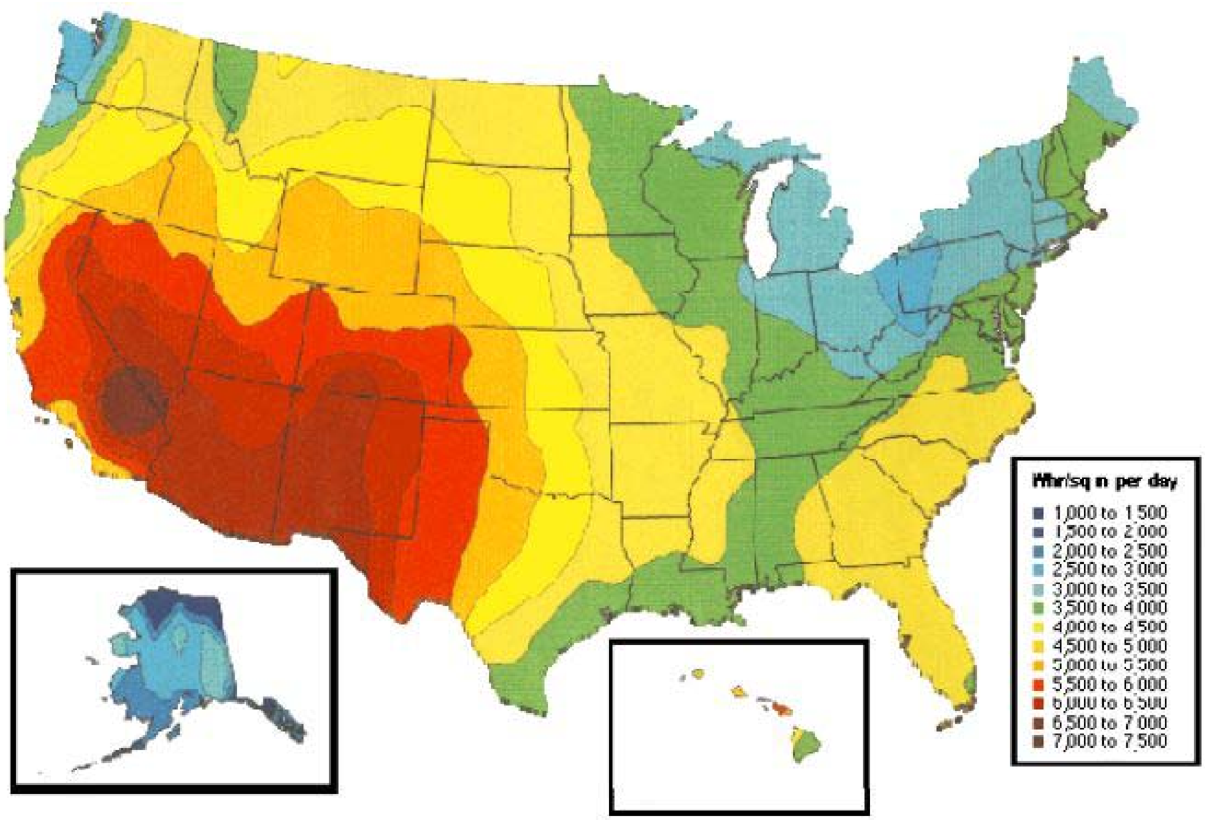
Month	High	Low	Rain	% Sun	Sunrise	Sunset	Insol.
January	66	38	0.8	78	7:32	5:43	3.25
February	70	42	0.8	80	7:12	6:12	4.12
March	75	47	0.9	84	6:39	6:36	5.58
April	84	52	0.3	89	5:58	6:59	7.09
May	94	58	0.3	93	5:28	7:21	7.98
June	102	68	0.1	94	5:18	7:39	8.14
July	105	76	0.9	85	5:29	7:39	6.82
August	104	75	1.1	85	5:50	7:14	6.16
September	98	68	0.9	89	6:11	6:35	5.82
October	88	57	0.7	88	6:32	5:55	4.69
November	75	46	0.8	83	6:59	5:26	3.64
December	66	40	1.1	77	7:25	5:22	3.02

Source: National Oceanic and Atmospheric Administration, NWS - Phoenix

Table 2 presents average monthly climate and weather information, sunrise and sunset times, and solar insolation. Arizona's insolation (incoming solar radiation) is among the highest in the nation, with a yearly average in Phoenix of 5.38kWh/m^2/day. Sunshine in the Phoenix area averages 78% in December-January, to a maximum of 94% in June (Schmidli, 1996). On average, Arizona boasts 320 days of sunshine annually (Valley Forward Association, 2011), and three Arizona cities are in the top five on the National Climate Data Center (2004) ranking of cities based on annual possible sunshine. Figure 1 shows that the southwest has the highest amount of kilowatt hours of solar energy potential per year for a kilowatt of solar installed.

Figure 1.

U.S. Solar Radiation Map



Source: www.solidsolar.com

Arizona is without a doubt well-suited for solar energy projects; other states with great solar insolation are New Mexico, Nevada, western parts of Texas, and portions of California, Colorado, and Utah.

Financial Considerations

A search of the USFA Executive Fire Officer Program Applied Research Projects Portal returned only one solar PV-related paper. That 2009 study out of Florida concluded that solar PV was not an economical alternative, but focused only on self-financing and identifying supplemental sources of funding (McCabe, 2009). In the short time since that applied research project was written, financial incentives, renewable energy standards, and net metering rules have all evolved. Incentives and regulations also vary from state to state, so it is important that municipal organizations in different regions assess solar power feasibility based on the local regularory environment. Three financing mechanisms are considered for this project: self-financing, third-party ownership-Power Purchase Agreement, and third-party ownership-solar lease.

Self-Financing. One way to acquire solar PV is simply to purchase the equipment. Consumers have traditionally self-financed the up-front costs of installing PV either with cash, or through bank loans, equity loans, and occasionally mortgages (Kollins, 2008). Ownership, however, brings with it responsibility for system maintenance costs and monitoring system performance to ensure maximum efficiency and rate of return. According to Frantzis (2008), since grid-supplied electricity has historically been more economical than distributed generation sources, early solar users tended to be less motivated by the internal rate of return (IRR), than with the prospect of demonstrating a commitment to environmental stewardship.

Public entities have the option of funding capital projects either through pay-as-you-go or borrowing, and may employ both methods depending upon the size and nature of the project (Gianakis & McCue, 1999). Pay-as-you-go relies on current revenues to pay for capital improvements. Current revenues include funds acquired through taxes or other own-source revenues, such as utility or impact fees, or through intergovernmental grants.[4] A public agency might also set aside funds each year until enough capital is saved to pay for the project; examples include revenues accumulated in a replacement fund or as retained earnings in a utility fund (Bland & Rubin, 1997). Seventeen states and the District of Columbia have set aside revenue for solar installations through a systems benefit charge (SBC), a small fee added to electricity bills either in the form of a modest charge per kWh or monthly flat fee (www.dsireusa.org).[5] SBC funds can be used by municipalities to offset the up-front costs of installing renewable energy systems. For example, a "portion of Connecticut's SBC funds are used to challenge cities and towns to a Clean Energy Campaign, whereby participation in green power programs leads to free PV systems for the community" (Cory, Coughlin, & Coggeshall, 2008, p. 10).

There is some potential to generate revenue from solar PV through the sale of renewable energy credits (RECs) or solar renewable energy credits (SRECs); SRECs are RECs that are specifically generated by solar power systems. Both RECs and SRECs are tradable, non-tangible energy commodities that represent 1 MW of electricity generation. The value of the REC depends on whether it is sold into a compliance or voluntary market. In Arizona, where the ACC has adopted a RES requiring 15% of retail electric sales from renewable energy sales, RECs will be a marketable commodity as utility companies purchase them to balance their energy production portfolio. Since the RES also contains a specific requirement for solar distributed generation, SRECs will hold an even higher value. However, Cory et al. (2008) notes that, in most cases, "the sale of SRECs will not be sufficient to structure a public-sector PV project with a payback period that is acceptable to the public entity" (p. 9).

Except for smaller projects, local governments generally finance capital expenditures through long-term debt instruments, or bonds. Cities issue bonds to support voter-approved projects and then agree to pay back the bond with interest. Bond funding is for assets with a long useful life such as buildings, utility systems, and street improvements. At a minimum, the asset should have the same useful life as the length of the bond repayment schedule. There are two types of municipal bonds: general obligation (GO) bonds and revenue bonds (Aronson & Schwartz, 1981; Gianakis & McCue, 1999; and Cory et al., 2008). With a GO bond, the principle and interest are secured unconditionally with the full faith, credit and taxing authority of the issuer. State laws typically define the purposes for which GO bonds can be sold, and set limits on the amount of bonds that can be issued, usually as a percentage of a city's assessed valuation. Revenue bonds are issued for municipally operated enterprises (such as water, electric, or gas utilities) and have no statutory limitations as to the amount that can be issued. Bonds issued for projects are repaid from revenues received from customers of the particular utility or through user fees.

Federal bond programs available to municipalities include the Clean Renewable Energy Bond (CREB) program and the Qualified Energy Conservation Bond (QEBC). Both programs allow local governments to issue bonds with a 0% interest rate meaning the borrower pays back only the principle on the bond. The bondholder receives federal tax credits in lieu of interest. Revenue from the bonds can be used for "qualified energy conservation projects" including capital expenditures for solar installations and energy efficiency programs that reduce energy consumption in publicly-owned buildings (Database of State Incentives for Renewables & Efficiency, 2010a, 2010b). The difference between the programs is that the CREB is administered by the Internal Revenue Service (IRS) under an open solicitation process, while the QECB bond program is administered by the states under allocations from the U.S. Treasury. In Arizona, the QECB is managed by the Arizona Commerce Authority (www.azcommerce.com). There is uncertainty surrounding the CREB program. The IRS is not currently accepting new CREB applications, and the future of the program depends upon continued congressional allocations (DSIRE, 2010a).

The high cost of solar energy relative to the cost of traditional energy sources remains the main impediment to wider adoption. The installed costs for PV in Arizona range from $7.6/W for a <10kW system, to $8.1/W for a <100kW system (Barbose, Darghouth, & Wiser, 2010). Severin Borenstein, Director of the University of California Energy Initiative and E.T. Grether Professor of Business Administration and Public Policy at the University at California-Berkeley, conducted a market value and cost analysis of solar photovoltaic electricity production using a middle-ground installed cost estimate of $8/W for a 10kW system. Borenstein (2008) concluded that:

> The net present cost of installing solar PV technology today far exceeds the net present benefit under a wide range of assumptions about levels of real interest rates and real increases in the cost of electricity. Lower interest rates and faster increases in the cost of electricity obviously benefit solar PV, but even under the extreme assumption of a 1% real interest rate and 5% annual increase in the real cost of electricity, the cost of solar PV is about 80% greater than the value of the electricity it will produce. Under more moderate assumptions about the real interest rate and the escalation in the cost of electricity, the net present cost of a solar PV installation built today is three to four times greater than the net present benefits of the electricity it will produce. (pp. 22-23)

Subsidies and incentives can help defray the installed cost of solar PV. A report by the Lawrence Berkeley National Laboratory entitled *Tracking the Sun III*, examines the installed cost of photovoltaic systems in the U.S. from 1998 to 2009. The report indicates that the average net installed cost of commercial solar PV was as low as $3.8/W, taking into consideration the financial incentives provide through utility, state and Federal programs (Barbose et al., 2010).

Incentives such as the federal investment tax credit (ITC) and Modified Accelerated Cost Recovery System (MACRS) can be used by businesses to offset the up-front cost of installing solar PV systems by reducing their tax burden. The federal ITC is equal to 30% of expenditures, with no maximum credit. Commercial PV owners can also take advantage of tax incentives through accelerated depreciation of capital investments in solar energy systems; the net present value of which is equal to 12% of the installed costs (Barbose et al., 2010). MACRS allows businesses to recover investments in certain property through depreciation deductions. Solar-electric technologies are classified as five-year property for tax liability purposes. This accelerated depreciation allows business owners to take advantage of the tax deduction over a shorter period of time, rather than the actual life of the property, which can be 25-30 years for solar PV systems. "The shorter the depreciation schedule, the greater the percentage of the asset that can be depreciated each year" (Cory et al., 2008, p. 22). Both the federal ITC and MACRS can "account for 40-60% of the installed cost of a solar PV system" (p. 21).

Unfortunately, because public agencies are not taxable entities, they are not eligible for incentives such as the federal ITC or MACRS, so the net installed cost of solar PV will be higher for local governments than for commercial consumers. However, local governments can benefit indirectly from these incentives through third-part ownership agreements such as a power purchase agreement (PPA) or solar lease.

Power Purchase Agreements. PPAs are a well-established contract mechanism in the utility industry, and are increasingly being used by solar service providers (SSP). According to Guice and King (as stated in Cory et al., 2008), "in 2007, 50% of the growth in the commercial and institutional market for solar in the United States was carried out using the third-party ownership model compared to just 10% in 2006" (p. 23). In this arrangement, a third-party owns, operates and maintains the PV system, and the customer "hosts" the system on site and purchases electricity generated by the system. The PPA allows the host customer to receive stable utility rates and electricity at or below the current retail rate, while the while the SSP and investors take advantage of tax credits and RECs, and income generated from electricity sales (US EPA, 2010).

Several themes emerge from the literature that highlights the opportunities and key reasons why third-party ownership PPA is becoming a popular strategy for financing new PV installations on public buildings (Corey et al., 2008; Kollins, 2008; Rahus Institute, 2008; US EPA, 2009):

- Defrays up-front capital cost. At around $8 per installed watt in Arizona, public sector PV systems can easily cost hundreds of thousands of dollars. Since the third-party ownership structure pushes the installation cost onto the SSP, the project requires little or no capital investment by the public agency, so the project can cash-flow positive from day one.
- Predictable energy pricing. One of the many benefits a solar PPA provides is a guaranteed, predictable cost of electricity less than conventional utility rates. Contracts range from 15-25 years, and most contain a fixed electricity cost escalator rate over the term of the agreement.
- Removes maintenance responsibility. PPA contracts assign responsibility for the operation and maintenance of PV equipment to the SSP, not the public entity. If the PV system is not operating properly, the host organization does not pay for the repairs; it only pays for the electricity that the system generates.
- Captures financial incentives. To capitalize on state and federal ITCs an organization must be a taxable enterprise, which public entities are not. The third-party ownership model introduces a tax equity investor into the arrangement that can take advantage of the 30% federal ITC and five-year MACRS depreciation tax benefits; cost savings are passed on to the public entity in the form of lower electricity rates.

- Provides project financing expertise. Tax equity financing is a niche market. SSP developers are better positioned to secure favorable terms for capital than local entities.

While the third-party ownership PPA model presents an attractive financing option for local governments, two key managerial issues emerge. First, the ownership of RECs can be assigned to any party and must be clearly addressed in the PPA. It is often the case that the SSP/third-party developer assumes ownership of the RECs and sells them to help finance the system. However, if the system host does not retain ownership of the RECs, the public entity cannot claim they are using solar power, only that they "host" solar panels on public facilities. In Arizona, the ACC-mandated RES requires 4.5% of retail energy sales to come from distributed generation by 2025, making RECs a valuable commodity. Moreover, Cory et al. (2008) note that RECs "can account for 40% - 80% of the total revenue stream for a project" (p. 7). As an option, SRECs can be sold and a portion of the proceeds used to purchase RECs from other renewable energy sources. In this way, the city could still claim it is using green energy sources to power its facilities.

Second, there are some legal questions as to whether third-party SSPs constitute a "public service corporation" subject to the regulations of the ACC. "As a historical matter to protect the public, most state laws have a broad definition of what is a utility and either a public utilities commission ruling or statutory change is needed in order for a PPA to be used with other than a utility customer" (Greguras, 2010, "Climate Change Report," para. 4). Arizona's constitution requires that "all corporations, other than municipal, engaged in providing gas, oil, or electricity…shall be deemed public service corporations," (Ariz. Const. art.15, § 2) and subject to regulation. In June 2010, the ACC ruled that solar service providers are not considered public service organizations, and therefore are not subject to regulation by the ACC (Hayes, 2011).

This decision currently only applies only to PPA contracts between an SSP and government entities, schools, and non-profit organizations (Greguras, 2010). While the matter seems to be resolved at the present time, it is possible that PPAs will be subject to further judicial scrutiny.

Solar Lease. A solar lease provides many of the same benefits as a third party ownership PPA, particularly no upfront costs and efficient monetization of state and federal ITCs. In a solar lease, the third-party developer covers the cost of installing the system, captures rebates and incentives, provides warranty service on the PV system, and collects any net excess generation produced to sell back to the utility company. The customer pays nothing initially, and then leases the equipment for a fixed monthly payment, although some contracts may include annual payment escalators. While a solar lease can maximize up-front savings and immediately lower electricity costs, the customer assumes more risk than in the PPA model. The SSP receives monthly payments for lease of the equipment, even if the system is not producing electricity. Ideally, savings on the electricity bill exceed the cost of the lease otherwise the customer ends up paying more for solar power on a levelized basis ($/kWh) than for conventional electricity (Kollins, 2008). Unless otherwise specified in the lease agreement, the customer is responsible for operation and maintenance (O&M) outside of warranty service.

Arizona Incentives and Policies for Solar Energy. In addition to the incentives previously mentioned in the literature, there are several incentives and policies in Arizona that have an impact on the economics of solar feasibility for the Mesa Fire Department. The federal Energy Policy Act of 2005 requires state utility commissions and large utility providers not regulated by the commission to assess their interconnectivity and net metering procedures (Keyes et al. 2011). Interconnection standards govern how an on-site solar generating system is allowed to physically connect to the grid (DSIRE, 2010c). Net metering is a billing arrangement that establishes the right of an owner to be compensated by the utility company for any net excess generation produced by the system; this is accomplished using a single, bi-directional meter. Net metering rules were adopted by the ACC in October 2008, and approved by the Attorney General in March 2009 (DSIRE, 2010d). Under Arizona rules, net metering is available to customers who generate electricity from solar PV or other renewable energy source. While SRP is not regulated by the ACC, the utility has established distributed generation interconnection guidelines and a net metering program for its customers (DSIRE, 2011; Salt River Project, 2011a).

For commercial PV systems up to 30 kW, SRP's EarthWise™ Solar Energy Program provides a one-time incentive of $1 per watt, up to a maximum of $30,000 (SRP, 2011a). In exchange for the incentive, SRP retains the RECs associated with the system (DSIRE, 2010e). Since the majority of the city of Mesa is serviced by SRP (City of Mesa, 2002), any solar PV installations would likely make use of this incentive.

Technical Factors

In order to identify roof space suitable for solar panel placement, it is necessary to review the literature for industry experts' recommendations and best practices for incorporating PV systems onto roof assemblies. The purpose is to understand what factors influence rooftop solar feasibility and establish evaluation criteria for evaluating solar ready roofs. From this review, a methodology can be designed to help the city quickly and economically target which Mesa Fire Department facilities should have a detailed engineering analysis of their structural and electrical systems in preparation for PV installation.

Solar PV cells are silicon-based semiconductor devices that convert sunlight into direct current (DC) electricity. A solar panel, or module, is comprised of individual solar cells that are wired together in series and encased in glass. Modules are wired together into an array, which is then mounted onto a roof or other platform. An inverter converts the DC electricity into alternating current (AC) in the desired voltage compatible with the building and utility power systems (Lisell & Mosey, 2010). "Today's PV systems come in a range of efficiencies and configurations" (Lunning Wende Associates, 2010, p.1) including: mono-crystalline and poly-crystalline silicone, and thin film amorphous. Mono-crystalline panels are the most efficient, but also the most costly. Thin film amorphous has low production costs due to lower cost of materials, but also has much lower efficiency than mono-crystalline or poly-crystalline panels.

Key roof factors that influence system performance include module orientation and tilt, shading, and roof form.

Module Orientation and Tilt. Solar panels will produce the most energy when they are aligned at an angle equal to the latitude where it is located; in Mesa the angle would be 33-degrees. Panels tilted correctly on flat roofs are more efficient for several reasons. When tilted to the angle of latitude, sunlight strikes the panel directly, maximizing their efficiency and energy output. A study by Swenson (2005) tested a series of horizontal and tiled arrays during winter months and found that losses for the horizontal arrays were approximately 20%, in comparison with the tilted arrays. Another reason is there is an inverse relationship between power output and operating temperature (Zauscher, 2006). Tilting the array allows air to flow around the panels cooling them, thereby increasing efficiency. Finally, particle buildup ("soiling") and other optical losses reduce solar panel efficiency; this is a particular concern in Arizona where dust can accumulate on top of horizontal surfaces. One model predicts that annual soiling losses in energy output around 4.8% to 5.5%, with an energy value of $0.25/kWh (Kimber, n.d.). Tilted panels reduce dust accumulation, and are easier to clean and maintain.

In the northern hemisphere, it is best to orient solar panels facing due south (Bryan, Rallapalli, & Jin, 2010). If the azimuth angle is greater than 15^{o} from due south, solar power output may be reduced by as much as 15% at lower latitudes, and 25% at higher latitudes (*Solar Electric Modules,* n.d.). East or west orientation is possible, though not preferable; north-facing surfaces are generally considered unsuitable for solar installations.

Shading. Shading has more impact on solar PV efficiency than orientation or angle. Shading reduces power output and creates thermal stress on the module (Hanitsch, Schultz, & Seigfried, 2001). PV panels are composed of multiple individual solar cells that produce a small amount of current and voltage; these cells are connected in series to produce a higher voltage (Lisell & Mosey, 2010). Partial shading of even one cell of a PV module will lower the string voltage, and can interfere with the inverter, reducing power output. Worse yet, an individual shaded cell “would act as a resistance to the whole series circuit, impeding current flow and dissipating power rather than producing it” (Lisell & Mosey, 2010, p. 2). In a study of the effects of shading on PV performance, Bryan et al. (2010) note, “shading of even one cell within a PV module can reduce the module’s power output by as much as 75 percent” (p. 3).

Shadows across PV modules can be cast by adjacent buildings, trees, or onsite obstacles such as flag poles, or communications and hose towers. Architectural elements of buildings, such as parapets or varying levels in roof profile, as well as rooftop mechanical equipment, including HVAC equipment or satellite dishes, can also create shaded areas rendering large sections of an otherwise solar-suitable roof unusable. The shadow cast by even a small object is impressive. Conducting a shadow analysis, Bryan et al. (2010) placed a 1 ft^2 block on a Phoenix rooftop during winter solstice. The block cast a shadow across a 14 ft^2 cumulative area. It was also determined that a 4-foot tall piece of mechanical equipment would cast a shadow more than 10 feet in length at noon.

Roof Form. Roof pitch, covering materials, and penetrations all impact suitability for PV. Large, flat, unobstructed roofs offer the most flexibility to install PV in a manner that optimizes performance. PV can be installed on pitched roofs, but may raise aesthetic concerns from neighbors. As the roof pitch gets steeper, the impact of gravity acting over the roof increases, so fewer PV panels can safely be installed, thus reducing the systems energy output potential. CAL FIRE-OSFM (2008) recommends that no more than 50% of a steep-sloped roof area be covered with PV panels. Pitched roofs can also make optimal panel orientation difficult. "Placement of PV panels on the south-facing slope will ensure that the sunlight strikes the solar collector at a more optimal angle than it would if the collectors are placed on the east, west, or north-facing roof sections" (Bryan et al., 2010, p. 4). Roof covering materials should be in good condition and in early stages of life, with a warranty for repair or replacement (Bryan et al., 2010). Finally, while most roof penetrations such as skylights or plumbing vents can be worked around, such elements can cast shadows and will impact panel layout.

Summary

Continued reliance on non-renewable sources of energy has negative financial environmental, and public health and safety implications. As the Phoenix-Mesa-Scottsdale region grows, it will continue to grapple with the consequences of poor air quality. GHG and particle pollution create significant public health risks, particularly for at-risk groups with pre-existing medical conditions such as asthma, chronic obstructive pulmonary disease, and cardiovascular disease. The public safety impacts of global climate change include an increased occurrence and severity of wildfires, floods, and strong storms. The implications for fire departments are enormous, compounded by tighter budgets and fewer resources. Since fire department facilities use grid-supplied electricity, they contribute to pollution emissions. Mesa's climate and location at latitude makes solar PV a feasible alternative source of energy.

In the Phoenix region, restricting factors of converting to solar power are not so much environmental-technical, as economic. Grid-supplied electricity is still less expensive than solar power, particularly when accounting for the up-front costs of solar conversion (Borenstein, 2008; McCabe, 2009). It is likely, however, that these costs will balance out in time given the volatility of the energy market and increasing state and federal regulations on GHG emissions (ACC, 2006; Holbert, 2007). Self-financing, either through pay-as-you-go or borrowing, remains an option for acquiring solar PV systems. But public agencies are ineligible to receive tax incentives, making achieving an acceptable rate of return unlikely. Changes in interconnection and net metering regulations, as well as a favorable ruling by the Arizona Corporation Commission on solar service providers, makes third-party ownership a viable option.

Ideally, a solar PV system can be installed with minimal changes to a building's roof structure or mechanical systems. Unfortunately, much of today's building stock was designed and built, understandably, without consideration of future solar energy retrofits. "An ideal roof for PV installation is one with a large, flat space, contiguous and uninterrupted by roof objects like skylights, HVAC equipment, plumbing vents and has a roof covering material that is the early stages of its life with a warranty for repair and replacement" (Bryan et al., 2010, p. 1). Not every building will be suitable for a solar power conversion, and it would be time consuming and expensive to conduct a detailed solar site analysis on every fire department facility.

Understanding what factors define a "solar ready" roof will aid in the design of a method to quickly and efficiently identify which rooftops have a higher potential for solar installation.

Procedures

The challenge of this research project is to take the factors that influence rooftop solar power feasibility and design a method that can be applied to evaluate a sizeable portfolio of fire department buildings; the intent is to target the opportunities for solar installation quickly and economically. This section details the methods used to obtain answers to the research questions. It presents the data collection plan and provides a rationale for selection of an evaluative research design. The bulk of this section is dedicated to a thorough explanation and justification of the technique used to identify useable rooftop space and the process for estimating rooftop PV potential on Mesa Fire Department facilities. A statement of the logic for selecting buildings for evaluation follows this discussion, as well as identification of the limitations and delimitations of this research.

Several research methods were employed to ensure sufficient information was gathered for this project. These techniques are described in the following sub-sections.

Literature Review. The literature review contained herein provides an account of what has been published by scholars, researchers and accredited experts on climate change and the public health and safety effects of energy-related pollution, as well as solar PV technology. Descriptive research through a survey of scholarly articles, books, and existing data was conducted to answer three questions: (a) how might converting to solar PV-generated power contribute to accomplishing the MFD's mission and strategic plan, (b) which financial mechanism will likely offer the most favorable internal rate of return to the City, and (c) what rooftop layout factors or design guidelines should be considered in order to identify roof space suitable for solar panel placement. The purpose was to offer an overview of the existing body of knowledge published on this topic.

Research began at the Learning Resource Center (LRC) at the National Fire Academy in Emmitsburg, Maryland. The LRC is a small research library that maintains a collection of applied research materials, books, and trade publications specific to fire and emergency management. The LRC online catalogue and EFOP Applied Research Projects Portal provided distance access to library materials. Additional materials were obtained from the ASU libraries. ASU and the ASU Polytechnic campus have academic programs on global sustainability, sustainable engineering and environmental technology; ASU has an extensive research program in renewable energy sources and solar technology. The ASU libraries maintain a collection of scholarly books and periodicals on solar energy. ASU libraries' online service "One Search" accesses dozens of top research databases, including 42 related to environmental sciences such as Earth and Environmental Science, Energy Citations Database, GreenFILE, and Pollution Abstracts, among others. Search engines accessed included Google, Google Scholar, the FEMA Disaster Information database, the Arizona Legislative Information System (ALIS Online), and the Mesa Council, Board, and Committee Research Center.

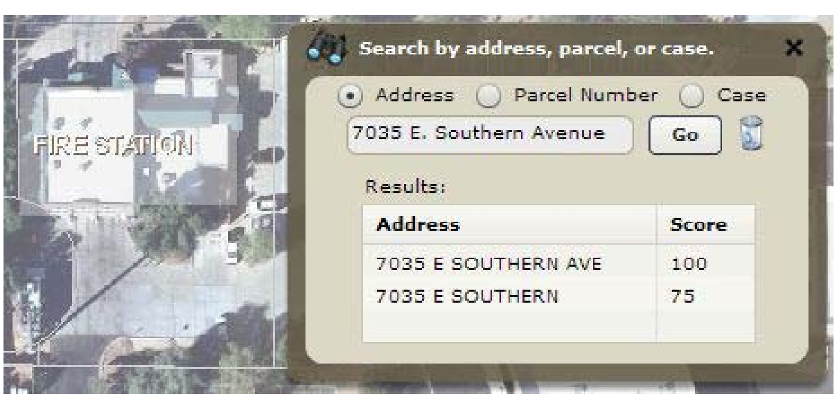
The literature review is a piece of discursive prose (Taylor, n.d.), seeking information on the research problem and offering a critical appraisal of the material. A summary of the key findings of the pertinent literature concluded the literature review section; analysis and interpretation relevant to the research questions is contained in the forthcoming sections.

Aerial Images Analysis. The purpose of this applied research project is to design a method to quickly an economically evaluate fire department facilities for rooftop solar energy potential. This will help inform the decision of the MFD as to which facilities should be targeted for a detailed engineering analysis for PV installations. The method used here replicates a portion of those developed by Bryan, Rallapalli, Rasmussen, and Fowles (2010) for estimating the rooftop solar feasibility on an urban scale. Their method used aerial images to conduct an initial assessment of 364 city-owned buildings in Phoenix, Arizona; 85 buildings were found to have good potential for solar installations.

Aerial images were acquired for MFD facilities using iMaps from the Mesa Planning Department. iMap uses ArcGIS (version 1.3) interactive applications over images from Google Earth; images date October 31, 2009. The iMap application has a robust set of tools and controls including search (by address, street intersection, parcel, or planning case), planning case drill down tool, parcel information, map layer control, Google street view, and measuring tool. Images of fire department facilities were located by entering the address into the search function (Figure 2). The images were clear enough to allow an initial eyeball assessment of roof type, rooftop equipment and penetrations, building orientation, and shading. Buildings were given a rating of one (1) through five (5), with a rating of 5 having the highest potential for PV installations and 1 having the lowest. The ratings follow the grading scheme created by Bryan et al. (2010):

Figure 2.

iMap Search Feature.



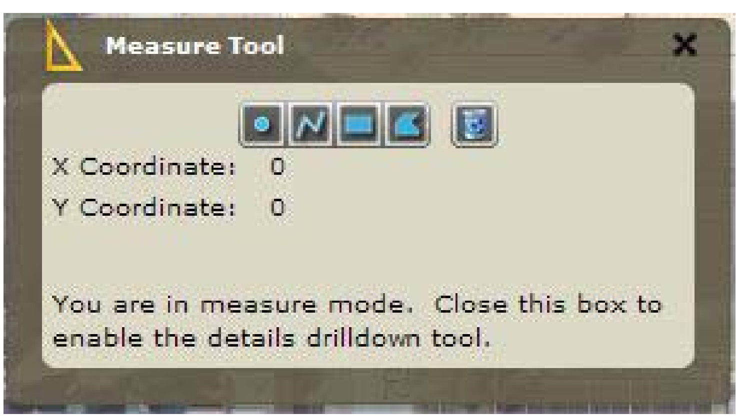
(5) Ideal for PV installation with maximum usable space, no shade causing obstructions and sound roof structure.
(4) Quite feasible for rooftop PV installation due to good orientation and limited Shading and sound roof structure.
(3) Somewhat feasible due to slightly larger areas available for PV installation, east or west orientation and limited shade causing obstructions.
(2) Less feasible for rooftop PV installation due to factors of building orientation (i.e. north facing sloped roof), roof structure, size, shade causing obstructions.
(1) Least feasible for rooftop PV installation due to excessive shading, small roof area, obstructions, etc. (p. 2).

Buildings rated a 4 or 5 were further assessed for available space. Rooftop area suitable for PV was highlighted and measured using a measuring tool embedded in the software. Selecting the measuring tool opens a panel of options for using an interactive approach for measuring distance and area, or for determining the coordinate at a click location (Figure 3). Area measurements were reported in square feet (ft^2). One feature enables the user to draw a polygon to measure area allowing for more accurate measurement of unusually shaped roof perimeters.

System Performance. Another element of the Bryan et al. (2010) methodology adopted for this project was to calculate the total solar power production capacity potential for each facility for eight different combinations of PV systems. Peak wattage (kWp/ft^2) and annual

Figure 3.

iMap Measuring Tool Feature



kWh/ft^2 production were calculated for thin film/amorphous with 8% efficiency, poly-crystalline silicone with 12% efficiency, and mono-crystalline with 16% efficiency, using three different mounting systems; horizontal laminate system, a ballasted system with 18^o tilt, and a one way tracking system. These efficiency ratings and tilt angles ensured conservative power output estimates. A peak wattage factor and annual energy production factor were determined for all systems using RETScreen® software. Rooftop area suitable for PV installation, as determined in aerial image analysis, was multiplied by the factors in Table 3 to determine peak wattage and annual kWh production for each fire department facility.

Power Consumption and Pollutant Output. In addition to an initial assessment of aerial images and calculations of potential system performance, consideration was also given to the electrical consumption of fire department facilities and their calculated pollutant emissions. Electrical consumption varies from facility to facility, and has impacts on PV system feasibility.

Table 3.

Peak Wattage and Annual kWh Production for Different Types of PV Systems

	Fixed 0^o Tilt	Fixed 18^o Tilt	Single-Axis
	Thin film/Amorphous		
Peak kWp/ft^2	0.00666	0.00592	x
Annual kWp/ft^2	11.583	11.208	x
	Poly-crystalline		
Peak kWp/ft^2	0.01008	0.00896	0.00896
Annual kWp/ft^2	16.479	15.912	21.096
	Mono-crystalline		
Peak kWp/ft^2	0.01332	0.01184	0.01184
Annual kWp/ft^2	21.78	21.024	27.88

Source: Bryan et al. (2010). *Methodology for estimating the rooftop solar feasibility on an urban scale*.

All other factors being equal, it is preferable to invest in PV on buildings with higher electrical costs and peak demand loads. Both the annual power consumption (kWh) and average electricity rate (¢/kWh) were reported; these figures were calculated using fire department utility expense reports (Appendix A). SRP (2011b) has a time-of-use pricing plan that applies different rates depending upon time of day and season (summer, summer peak, and winter): on-peak ($0.1347 - $0.1667/kWh), shoulder ($0.0979 - $0.1075/kWh), and off-peak ($0.0531 - $0.0601/kWh). By calculating the average electricity rate (¢/kWh), this method takes into account which facilities have higher on-peak energy consumption, rather than just looking at higher overall energy use.

Pollutant output of MFD facilities was determined using the Electric Power Pollution Calculator provided by the Texas State Energy Conservation Office (TESCO, www.infinitepower.org/calc_pollution.htm). The calculator determines pounds of emissions for sulphur dioxide (SO_2), oxides of nitrogen (NO_X), particulate matter (PM_{10}), carbon dioxide (CO_2), and volatile organic compounds (VOC). These pollutants are major contributors to global warming and poor air quality in the Phoenix region. Emissions can be adjusted based on the fuel used at the power generating station, including those utilizing western coal, eastern coal, natural gas, biomass, or oil. The majority of the city of Mesa is certified to be served by SRP. Electrical power for the Mesa area is generated at the Santan Generating Station (City of Mesa, 2002), which is fueled by natural gas (SRP, 2011c); thus, pollution calculations were made for natural gas.[6] Because power plants are typically only 36% efficient, they produce large amounts of waste heat and require copious amounts of water for cooling (TESCO, n.d.), estimates of the gallons of water used for cooling were also calculated. Data were entered for the total annual pollutant output for each facility.

Site Visits. Data collected were entered into an excel spreadsheet for comparison. Facilities deemed appropriate for solar power were visited to confirm the initial analysis made from aerial photos. The site visits were necessary to ensure no structural changes or rooftop mechanicals were added after the satellite images had been taken and uploaded onto Google Earth. The condition of roofing materials were examined and aesthetic elements documented for consideration. In one instance, the site visit determined that the roof type at fire station 216, which through aerial analysis was thought to be a flat roof, was actually a low-slope roof with an east-west pitch. While this did not eliminate the fire station as a potential solar PV site, it does raise installation issues that must be considered. Otherwise, initial assessments from the aerial images were found to be rather accurate.

Limitations and Delimitations. The research process began by compiling a list of all fire department buildings, including joint-operated facilities, along with their addresses. Altogether, 16 buildings – 15 fire stations and the training academy – were included in the study. All of the facilities selected for this applied research project are within the SRP service area. Residents and business in the city of Mesa receive electrical utility service either from SRP or the city of Mesa. Approximately 5.5 square-miles around downtown, and several acres in east Mesa, are served by the City of Mesa Electric Utility (MEU). As a municipal utility, MEU is not regulated by the ACC and is not subject to the renewable energy requirements contained in the RES. MEU does not have a renewable energy incentive, such as the SRP EarthWise™ program. Since the EarthWise™ program would be an important economic incentive for any third-party ownership arrangement; facilities within the MEU service area were eliminated from consideration. These included Fire Station 201, at 360 East First Street; Fire Prevention offices, at 13 West 1st Street;

Fire Administration, at 64 North Center Street; the Health and Fitness Center, at 1105 East 2nd Avenue; and the East Mesa Service Center and Resource Test Pit, at 6935 East Decatur.

Three other facilities were not considered for this study. Station 203, located at 1340 West University Drive, was built in the 1950s and has been slated for replacement in the near term. Another facility, Station 215, located at 5945 South Sossaman, is a former US Air Force fire station built to serve Williams Air Force Base, which closed in 1993. Station 215 was built in 1958. A new facility located at 6353 South Cargo Way was only recently completed and includes both structural and aircraft rescue firefighting operations to serve the Phoenix-Mesa Gateway Airport and ASU Polytechnic campus. The FY09/10 utility expense report records data for the old facility; utility data for the new station was not yet available. Lastly, Station 218, located at 845 North Alma School Road, opened in March 2010. The FY09/10 utility information did not include a full year's electricity consumption data to make a complete analysis of this facility.

Another limitation is that, rather than conducting an exhaustive study of renewable energy options, this project focuses on rooftop solar PV technology; furthermore, it calculates potential peak wattage and annual kWh production for only three of the most popular types of PV: thin film/amorphous, mono-crystalline silicone, and poly-crystalline silicone. Thus, it excludes other renewable sources of energy and distributed generated resources such as wind, micro-hydroelectric, fuel cells, or other sources. This project does not address energy efficiency or conservation measures, which themselves can substantially reduce energy consumption.

Finally, this applied research project provides only a preliminary solar site analysis based upon factors identified in a literature review. It should be considered a lay perspective on the potential of the recommended sites to produce sufficient solar power to make installation of rooftop PV economically and technologically feasible. An informed decision to proceed with this project must be made with the inclusion of a detailed engineering study of the buildings' electrical and structural elements, as well as an assessment by a renewable energy consultant.

Results

Making a switch to solar power has many potential benefits for the Mesa Fire Department in terms of environmental sustainability and long-term energy price stability. But done without due diligence, installing solar panels could prove costly. Before deciding whether to pursue solar power installations, several questions about environmental issues, financial considerations, and technical factors had to be answered. This section represents the key considerations in determining the feasibility of installing rooftop PV systems on fire department facilities.

Question 1. *How might converting to solar photovoltaic-generated power contribute to accomplishing the Mesa Fire Department's mission and strategic plan?*

As described in the Background and Significance section, the MFD's *Strategic Plan 2006* defines the organization's desired future state, its purpose, and declares the values that should guide decision-making (p. 5). To achieve that mission for the future, ensure alignment with the City's mission, and provide guidance for operational components of the plan, the department focuses on seven key areas; among these is attention to neighborhood and environmental vitality. Part of the vision for this key area is to "promote environmental awareness" (p. 33). Two goals address this vision. Goal FD5.1 seeks to use a comprehensive plan to support the Council's and citizens' vision for Mesa; the strategy is to continue to implement the Mesa 2025 General Plan. Goal FD5.2 seeks to keep Mesa's neighborhoods healthy, attractive, and positive places in which to live, work, learn and play. The strategies under goal FD5.2 are to (a) identify and resolve neighborhood issues before they become a public safety or quality of life concern, and (b) actively engage neighborhoods to work to reduce the threat of loss of life and property and improve their quality of life (p. 34).

The fire department's strategic plan purposefully aligns with the City's General Plan, *Mesa 2025: A Shared Vision,* which was approved by voters in November, 2002. *Mesa 2025* provides a vision for the community and is intended to guide decision-making as the city grows. Protection of the natural environment is a central theme in the general plan. A key issue identified in chapter 8, Public Facilities, Buildings, and Services, is the conservation of energy resources. Policy PFBS-1.2c "encourages the development and use of alternative and renewable energy resources" (p. 8-11). Chapter 10, Environmental Planning and Conservation, deals specifically with environmental sustainability, including air quality management and energy conservation; the latter element calling for promotion of "solar-conscious design" (p. 10-2). Policy EPC-1.4b encourages development plans that incorporate energy conservation through, among other methods, the "use of active and passive solar energy systems" (p. 10-6). Policy EPC-1.4c calls upon city departments to "continue to apply energy conservation techniques in the development and operation of municipal facilities" (p. 10-6).

The MFD's vision of "progressive commitment to our community" (2006, p. 7); a strategic plan that promotes "environmental vitality;" and a stated commitment to contribute to accomplishing the goals of the Mesa General Plan, which specifically calls for environmental stewardship through adoption of solar energy in public facilities, all suggest that converting fire department facilities to solar energy is appropriate to the Department's strategic plan. Furthermore, the mission of the MFD is to dedicate itself to "the safety and welfare of the community through emergency response, prevention, and education" (p. 7). The literature review documents the climate research and epidemiological studies that demonstrate a correlation between GHG emissions and particle pollution and public health and safety threats; the MFD is on the front line for confronting these issues. Taking a leadership role in environmental stewardship by adopting alternative energy serves the department's mission of prevention and education by displaying initiative and responsibility in proactively planning for the effects of climate change.

Question 2. *Which financing mechanism will likely offer the most favorable internal rate of return to the City?*

This applied research project identified three financing mechanisms available to the city of Mesa to acquire rooftop solar PV systems: self-financing, or third-party ownership through either a power purchase agreement or solar lease. The high net installed cost of solar energy in relation to grid-supplied power remains a major impediment to its wider adoption. Economic studies of solar power continue to conclude that, although costs are declining, without significant federal, state, and utility incentives, the installed costs of solar PV far exceeds the net present benefit (Borenstein, 2008; Frisvold et al., 2009; Barbose et al., 2010). As non-taxable entities, local governments cannot capture the full range of tax incentives available to private corporations, assuming they purchase the PV system. The use of 0% federal bond programs such as CREB and QEBC, as well as the sale of SRECs on the utility market and reduced electricity costs, offer some financial benefits. However, there is uncertainty about the sustainability of the CREB program, and the value of SRECs is dependent upon market conditions; specifically whether a state has a mandatory or voluntary renewable energy standard. Ultimately, these incentives are necessary but not sufficient to offset the upfront cost of installing PV. Therefore, it is concluded that self-financing will not achieve an acceptable rate of return for the city of Mesa. This result confirms the findings of a previous renewable energy applied research project conducted by McCabe (2009), which concluded the costs for a city to purchase, design, install, operate, and maintain solar PV units was not yet economically feasible.

Third-party ownership offers an alternative to self-financing that can maximize the use of incentives by introducing a private, taxable entity into a solar power partnership. A third-party ownership arrangement through a power purchase agreement offers many benefits: provides predictable energy costs, captures federal incentives like the ITC and MACRS, defrays up-front capital costs, and transfers responsibility for O&M to the solar service provider. Solar leases offer many of these same benefits however, since the public agency would be leasing the solar equipment from the SSP rather than purchasing the electricity, the agency takes on responsibility for system performance. The risk is that if the system does not produce the anticipated energy output, the residual energy costs from net-supplied electricity in addition to monthly solar equipment rental payments could result in paying more for solar energy on a levelized basis than for conventional electricity (Kollins, 2008). All options being available, it appears a third-party PPA offers the greatest potential for an acceptable IRR for the city to finance solar PV installations on public property.

Question 3. *What rooftop layout factors or design guidelines should be considered in order to identify roof space suitable for solar panel placement?*

Several agencies, including the National Roofing Contractors Association and the National Renewable Energy Laboratory, have produced guidelines for roof-mounted solar system installations and planning. Particularly helpful to this project were conference papers written by Bryan et al (2010) from the School of Architecture and Landscape Architecture at Arizona State University. Bryan's paper, *Designing a solar ready roof: Establishing the conditions for a high-performance solar installation* identifies 13 factors that influence solar feasibility and suggests guidelines for designing a solar ready roof. These include orientation, roof slope, levels in roof profile, external shade, roof penetrations, skylights, structural constructions, architectural elements and aesthetics, roof storage, roof equipment, roof structure, future additions, and system connections. These factors were later translated into a methodology used to estimate the rooftop solar potential of public buildings in Phoenix.

Question 4. *Which fire department facility rooftops have a higher potential for PV installation?*

The answer to question 3 provided the necessary information to establish evaluation criteria to identify which Mesa Fire Department facilities have a higher solar energy potential. Using aerial images acquired from the Mesa Planning Department iMaps program, fire department buildings were rated on a scale of (1) least feasible for rooftop PV, to (5) ideal for PV installation. Ten (10) of the 15 MFD buildings evaluated for this project rated a 1, 2, or 3 and therefore were eliminated from any further consideration (Appendix B). This finding exceeds but is consistent with the assumptions of Bryan et al. (2010) that only around 25% of rooftop space are suitable for solar installations, and supported by their finding that 85 of 364 Phoenix city buildings (23.35%) were suitable for unobstructed and continuous PV operation. Eliminating these facilities from further consideration does not mean that they are completely unsuited for solar installations, only that they are less feasible. The purpose of this applied research project was to quickly and economically identify fire department facilities that have a higher solar potential, so that appropriate facilities can be targeted for more detailed engineering analysis. Several factors were used to evaluate which fire department facilities had the higher solar energy potential. These included an assessment of aerial images to identify usable rooftop space, power consumption and pollutant output, and calculations for system performance.

Table 4.

Power Consumption and Costs, 2009/10

Facility	Square Foot	Usable Area	Rating	Energy Cost ($)	Annual kWh	₵/kWh
Station 206	17,264	7100	4	22,164.12	238,160	9.30
Station 212	17,818	8300	5	39,654.50	430,560	9.20
Station 216	9,012	3500	4	9,991.06	101,640	9.98
Station 217	10,284	3000	4	13,821.61	144,240	9.58
Training Academy	24,235	5800	5	53,321.16	518,960	10.28

Table 4 presents the data for rooftop area, power consumption, and electricity costs for five MFD facilities rated a 4 or 5 from an aerial image analysis. After an examination of aerial images on MFD facilities, two facilities were given a rating of 5 for maximum available rooftop space with no shading and a sound roof structure. Fire Station 212, located at 2430 South Ellsworth, is a joint public safety facility that includes the Superstition Patrol Division. This facility has 17,818 square-feet (s.f.) under roof and an estimated usable rooftop area of 8,300 s.f. Also rated a 5, the Public Safety Training Academy, at 3260 North 40th Street, has a 16,244 s.f. auditorium and classroom building with over 5,400 s.f. of usable rooftop area. Fire Station 206, at 815 North Lindsay Road, is another large facility that includes a Volunteer Center with a total of 17,206 s.f. of space; however, 206 was rated a 4 because of its metal-clad roofing material and mostly east-west low-pitch orientation. Otherwise, the Station 206 has a maximum potential usable rooftop space of up to 7,100 s.f. Fire Stations 216, located at 7966 East McDowell Road, and 217, at 10434 East Baseline Road, were rated a 4. Both are smaller facilities with a low-pitched roof with east-west orientation, and some shading issues from HVAC locations.

Table 4 also highlights electricity consumption for these facilities. Fire Station 212 and the Public Safety Training Academy had the highest energy costs in FY09/10 at 430,560 kWh and 518,960 kWh, respectively. The Academy also had the highest cost for energy at $53,321.16 and highest cost per kWh of 10.28¢/kWh. Surprisingly, Fire Station 212, while having the second highest cost for energy, $39,654.50, had the lowest cost per kWh at 9.2¢/kWh; this is likely due to less on-peak usage.

Table 5 documents pollutant output. Not surprisingly, facilities with higher usage produced more GHG and particle pollutants. It should be noted, however, that this may not be the case for every jurisdiction. Large urban areas or countywide fire departments may receive power from two or more suppliers. These suppliers may produce energy from different sources of fossil fuel such as western coal, eastern coal, natural gas, or nuclear; some may use renewable energy sources such as concentrated solar photovoltaic, wind, hydroelectric, or geothermal. The pollutant output of each fire department facility will depend upon who provides the power and what sources of energy are being used.

Table 5.

Pollutant Output, 2009/10

Facility	Ann kWh	SO_2	NO_X	PM_{10}	CO_2	VOC	Water
Station 206	238,160	1.429	271.5	9.526	304800	23.82	178600
Station 212	430,560	2.583	490.8	17.220	551100	43.06	322900
Station 216	101,640	0.6098	115.9	4.066	130100	10.16	76230
Station 217	144,240	0.8654	164.4	5.770	184.600	14.42	108200
Training Academy	518,960	3.114	591.6	20.760	664,300	51.9	389200
All MFD Facilities	3,153,249	18.92	3,595	126.100	4,036,000	315.3	2,365,000

Source: TESCO, www.infinitepower.org/calc_pollution.htm

Finally, RETScreen® modeling conducted by Bryan et al. (2010) suggested solar PV system performance under Phoenix-area conditions for horizontal and slightly tilted systems ranged from peak solar output of 0.00666 kW/ft^2 to 0.01184 kW/ft^2. From these estimates, calculations for peak wattage and annual kWh production were made for three different PV types and three mounting systems. Results from the evaluation of the five facilities are presented in Appendices C-G. With the largest estimated available rooftop area of 8,300 s.f., Fire Station 212 recorded the highest solar energy potential ranging from 93,026.4 annual kWh for thin-film/amorphous at a fixed 18^o angle, to 231,404 for mono-crystalline panels in a single-axis configuration. This was followed by Fire Station 206 (7,100 s.f.; 79,576.8 to 197,948 annual kWh) and the Public Safety Training Academy (5,800 s.f.; 65,006.4 to 161,704 annual kWh). It is worth noting that none of the facilities evaluated reached net-zero energy use (Torcellini et al., 2006); that is, it produced as much energy as it uses. Fire Station 216 was close. In FY09/10 the station used 101,640 kWh of energy. The highest estimated annual kWh of output for solar PV was 97,580 kWh, or 96% of the energy needs. The Public Safety Training Area, on the other hand, used 518,960 kWh in FY09/10, and had a maximum estimated solar energy output of 150,552 annual kWh based on 5,800 s.f. of available rooftop space; only 29% of the facility's energy needs.

Considering the totality of these observations, Fire Station 212 and the Public Safety Training Academy appear to have the right balance of solar energy potential and "solar ready" rooftop conditions for PV installation. Fire Station 206 has a high solar energy potential due to available rooftop space, but the installation is complicated somewhat by a metal-clad pitched roof with an east-west orientation.

Discussion

There are anthropogenic factors that contribute to air quality in Arizona and influence global environmental change. Torcellini et al. (2006) observed that buildings "have a significant impact on energy use and the environment" (p. 1). According to the ACCAG inventory (Bailie, 2006), electricity use accounts for 40% of Arizona's GHG emissions. Non-renewable sources of energy, such as coal, oil, and natural gas, contain high concentrations of carbon; when burned, their byproducts include carbon CO, CO_2, SO_2, VO_X, PM, and ozone. Nationally, the American Lung Association (2011) estimates that more than 175 million people – 58% of the U.S. population – suffer from dangerous pollution levels. The Phoenix-Mesa-Scottsdale region appears on all three lists of most polluted cities in the *2011 State of the Air* report. Such environmental issues have direct implications for the Mesa Fire Department's mission in terms of providing for the safety and welfare of the community through emergency response, prevention, and education.

An audit of the energy consumption and pollution output of all MFD facilities quantifies the Department's overall contribution to GHG and particle pollution in the region. MFD facilities in the SRP service area collectively used 3,153,249 kWh of energy in FY09/10 (Appendix A). This amount of energy produced 18.92 pounds (lbs.) of SO_2, 3,595 lbs. of NO_X, 126.1 lbs. of PM_{10} emissions, 4,036,000 lbs. of CO_2, and 315.3 lbs. of VOCs (TESCO, n.d.). In providing this electricity to MFD facilities, the power plant used and estimated 2.365 million gallons of water for cooling. Power from SRP provided to the City of Mesa is generated at the Santan Power Generating Station in Gilbert, three miles south of the Mesa city limits. As a result, all of the pollutants emitted from this plant directly contribute to Mesa's air quality problems.

The literature is replete with studies documenting the negative public health and safety externalities of emissions from electricity generated from fossil fuels. Epidemiological studies conducted in Arizona show a strong correlation between mortality outcomes in the elderly and PM_{10}. Cardiovascular mortality is significantly associated with CO, NO_2, SO_2, $PM_{2.5}$, PM_{10}, and ozone levels in the atmosphere (Mar et al., 2000); 13.3% of Mesa's population is over age 65 (U.S. Census, 2010). Elevated levels of PM_{10} have also been shown to exacerbate asthma-related symptoms in children and affects lung development (ADEQ, 2008; American Lung Association 2011); 27.3% of Mesa's population is age 17 and under (U.S. Census Bureau, 2010). All totaled, 178,250 residents of Mesa are considered at-risk to the health effects of GHG and particle pollution based on age alone.[7]

In addition to the impact on human health and wellness, global warming is expected to contribute to the frequency and severity of a variety of natural calamities, including wildfires. Research from the University of Arizona (Westerling et al., 2006) observed that, since 1987, the wildfire season has grown longer and fires larger. Arizona has experienced several large-loss wildfires in the past decade (ACCAG, 2006; Owens, 2009). Mesa has been identified as one of 43 communities in Maricopa County as potentially at-risk from catastrophic wild land fire (Maricopa County Department of Emergency Management, 2010). These at-risk areas include the Desert Uplands Area of northeast Mesa, which encompasses 10,680 acres of desert land surrounded by the Tonto National Forest and Usery Mountain Regional Park; and southeast Mesa which shares a seven-mile long border with undeveloped Arizona State Trust land in Pinal County. "The highest wildfire risk is associated with paloverde-mixed cacti vegetation in the southeastern area of the city" (MCDEM, 2010, p. 60) and desert shrub-scrub vegetation along the Pinal County border (Pinal County Office of Emergency Management, 2009). A cumulative risk analysis documented in the Maricopa County Community Wildfire Protection Plan rates 4,012 acres of Wild land-Urban Interface in Mesa at “high risk” and 14,013 at “moderate risk” of wildfire (p. 76).

Converting buildings with higher solar energy potential to photovoltaic power has many benefits for the Mesa Fire Department. The economic benefits include a reduction in the operating costs of fire department facilities through an offset in grid-supplied electricity use; the reduction in fossil fuel consumption and lowering of GHG and PM emissions provides an environmental benefit; and there is a social benefit through public education and awareness of the positive impacts of renewable energy sources. However, Mesa must guard against an unrealistic expectation that solar power has the capability to wholly solve the Department’s budget shortfall or regional air quality issues.

A key factor in the decision to pursue this project was the city’s continuing budget shortfall. Since the FY08/09, general fund revenues have declined over $108 million. Further, at a March 31, 2011 presentation to City Council, the Mesa’s acting Chief Financial Officer forecasted a net two-year budget shortfall of $7.4 million going into the 2011/12 fiscal year. The MFD budget has reduced from the FY07/08 budget of $67,476,455 to a FY09/10 low of $59,610,917 (City of Mesa, 2009, 2010); this reduction comes amidst an increase in call volume from 49,690 incidents in 2008 to 51,089 in 2010, as well as the opening of Fire Station 218, and the planned construction of Fire Stations 219 and 220 in FY11/12. But solar PV is not a panacea for the City’s or Department fiscal problems. At best, in FY09/10, the two sites recommended for solar PV installation – Fire Station 212 and the Public Safety Training Facility – would account for a fire department operating expense reduction of $36,574.21 for electricity consumption, assuming these buildings reach net-zero energy consumption (Torcellini et al., 2006), which is unlikely.[8] The net savings from a solar conversion would depend upon electricity consumption, future energy prices, and contractual arrangements set forth in a PPA.

Similarly, the contribution of pollutants produced by fire department facilities is minute in relation to the overall output of the Santan Generating Station. At full capacity, Santan is rated to generate 1,225 MW of electricity (SRP, 2011c). In FY09/10, MFD facilities in the SRP service area used 3153.25 MWh, or an estimated 0.357 MW of energy, a mere fraction (2.914e-4) of the electricity generated.[8]

Finally, there are two outstanding legal issues that could complicate third-party agreements: (a) whether solar power providers should be regulated as a utility, and (b) the legal authority of the ACC to legislate a distributed generation requirement as part of the RES. The legal environment does seem to be stabilizing, however. In June 2010, the ACC ruled that solar service providers were not subject to regulation (Hayes, 2011). And in April 2011, the Arizona Court of Appeals ruled unanimously to uphold alternative energy rules passed by the ACC in 2006; similar rulings have been issued by the Arizona Supreme Court, the Court of Appeals, and the Maricopa County Superior Court (Randazzo, 2011). The case is likely to be reviewed again by the Arizona Supreme Court.

Despite these limitations, Arizona's solar climate, favorable legislation in the form of interconnection standards and net metering rules, and a Renewable Energy Standard and Tariff requiring a percentage of energy be generated through distributed generation (ACC, 2006; Corey et al., 2008), makes solar power a viable energy alternative for the Mesa Fire Department. Financing PV systems through a Power Purchase Agreement brings in a third-party taxable entity that can capitalize on federal ITCs and MACRS depreciation, the sale of RECs, and the SRP EarthWise™ incentive to make solar power economically feasible. Even if the economic return to the MFD is cost neutral, there is a value to the public image and education opportunity afforded to the MFD for installing solar PV. Returning to the ED pre-course reading material *Leadership on the Line* by Heifetz and Linsky (2002), a component of getting on the balcony is to focus on the behavior of senior authority. Mesa's elected leadership has sent critical signals related to the importance of taking a regional leadership role in stewardship of the environment. By implementing the forthcoming recommendations, the MFD can fill a unique niche in this endeavor by educating the public as to the public health and safety externalities of non-renewable energy consumption.

Recommendations

The results of this applied research project suggest that converting some MFD facilities to solar power is technologically feasible, and may even have positive environmental and fiscal impacts for the city of Mesa. Based on these findings, the following recommendations should be carefully considered:

- Move forward on a solar pilot project. A pilot project would limit financial risk while allowing the MFD to further explore the impacts of solar power. Fire Station 212 and the Public Safety Training Building demonstrate a high potential for solar power given their size, utility consumption, and maximum usable rooftop space with no shade causing obstructions and sound roof structure. Fire Station 206 and Volunteer Center is a viable third alternative site, but has installation issues related to orientation and roofing materials.

- Develop detailed engineering plans and specifications. The next step in this project is to develop a detailed structural and electrical engineering analysis for the selected sites. Electrical systems need to be assessed to ensure the ability to integrate electrical output of the PV system and appropriate space for related appurtenances. A structural engineering analysis will determine if roof assemblies can support the added dead load of the PV system. Specifications for rooftop PV systems must take into consideration critical building code requirements, including fire and wind-uplift standards.
- Negotiate a Letter of Intent (LOI) for a Power Purchase Agreement. The LOI is intended to set forth certain preliminary, indicative and non-binding terms under which the SSP would propose to enter into a PPA with the city of Mesa, and serve as the basis for further discussions and negotiations. Given a current cost of energy to MFD facilities of 9.2 to 10.28₡/kWh, a goal of delivering at $.06-.08/kWh with a 2% escalator is realistic based on the assumption of an SRP performance-based incentive of $.0147/kWh over a 20 year term.
- Consider Fire Station 216 as a Net-Zero Energy Building project. Due to its small size and relatively large rooftop area available for PV installation, this station has the highest potential to become a net-zero energy building if PV installation is coupled with energy conservation methods. A detailed energy audit should be conducted to see if Fire Station 216 could serve as the City's first net-zero energy building project.

- Explore other applications for solar energy. This project focused only on the feasibility of installing rooftop solar PV for electricity generation. The MFD should consider other applications of solar such as solar water heating. Solar panels on fire apparatus can reduce particle pollution by keeping batteries charged without having to idle the truck while it's away from the station (Markley, 2008), and reduce fuel costs (McLoone, 2008).
- Integrate solar power and energy conservation into *Strategic Plan 2006*. *Strategic Plan 2006* uses a "connected" planning approach that continuously re-evaluates the plan and MFD programs, services, and activities to stay current and on course with the Department's mission. In light of the environmental impacts of GHG and particle pollution that result from conventional sources of energy, and the specificity with which the city of Mesa identifies installing solar power as an objective to its general plan for city facilities, the MFD should update KRA FD5 Neighborhood and Environmental Vitality (pp. 33-34) to include a goal and strategies for implementing solar power whenever feasible.
- Consider solar installations during design and construction of future facilities. This project demonstrated that only about 30% of fire department facilities were considered as feasible target sites for solar PV retrofits. Limiting factors included orientation, shading, and rooftop layout. Future facilities should be designed with a maximum of usable space. Preferably, building-integrated photovoltaics (BIPV) should be used as a replacement for conventional building materials in the construction of new fire stations and municipal buildings. This has the advantage of offsetting the initial cost for conventional materials and labor.

- Develop and implement a public safety campaign on clean energy. Solar PV on fire stations can serve to educate the public about alternative energy sources, and the negative public health and safety externalities of conventional energy generation. Furthermore, it can establish the MFD as a leader in innovative technology and enhance the Department's public image.

While it is beyond the scope of an applied research project to make recommendations other than those that contribute to the focus organization, the findings of the literature review nevertheless compel broader recommendations to key stakeholders. Epidemiological studies document the negative public health consequences of air pollution, and, despite an ongoing political debate, there is robust scientific consensus on the effects of climate change (Oreskes, 2004). These impacts have global implications which require the attention of the federal government. The federal government must recognize that first responders are on the front lines of dealing with the impacts of climate change, and provide financial and technical assistance to local governments to prepare for a broad range of adaptation issues. Several recommendations are appropriate: (a) the U.S. Fire Administration (USFA) should entertain research proposals under the Fire Prevention and Safety Grants that seek to investigate the connection between GHG and particle pollution and local fire and EMS incidents, and identify mitigation measures relevant to the findings; (b) the USFA should join with other federal agencies to commission a report that assembles "best practices" for alternative energy uses in the fire service and make the report available through USFA Publications, and (c) the USFA strategic plan should be updated to specifically address environmental sustainability measures as a means to improve public health and safety at the national level.

Lastly, it should be understood that these results may not translate to other regions as "the economics of on-site solar in many states may still be marginal when compared to average retail electric rates, even with federal incentives" (Cory et al., 2008, p. vii). The methodology developed here can be used by other fire departments, particularly those with large facility portfolios, to conduct a preliminary site analysis to determine if solar PV installation is feasible. Calculations for system performance, power consumption, and pollutant output will differ based on local conditions. Future applied research projects might consider how portions of this methodology could be applied to assess the feasibility of other renewable energy technologies such as wind, geothermal, micro-hydroelectric, or other sources.

Footnotes

[1]The study does not take into consideration “Let Burn” policies and land management objectives that may have affected the number of acres burned per fire over time. Ecologists have suggested that naturally occurring fires, such as those started by lightning, are good for the health of national forests, so fires have been left to burn. Land management decisions have also resulted in thicker vegetation in some forests resulting in larger fires.

[2]It is questionable whether local initiatives can make meaningful contributions to climate change mitigation in the absence of policy changes at the state and national level.

[3]Direct emissions are those attributed to energy production. Cumulative emissions include direct emissions, upstream emissions from fuel exploration, extraction, and transportation, and downstream emissions from waste management, plant decommissioning, and waste disposal.

[4]Federal grants available to local and tribal governments for green or solar initiatives include the U.S. Department of Treasury Renewable Energy Grants, the DOE Tribal Energy Grant program, and the USDA High Energy Cost Grant and Rural Energy for America program.

[5]States that have implemented a system benefit charge (SBC) include California, Connecticut, Delaware, Illinois, Oregon, Maine, Massachusetts, Michigan, Minnesota, Montana, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, and Wisconsin.

[6]In calculating GHG and particulate pollution generated by energy in MFD facilities, this project considers the main source of Mesa’s energy – natural gas – and does not take into account the “base energy” in the electric grid. In Arizona, this base energy is generated at Palo Verde Nuclear Power Station and the Four Corners Power Plant, which burns western coal.

[7]The American Lung Association considers populations aged 18 and younger, and 65 and older “at-risk groups.”

[8]The fire and police departments split utility costs 50-50 for the Public Safety Training Area and 75-25 for Fire Station 21./Superstition Patrol Division, with the fire department paying 25% of the costs.

[9]Energy use in MW was determined by first converting kWh to MWh. To convert MWh to MW, the MWh were divided by the time applied in hours (365 days x 24 hours = 8760). MWh/8760=MW.

References

American Lung Association. (2006). *Lung disease data: 2006*. Retrieved from http://www.lungusa.org/assets/documents/publications/lung-disease-data/LDD_2006.pdf

American Lung Association. (2011). *State of the air: 2011 report*. Retrieved from http://www.stateoftheair.org

Arizona Climate Change Advisory Group. (2006). *Climate change action plan*. Retrieved from http://www.azclimatechange.gov/docs.html

Arizona. Const. art.15, § 2

Arizona Corporation Commission. (2006). *Renewable Energy Standard and Tariff*. Retrieved from http://www.cc.state.az.us/divisions/utilities/electric/environmental.asp

Arizona Department of Environmental Quality. (2008). *Protecting our children: Assessing the link between PM10 pollution and childhood asthma in Maricopa County*. Retrieved from http://www.azdeq.gov/ceh/download/Exchange%20Grant%20Summary.pdf

Arizona Department of Environmental Quality. (2011, January 25). *ADEQ, Maricopa County choose to improve dust control plan: ADEQ withdraws earlier plan to U.S. EPA* [Press release]. Retrieved from http://lib.trinity.edu/research/citing/apaelectronicsources.pdf

Arizona Department of Environmental Quality. (2011). *Fires, smoke, and your health* [Brochure]. Retrieved from http://www.azdeq.gov/environ/air/smoke/download/fire_smoke_your_health_brochure.pdf

Aronson, J. R. & Schwartz, E. (1981). *Management policies in local government finance*. Washington, DC: International City Management Association.

Bailie, A., Lazarus, M., Peterson, T., Hausker, K., Kuch, P., Williams, E., …Roe, S. (2006). *Final Arizona greenhouse gas inventory and reference case projections, 1990-2020.* Retrieved from the Arizona Climate Change website: http://www.azclimatechange.gov/docs.html

Barbose, G., Darghouth, N., & Wiser, R. (2009). *Tracking the sun III: The installed cost of Photovoltaics in the U.S. from 1998-2007*. Retrieved from the Lawrence Berkeley National Laboratory website: http://eetd.lbl.gov/ea/ems/reports/lbnl-4121e.pdf

Betsill, M. M. (2001). Mitigating climate change in U.S. cities: Opportunities and obstacles. *Local Environment, 6*(4), 393-406. doi:10108/1354983012009169.9

Bland, R. & Rubin, I. (1997). *Budgeting: A guide for local governments*. Washington, DC: International City/County Management Association.

Bonnicksen, T. M., (2008). *Greenhouse gas emissions from four California wildfires: Opportunities to prevent and reverse environmental and climate impacts* (FCEM Report No. 2). Retrieved from Forest Foundation website: http://www.resourcespolicy.net/images/Forest_Carbon_Emissions_Model_FCEM_Report_2.pdf

Borenstein, S. (2008). *The market value and cost of solar photovoltaic electricity production.* (Report No. CSEM WP 176). Retrieved from University of California Energy Institute website: http://www.ucei.berkeley.edu/PDF/csemwp176.pdf

Bryan, H., Rallappalli, H., & Jin, H. J. (2011, May). Designing a solar ready roof: Establishing the conditions for a high-performing solar installation. In K. Hotchkiss (Chair), *SOLAR 2010* [CD-ROM]. Symposium conducted at the meeting of the American Solar Energy Society National Solar Conference, Phoenix, AZ.

Bryan, H., Rallappalli, H., Rasmussen, P., & Fowles, G. (2010, May). Methodology for estimating the rooftop solar feasible on an urban scale. In K. Hotchkiss (Chair), *SOLAR 2010* [CD-ROM]. Symposium conducted at the meeting of the American Solar Energy Society National Solar Conference, Phoenix, AZ.

Burlage, J. (2009). *Financial viability of a 2 MW solar photovoltaic installation in the industrial sector of New Jersey*. Unpublished manuscript. Duke University, Nicholas School of the Environment and Earth Sciences. Retrieved from http://hdl.handle.net/10161/1372

California Department of Forestry and Fire Protection, Office of the State Fire Marshal. (2008). *Solar photovoltaic installation guide*. Retrieved from http://osfm.fire.ca.gov/training/pdf/photovoltaics/solarphotovoltaicguideline.pdf

City of Mesa. (2002). *City of Mesa General Plan*. Retrieved from http://www.mesaaz.gov/planning/PDF/GeneralPlan/MesaGeneralPlan.pdf

City of Mesa. (2008). *Executive budget plan City of Mesa, Arizona for the fiscal year 2008/2009*. Retrieved from http://www.mesaaz.gov/budget/Documents/FY_08_09/FY_2008-2009_City_of_Mesa_Executive_Budget_Plan.pdf

City of Mesa. (2009). *Executive budget plan City of Mesa, Arizona for the fiscal year 2009/2010*. Retrieved from http://www.mesaaz.gov/budget/Documents/FY_09_10/FY_2009-2010_City_of_Mesa_Executive_Budget_Plan.pdf

City of Mesa. (2010). *Executive budget plan City of Mesa, Arizona for the fiscal year 2010/2011*. Retrieved from http://www.mesaaz.gov/budget/Documents/FY_10_11/City_of_Mesa_AZ_FY_2010-2011_Executive_Budget_Plan.pdf

Considine, T., & McLaren, D. (2008). *Powering Arizona: Choices and trade-offs for electricity policy*. *A study of Arizona's energy future*. Unpublished manuscript. Arizona State University, W. P. Carey School of Business. Retrieved from http://www. communicationsinstitute.org/uploads/File/Powering-Arizona-Study-Draft-Final.pdf

Cory, K., Coughlin, J., & Coggeshall, C. (2008). *Solar photovoltaic financing: Deployment on public property by state and local governments* (NREL/TP-670-43115). Washington, DC: National Renewable Energy Laboratory. Retrieved from http:// www1.eere.energy.gov/wip/pdfs/tap_webinar_20080813_43115.pdf

Database of State Incentives for Renewables & Efficiency. (2010a). *Clean renewable energy bonds (CREBs).* Retrieved March 16, 2011, from http://www.dsireusa.org/incentives/ index.cfm?State=US&ee=1&re=1

Database of State Incentives for Renewables & Efficiency. (2010b). *Qualified energy conservation bonds (QECB).* Retrieved March 16, 2011, http://www.dsireusa.org/ incentives/index.cfm?State=US&ee=1&re=1

Database of State Incentives for Renewables & Efficiency. (2010c). *Arizona – Interconnection*. Retrieved March 17, 2011, from http://www.dsireusa.org/incentives/index.cfm? re=1&ee=1&0&st=0&srp=1&state=AZ

Database of State Incentives for Renewables & Efficiency. (2010d). *Arizona – Net metering*. Retrieved March 17, 2011, from http://www.dsireusa.org/incentives/index.cfm? re=1&ee=1&spv=0&st=0&srp=1&state=AZ

Database of State Incentives for Renewables & Efficiency. (2010e). *SRP – EarthWise solar incentive program*. Retrieved March 17, 2011, from http://www.dsireusa.org/incentives/ index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=AZ

Database of State Incentives for Renewables & Efficiency. (2011). *SRP – Net metering*. Retrieved March 17, 2011, from http://www.dsireusa.org/incentives/index.cfm?re=1 &ee=1&spv=0&st=0&srp=1&state=AZ

Eastwood, S. (2006, January). *Brown air in the valley, Air pollution creates a brown cloud over Phoenix* [Online exclusive]. *About.com*. Retrieved from http://phoenix.about.com/od/ weather/a/browncloud.htm

Fierro, M., (1999). *Ozone health effect*. Retrieved from The University of Arizona, Southwest Environmental Health Sciences Center website: from http://coep.pharmacy.arizona.edu/ air/air_quality/OZONE.pdf

Frantzis, L., Graham, S., Katofsky, R., & Sawyer, H. (2008). *Photovoltaics business models* (NREL/SR-581-42304). Washington, DC: National Renewable Energy Laboratory. Retrieved from http://www.nrel.gov/docs/fy08osti/42304.pdf

Frisvold, G., Patton, W. P., & Reynolds, S. (2009, January 9). *Arizona solar energy and economics outlook*. Retrieved from The University of Arizona, Economic and Business Research Center website: http://ebr.eller.arizona.edu/sustainability/arizona_solar_energy_ and_economic_outlook.pdf

Gamble, J. L., Ebi, K. L., Grambsch, A. E., Sussman, F. G., & Wilbanks, T. J. (2008). *Analysis of the effects of global climate change on human health and welfare and human systems* (SAP 4.6). Washington, DC: U.S. Environmental Protection Agency. Retrieved from U.S. Climate Change Science Program website: http://www.climatescience.gov/Library/ sap/sap4-6/final-report/

Gianakis, G. & McCue, C. (1999). *Local government budgeting: A managerial approach*. Westport, CT: Praeger Publishers.

Greguras, F. (2010, July 12). When is a power purchase agreement provider regulated as a utility? [Web log message]. Retrieved from http://www.climatelawreport.com/2010/07/articles/financing-investing/when-is-a-power-purchase-agreement-provider-regulated-as-a-utility/

Grineski, S., Bolin, B., & Boone, C. (2007). Criteria air pollution and marginalized populations: Environmental inequality in Metropolitan Phoenix, Arizona. *Social Science Quarterly, 88*(2), 535-554. doi:10.1111/j.1540-6237.2007.00470.x

Hanitsch, R. E., Schultz, D., & Seigfried, U. (2001). *Shading effects on output power of grid connected photovoltaic generator systems*. Unpublished manuscript. Technical University Berlin, Institute of Electrical Power and Automation Technology. Retrieved from http://www.cder.dz/download/upec-12.pdf

Hayes, A. (2011, February 21). Distributed generation: Challenging the utility model [Web log message]. Retrieved from http://www.ajelp.com/documents/Hayes_Distributed Generation_Blog_Final.pdf

Heifetz, R. A., & Linsky, M. (2002). *Leadership on the line: Staying alive through the dangers of leading*. Boston, MA: Harvard Business School Press.

Holbert, K. E. (2007). An analysis of utility incentives for residential photovoltaic installations in Phoenix, Arizona. In IEEE (Ed.). *39th North American Power Symposium* (pp. 189-196). New York, NY: IEEE Xplore. doi:10.1109/NAPS.2007.4402309

Keyes, J. B., Fox, K. T., Wiedman, J. F., Quinlan, M., Varnado, L. A., McAllister, K., & Haynes, R. (2011). *Net metering and interconnection procedures: Incorporating best practices*. Retrieved from Interstate Renewable Energy Council website: http://irecusa.org/irec-programs/publications-reports/

Kimber, A. (n.d.). *The effects of soiling on photovoltaic systems located in arid climates*. Retrieved from Sun Power Corporation website: http://www.5thgenerationsolar.com/pdf/Solar%20Soiling%20Effect%20Study%20-%205BV_1_12.pdf

Kobayashi, T., & Hung, L. C. (2008). Global warming and the fire service: A local view from Asia. *Fire & Rescue, 69*: 38-40. Retrieved from: http://www.hemmingfire.com/news/fullstory.php/aid/62/Global_warming_and_the_fire_service__96_the_local_view_in_Asia.html

Kollins, K. (2008). *Solar PV financing: Potential legal challenges to the third party PPA model*. (Master's thesis, Duke University). Retrieved from http://dukespace.lib.duke.edu/dspace/

Lisell, L., & Mosey, G. (2010). *Feasibility study of economics and performance of solar photovoltaics in Nitro, West Virginia* (NREL/TP-6A2-48594). Washington, DC: National Renewable Energy Laboratory. Retrieved from http://www.nrel.gov/docs/fy10osti/48594.pdf

Luning Wende Associates. (2010). *Solar ready building design guidelines*. Retrieved from: http://www.state.mn.us/mn/externalDocs/Commerce/Solar_Ready_Building_Design_Guidelines_020211042659_SolarBuildingDesignGuidelines.pdf

MacIntosh, D. I., & Spengler, J. D. (2011). *Emission of hazardous air pollutants from coal-fired Power plants* (EH&E Report No. 17505). Retrieved from American Lung Association website: http://www.lungusa.org/assets/documents/healthy-air/coal-fired-plant-hazards.pdf

Mar, T. F., Norris, G. A., Koening, J. Q., & Larson, T. V. (2000). Association between air pollution and mortality in Phoenix, 1995-1997. *Environmental Health Perspectives, 108*(4), 347-353. doi:10.2307/j100482

Maricopa County Air Quality Department. (2011). *Inversion*. Retrieved from http://www.maricopa.gov/aq/divisions/monitoring/inversion.aspx

Maricopa County Department of Emergency Management. (2010). *Maricopa County community wildfire protection plan*. Retrieved from http://www.maricopa.gov/Emerg_Mgt/pdf/MCCWPP%20Public%20Review%20Draft%200223_2010.pdf

Maricopa County Environmental Services Department. (2000, February 9). *Particulate matter High air pollution advisory is in effect* [Press release]. Retrieved from http://www.maricopa.gov/EnvSvc/BusinessServices/News/archive/ADVSRY.PDF

Markley, R. (2008, May 1). Electricity on the go. *Fire Chief*. Retrieved from http://firechief.com/apparatus/electricity_go_0501/

McCabe, P. (2009). *Identifying and implementing renewable energy solutions for Winter Park Fire Rescue.* Unpublished manuscript. National Fire Academy, Executive Fire Officer Program. Retrieved from http://www.usfa.dhs.gov/pdf/efop/efo44332.pdf

McKinnon, S. (2010, October 1). Phoenix area heat extending ozone risk. *Arizona Republic*. Retrieved from http://www.azcentral.com

McLoone, C. (2011, March). Solar panels offer fire departments more than green capital. *Fire Apparatus & Emergency Equipment.* Retrieved from http://www.fireapparatusmagazine.com/index/current-issue/fire-apparatus/volume-16/issue-03.html

Medina-Ramon, M., Zanobetti, A., & Schwartz, J. (2006). The effect of ozone and PM10 on hospital admissions for pneumonia and chronic obstructive pulmonary disease: A national multicity study. *American Journal of Epidemiology, 163*(6), 579-588. doi:10.1093/aje/kwl078

Meng, Y-Y., Rull, R. P., Wilhelm, M., Lombardi, C., Balmes, J., & Ritz, B. (2010). Outdoor air pollution and uncontrolled asthma in the San Joaquin Valley, California. *Journal of Epidemiology and Community Health, 64*(2), 142-147. doi:10.1136/jech.2009.083576

Mesa Fire Department. (2006). *Strategic Plan 2006*. Retrieved from http://mesaaz.gov/fire/Technical/pdf/2006FIRESTRATEGICPLAN.pdf

Morrison Institute. (2008). *Megapolitan: Arizona's sun corridor*. Retrieved from http://morrisoninstitute.asu.edu/publications-reports/special-reports/2008-megapolitan-arizonas-sun-corridor

National Climate Data Center. (2004). *Ranking of cities based on % annual possible sunshine in descending order from most to least average possible sunshine*. Retrieved from http://www.ncdc.noaa.gov/oa/climate/online/ccd/pctposrank.txt

National League of Cities. (2011). *National municipal policy* (p. 60). Retrieved from http://www.nlc.org/influence-federal-policy/resources/national-municipal-policy

National Oceanic and Atmospheric Administration. (2010). *2009 Review*. Retrieved from the National Weather Service website: http://www.wrh.noaa.gov/psr/pns/2010/January/Brief1.php

National Research Council. (2008). *Estimating mortality risk reduction and economic benefits from controlling ozone air pollution*. Washington, DC: Author. Retrieved from the National Academy Press website: http://www.nap.edu/catalog/12198.html

Oreskes, N. (2004, December). The scientific consensus on climate change. *Science, 306*(5702), 1686. doi:10.2307/j100000

Owens, S. (2009). Climate change in action in Arizona. *UCLA Journal of Environmental Law and Policy, 27*(2), 317-335.

Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., & Hanson, C. E. (Eds.). (2007). *Climate change 2007: Impacts, adaptation and vulnerability*. Cambridge, UK: Cambridge University Press.

Pearce, J. M. (2002). Photovoltaics – A path to sustainable futures. *Futures, 34*(7), 663-674. doi:10.1016/S0016-3287(02)00008-3

Pechony, O., & Shindell, D. T. (2010). Driving forces of global wildfires over the past millennium and the forthcoming century. *Proceedings of the National Academy of Sciences of the United States of America, 107*(45), 19167. doi:10.1073/pnas.1003669107

Pinal County Office of Emergency Management. (2009). *Pinal County community wildfire protection plan*. Retrieved from http://pinalcountyaz.gov/Departments/PublicWorks/EmergencyManagement/Documents/Pinal%20County%20CWPP.pdf

Prokopetz, J., & Sargent, R. (2010, March). *Building better: How high-efficiency buildings will save money and reduce global warming*. Retrieved from http://www.environmentamerica.org/uploads/d6/09/d6098e7f9dacc59129a776f81df87caf/Building-Better-vAME.pdf

Rahus Institute. (2008). *The consumers' guide to solar power purchase agreements*. Retrieved from California Solar Center website: http://www.californiasolarcenter.org/sppa.html

Randazzo, R. (2011, April 8). Regulators' rule on alternative energy is upheld. *Arizona Republic*, p. D1-D2.

Romieu, I., Kunzli, N., Samet, J., Pope, A., Smith, K., Cohen, A., …Krzyzanowski, M. (2005). The global burden of disease due to outdoor air pollution. *Journal of Toxicology and Environmental Health Part A, 68*(13-14), 1301-1307. doi:10.1080/152873905909366166

Salt River Project. (2011a). *Solar electricity for your business from SRP EarthWise Solar Energy*. Retrieved March 31, 2011, from http://www.srpnet.com/environment/earthwise/solarbiz/solarelectric.aspx

Salt River Project. (2011b). *Business time-of-use plan (E-32)*. Retrieved April 2, 2011, from http://www.srpnet.com/prices/business/tou.aspx

Salt River Project. (2011c). *Santan generating station*. Retrieved from http://www.srpnet.com/about/stations/santan.aspx

Schmidli, R. J. (1996). *Climate of Phoenix, Arizona: An abridged on-line version of NOAA technical memorandum NWS WR-177*. Retrieved from http://www.public.asu.edu/~atrsc/phxwx.htm?q=cerveny/phxwx.htm

Solar electric modules. (n.d.) Retrieved March 25, 2011, from http://www.wholesalesolar.com/pdf.folder/Download%20folder/solar-panels.pdf

Swenson, R. B. (2005). *Comparing horizontal and tilted photovoltaic arrays*. Retrieved from http://www.ecotopia.com/ises/2005/ComparingHorizontalTiltedPV.pdf

Taylor, D. (n.d.). *The literature review: A few tips on conducting it*. Retrieved from University of Toronto, Health Sciences Writing Centre website: Retrieved from http://www.writing.utoronto.ca/advice/specific-types-of-writing/literature-review

Texas State Energy Conservation Office. (n.d.) *Electric power pollution calculator*. Retrieved April 16, 2011, from http://www.infinitepower.org/calc_pollution.htm

Torcellini, P., Pless, S., Deru, M., & Crawley, D. (2006). *Zero energy buildings: A critical Look at the definition* (NREL/CP-550-39833). Washington, DC: National Renewable Energy Laboratory. Retrieved from http://www.nrel.gov/sustainable_nrel/pdfs/39833.pdf

U.S. Census Bureau. (2010, November 4). *State and county quickfacts: Mesa (city), Arizona*. Retrieved from http://quickfacts.census.gov/

U.S. Conference of Mayors. (2009, October 2). *1,000th mayor – Mesa, AZ Mayor Scott Smith signs the U.S. Conference of Mayors climate protection agreement* [Press release]. Retrieved from http://www.usmayors.org/pressreleases/uploads/1000signatory.pdf

U.S. Department of Homeland Security. (2009*). A.R.R.A. Assistance to Firefighters Fire Station Construction Grants guidance and application kit*. Retrieved from http://www.fema.gov/pdf/government/grant/arra/fy09_arra_fsc_guidance.pdf

U.S. Environmental Protection Agency. (2004). *Air quality criteria for particulate matter* (Final Report, October 2004). Washington, DC: Author. Retrieved from http://cfpub.epa.gov/ncea/cfm/recorddisplay.cfm?deid=87903

U.S. Environmental Protection Agency. (2006). *Air quality criteria for ozone and related to petrochemical oxidants* (2006 Final). Washington, DC: Author. Retrieved from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=149923

U.S. Environmental Protection Agency. (2009, July 28). *EPA webinar on solar power purchase agreements.* Retrieved from http://www.epa.gov/greenpower/events/july28_webinar.htm

U.S. Environmental Protection Agency. (2010). *Solar power purchase agreements*. Retrieved March 31, 2011, from http://www.epa.gov/greenpower/buygp/solarpower.htm

U.S. Environmental Protection Agency. (2011). *Particulate matter*. Retrieved from http://www.epa.gov/pm/

U.S. Fire Administration. (2010a). *Executive development* [Student manual]. Emmitsburg, MD: Author.

U.S. Fire Administration. (2010b). *Strategic plan fiscal years 2010-2014*. Retrieved from http://www.usfa.dhs.gov/downloads/pdf/strategic_plan.pdf

Valley Forward Association. (2011, February). *Arizona's guide to electric energy choices*. Retrieved from http://www.valleyforward.org/issues/22/

Weisser, D. (2007). A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies. *Energy, 32*(9), 1543-1559. doi:10.1016/j.energy.2007.01.008

Weterling, A. L., Hildalgo, H. G., Cayan, D. R., & Swetnam, T. W. (2006). Warming and earlier spring increase western U.S. forest wildfire activity. *Science, 313*, 940-943. doi:101126/science.1128834

Zauscher, M. D. (2006). *Solar photovoltaic panels from a heat transfer perspective*. Unpublished manuscript. University of San California, San Diego, Department of Mechanical and Aerospace Engineering. Retrieved from http://courses.ucsd.edu/rherz/maw221a/reports/Zauscher_221A_F06.pdf

Appendix A

2009-2010 Fire Department Utility Expense Report

2009/2010 Utility Expense Report — **July**

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Prevention Building	13 W. 1st St./64 N Center	21,588	3,384.49				3384.49	3384.49
Station 1	360 E. 1st St.	26,565	6,591.92				6591.92	6591.92
Health & Fitness	1105 E. 2nd Ave.	2,556	110.68		436.49	3,480	547.17	547.17
Station 2	830 S. Stapley	9,081	584.73		1,810.68	16,880	2395.41	2395.41
Station 3	1340 W. University	3,601	487.25		1,247.28	12,028	1734.53	1734.53
Station 3 exercise room	1342 W. University				206.27	1,682	206.27	206.27
Station 4	1426 S. Extension	6,284	697.33		1,669.25	15,200	2366.58	2366.58
Station 5	730 S. Greenfield	4,663	753.31		1,202.66	10,160	1955.97	1955.97
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	969.24		2,810.13	27,000	3779.37	3779.37
Station 7	2505 S. Dobson 25% Fire 75% Police	3,374	229.86		860.45	33,840	1090.31	1090.31
Station 8	4530 E. McKellips	5,019	340.05		3,131.38	30,640	3471.43	3471.43
Station 9	7035 E. Southern	8,268	600.62		2,064.90	20,080	2665.52	2665.52
Station 10	1502 S. 24th St.	4,730	1,976.84		733.15	7,040	2709.99	2709.99
Station 11	2130 N. Horne	4,862	515.59		815.34	6,320	1330.93	1330.93
Station 12	2430 S. Ellsworth 25% Fire 75% Police	5,148	362.38		1,215.86	46,080	1578.24	1578.24
Station 13	7816 E. University	4,534	589.68		1,044.95	8,400	1634.63	1634.63
Station 14	5950 E. Virginia	6,186	324.53		1,543.42	14,400	1867.95	1867.95
Station 15	5945 S. Sossaman	16,130	521.17	63.82	2,170.81	27,760	2755.80	2755.80
Station 16	7966 E. McDowell	9,012	531.53		1,467.82	13,560	1999.35	1999.35
Station 17	10434 E. Baseline	10,284	907.31	171.56	1,679.33	14,880	2758.20	2758.20
Substation	2507 S. Dobson		481.13				481.13	481.13
Council Chambers	57 E. 1st St.		35.22				35.22	35.22
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	274.85				274.85	274.85
Training Facility	3260 N. 40th St. 50% Police/Fire		1,306.53		3,429.94	57,200	4736.47	4736.47
Resource Test Pit	7121 E. Adobe		32.88				32.88	32.88
Substation	4534 E. McKellips		85.72				85.72	85.72
Total		**185,902**	**22,694.84**	**235.38**	**29,540.11**	**366,630**	**52470.33**	**52470.33**

Note: Yellow-highlighted fields inidcate shared facilities. Percentages charged are reflected in address field. Dollar amount shown reflects our share, but the actual kilowatt hours reflects the total for the entire facility.

2009/2010 Utility Expense Report

Aug

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Demand	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st St./64 N Center	21,588	3,908.49				3,908.49	7,292.98
Station One	360 E. 1st St.	26,565	6,632.69				6,632.69	13,224.61
Health & Fitness	1105 E. 2nd Ave.	2,556	114.49		389.27	2,880	503.76	1,050.93
Station 2	830 S. Stapley	9,081	690.05		1,737.22	16,560	2,427.27	4,822.68
Station 3	1340 W. University	3,601	366.51		1,311.56	13,148	1,678.07	3,412.60
Station 3 Fitness	1342 W. University				278.49	2,390	278.49	484.76
Station 4	1426 S. Extension	6,284	814.06		1,579.25	14,640	2,393.31	4,759.89
Station 5	730 S. Greenfield	4,663	702.54		1,244.93	11,000	1,947.47	3,903.44
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	902.73		3,293.96	32,120	4,196.69	7,976.06
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	245.90		985.80	39,520	1,231.70	2,322.01
Station 8	4530 E. McKellips	5,019	337.44		3,445.46	34,080	3,782.90	7,254.33
Station 9	7035 E. Southern	8,268	423.78		2,129.44	21,040	2,553.22	5,218.74
Station 10	1502 S. 24th St.	4,730	1,532.59		862.69	8,400	2,395.28	5,105.27
Station 11	2130 N. Horne	4,862	381.35		951.04	8,320	1,332.39	2,663.32
Station 12	2430 S. Ellsworth 25% Fire/75% Police	5,148	297.56		1,326.08	51,360	1,623.64	3,201.88
Station 13	7816 E. University	4,534	269.15		934.36	7,640	1,203.51	2,838.14
Station 14	5950 E. Virginia	6,186	324.40		1,094.40	12,640	1,418.80	3,286.75
Station 15	5945 S. Sossaman	16,130	621.34	60.62	2,199.70	26,640	2,881.66	5,637.46
Station 16	7966 E. McDowell	9,012	453.91		1,402.77	12,600	1,856.68	3,856.03
Station 17	10434 E. Baseline	10,284	840.98	180.44	2,026.50	19,080	3,047.92	5,806.12
Substation	2507 S. Dobson		377.70				377.70	858.83
Council Chambers	57 E. 1st St.		33.18				33.18	68.40
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	276.37				276.37	551.22
Training Facility	3260 N. 40th St. 50% Police/Fire		1,448.12		3,944.87	66,320	5,392.99	10,129.46
Resource Test Pit			32.88				32.88	65.76
Substation	4534 E. McKellips		85.72				85.72	171.44
Total		185,902	22,113.93	241.06	31,137.79	400,378	53,492.78	105,963.11

facilities. Percentages charged are reflected in address field. Dollar amount shown reflects our share, but the actual kilowatt hours reflects the total for the entire facility.

2009/2010 Utility Expense Report

Sept

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st St./64 N Center	21,588	3,142.78				3,142.78	**10,435.76**
Station 1	360 E. 1st St.	26,565	5,370.91				5,370.91	**18,595.52**
Health & Fitness	1105 E. 2nd Ave.	2,556	118.44		323.87	2760	442.31	**1,493.24**
Station 2	830 S. Stapley	9,081	911.42		1,275.84	12800	2,187.26	**7,009.94**
Station 3	1340 W. University	3,601	386.31		1,042.46	11708	1,428.77	**4,841.37**
Station 3 Fitness					202.49	1972	202.49	**687.25**
Station 4	1426 S. Extension	6,284	887.37		1,191.29	12480	2,078.66	**6,838.55**
Station 5	730 S. Greenfield	4,663	579.65		1,036.83	10280	1,616.48	**5,519.92**
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	1,003.64		2,964.82	31760	3,968.46	**11,944.52**
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	253.37		640.92	28560	894.29	**3,216.30**
Station 8	4530 E. McKellips	13,515	329.95		2,790.63	30880	3,120.58	**10,374.91**
Station 9	7035 E. Southern	8,268	449.17		1,700.69	17680	2,149.86	**7,368.60**
Station 10	1502 S. 24th St.	4,730	1,260.33		754.74	8080	2,015.07	**7,120.34**
Station 11	2130 N. Horne	4,862	415.27		794.19	8240	1,209.46	**3,872.78**
Station 12	2430 S. Ellsworth 25% Fire/75% Police	5,148	329.03		1,067.62	47840	1,396.65	**4,598.53**
Station 13	7816 E. University	4,534	516.36		827.35	8000	1,343.71	**4,181.85**
Station 14	5950 E. Virginia	6,186	330.83		1,168.93	12920	1,499.76	**4,786.51**
Station 15	5945 S. Sossaman	16,130	580.80	64.36	1,825.04	26400	2,470.20	**8,107.66**
Station 16	7966 E. McDowell	9,012	538.70		1,273.52	13920	1,812.22	**5,668.25**
Station 17	10434 E. Baseline	10,284	971.12	167.12	1,817.72	20160	2,955.96	**8,762.08**
Substation	2507 S. Dobson		546.66				546.66	**1,405.49**
Council Chambers	57 E. 1st St.		32.41				32.41	**100.81**
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	268.36				268.36	**819.58**
Training Facility	3260 N. 40th St. 50% Police/Fire		1,312.69		3,150.23	60000	4,462.92	**14,592.38**
Resource Test Pit	7121 E. Adobe		33.90				33.90	**99.66**
Substation	4534 E. McKellips		85.72				85.72	**257.16**
Total		**194,398**	**20,655.19**	**231.48**	**25,849.18**	**366440**	**46,735.85**	**152,698.96**

Note: Yellow-highlighted fields indicate shared facilities. Percentages charged are reflected in address field. Dollar amount shown reflects our share, but the actual kilowatt hours reflects the total for the entire facility.

2009/2010 Utility Expense Report — Oct

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st St./64 N Center	21,588	2,461.76				2,461.76	12,897.52
Station 1	360 E. 1st St.	26,565	4,768.51				4,768.51	23,364.03
Health & Fitness	1105 E. 2nd Ave.	2,556	103.93		139.57	1040	243.50	1,736.74
Station 2	830 S. Stapley	9,081	548.78		957.12	9120	1,505.90	8,515.84
Station 3	1340 W. University	3,601	384.08		916.96	9988	1,301.04	6,142.41
Station 3 Fitness	1342. W. University				134.82	1208	134.82	822.07
Station 4	1426 S. Extension	6,284	1,106.48		882.38	8640	1,988.86	8,827.41
Station 5	730 S. Greenfield	4,663	372.99		847.04	8240	1,220.03	6,739.95
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	865.74		2,190.73	22920	3,056.47	15,000.99
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	237.86		538.93	23600	776.79	3,993.09
Station 8	4530 E. McKellips	13,515	335.48		2,573.38	28000	2,908.86	13,283.77
Station 9	7035 E. Southern	8,268	438.80		1,290.63	13680	1,729.43	9,098.03
Station 10	1502 S. 24th St.	4,730	547.01		594.01	6240	1,141.02	8,261.36
Station 11	2130 N. Horne	4,862	349.19		679.50	6880	1,028.69	4,901.47
Station 12	2430 S. Ellsworth 25% Fire/75% Police	5,148	312.85		800.80	31200	1,113.65	5,712.18
Station 13	7816 E. University	4,534	496.15		614.27	5680	1,110.42	5,292.27
Station 14	5950 E. Virginia	6,186	364.42		826.18	8320	1,190.60	5,977.11
Station 15	5945 S. Sossaman	16,130	547.92	61.65	1,305.46	17440	1,915.03	10,022.69
Station 16	7966 E. McDowell	9,012	553.66		725.01	6960	1,278.67	6,946.92
Station 17	10434 E. Baseline	10,284	849.60	185.56	1,585.97	17400	2,621.13	11,383.21
Substation	2507 S. Dobson		581.22				581.22	1,986.71
Council Chambers	57 E. 1st St.		31.08				31.08	131.89
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	238.55				238.55	1,058.13
Training Facility	3260 N. 40th St. 50% Police/Fire		1,383.74		2,956.23	57200	4,339.97	18,932.35
Resource Test Pit	7121 E. Adobe		37.36				37.36	137.02
Substation	4534 E. McKellips		85.72				85.72	342.88
Total		**194,398**	**18,002.88**	**247.21**	**20,558.99**	**283756**	**38,809.08**	**191,508.04**

Note: Yellow-highlighted fields indicate shared facilities. Percentages charged are reflected in address field. Dollar amount shown reflects our share, but the actual kilowatt hours reflects the total for the entire facility.

2009/2010 Utility Expense Report

Nov

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Station 1/Offices	13 W. 1st St./64 N Center	21,588	1647.91				1,647.91	**14,545.43**
Station 1	360 E. 1st St.	26,565	2939.28				2,939.28	**26,303.31**
Health & Fitness	1105 E. 2nd Ave.	2,556	116.38		103.61	960	219.99	**1,956.73**
Station 2	830 S. Stapley	9,081	563.77		663.37	7600	1,227.14	**9,742.98**
Station 3	1340 W. University	3,601	317.62		642.18	7388	959.80	**7,102.21**
Station 3 Fitness					67.62	604	67.62	**889.69**
Station 4	1426 S. Extension	6,284	766.92		662.80	7760	1,429.72	**10,257.13**
Station 5	730 S. Greenfield	4,663	292.99		598.63	6480	891.62	**7,631.57**
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	895.90		1,457.89	16680	2,353.79	**17,354.78**
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	216.13		398.26	20640	614.39	**4,607.48**
Station 8	4530 E. McKellips	13,515	317.92		1,467.40	17200	1,785.32	**15,069.09**
Station 9	7035 E. Southern	8,268	321.28		775.90	9120	1,097.18	**10,195.21**
Station 10	1502 S. 24th St.	4,730	400.35		532.17	5840	932.52	**9,193.88**
Station 11	2130 N. Horne	4,862	249.58		404.68	4400	654.26	**5,555.73**
Station 12	2430 S. Ellsworth	5,148	250.57		644.04	32160	894.61	**6,606.79**
Station 13	7816 E. University	4,534	294.17		449.84	4720	744.01	**6,036.28**
Station 14	5950 E. Virginia	6,186	305.68		605.71	6960	911.39	**6,888.50**
Station 15	5945 S. Sossaman	16,130	439.44		987.29	16400	1,426.73	**11,449.42**
Station 16	7966 E. McDowell	9,012	433.55		566.94	6600	1,000.49	**7,947.41**
Station 17	10434 E. Baseline	10,284	578.29	391.39	912.86	10440	1,882.54	**13,265.75**
Station 18	845 N. Alma School		41.06				41.06	**41.06**
Substation	2507 S. Dobson		418.77				418.77	**2,405.48**
Council Chambers	57 E. 1st St.		25.49				25.49	**157.38**
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	213.36				213.36	**1,271.49**
Training Facility	3260 N. 40th St. 50% Police/Fire		990.92		1,743.64	38640	2,734.56	**21,666.91**
Resource Test Pit	7121 E. Adobe		44.27				44.27	**181.29**
Substation	4534 E. McKellips		85.72				85.72	**428.60**
Total		**194,398**	**13167.32**	**391.39**	**13,684.83**	**220,592**	**27,243.54**	**218,751.58**

Note: Yellow-highlighted fields indicate shared facilities. Percentages charged are reflected in address field. Dollar amount shown reflects our share, but the actual kilowatt hours reflects the total for the entire facility.

2009/2010 Utility Expense Report

Dec

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st St./64 N Center	21,588	1,457.41				$1,457.41	16,002.84
Station 1	360 E. 1st St.	26,565	3,083.55				$3,083.55	29,386.86
Health & Fitness	1105 E. 2nd Ave.	2,556	108.03		$69.80	560	$177.83	2,134.56
Station 2	830 S. Stapley	9,081	505.19		$567.59	6,880	$1,072.78	10,815.76
Station 3	1340 W. University	3,601	289.05		$547.15	6,108	$836.20	7,938.41
Station 3 Fitness			49.57		$36.81	232	$86.38	976.07
Station 4	1426 S. Extension	6,284	410.69		$603.93	7,120	$1,014.62	11,271.75
Station 5	730 S. Greenfield	4,663	233.22		$628.63	6,720	$861.85	8,493.42
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	1,154.68		$1,273.81	16,240	$2,428.49	19,783.27
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	240.71		$315.86	16,000	$556.57	5,164.05
Station 8	4530 E. McKellips	13,515	328.25		$1,373.90	15,920	$1,702.15	16,771.24
Station 9	7035 E. Southern	8,268	242.97		$976.24	12,080	$1,219.21	11,414.42
Station 10	1502 S. 24th St.	4,730	235.29		$664.03	7,680	$899.32	10,093.20
Station 11	2130 N. Horne	4,862	450.57		$371.94	4,080	$822.51	6,378.24
Station 12	2430 S. Ellsworth 25% Fire/75% Police	5,148	116.70		$597.48	29,120	$714.18	7,320.97
Station 13	7816 E. University	4,534	174.48		$892.60	10,120	$1,067.08	7,103.36
Station 14	5950 E. Virginia	6,186	333.48		$462.55	5,320	$796.03	7,684.53
Station 15	5945 S. Sossaman	16,130	129.84		$686.90	11,040	$816.74	12,266.16
Station 16	7966 E. McDowell	9,012	416.41		$480.15	5,520	$896.56	8,843.97
Station 17	10434 E. Baseline	10,284	443.07		$749.81	8,400	$1,192.88	14,458.63
Station 18	845 N. Alma School		0.00				$0.00	41.06
Substation	2507 S. Dobson		135.39				$135.39	2,540.87
Council Chambers	57 E. 1st St.		22.21				$22.21	179.59
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	162.49				$162.49	1,433.98
Training Facility	3260 N. 40th St. 50% Police/Fire		646.55		$1,525.29	35,040	$2,171.84	23,838.75
Resource Test Pit	7121 E. Adobe		33.90				$33.90	215.19
Substation	4534 E. McKellips		85.72				$85.72	514.32
Total		194,398	11,489.42	0.00	$12,824.47	204,180	$24,313.89	243,065.47

Note: Yellow-highlighted fields indicate shared facilities. Percentages charged are reflected in address field. Dollar amount shown reflects our share, but the actual kilowatt hours reflects the total for the entire facility.

2009/2010 Utility Expense Report

Jan

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st St./64 N. Center	21,588	1,471.27				1471.27	17474.11
Station 1	360 E. 1st St.	26,565	3,192.89				3192.89	32579.75
Health & Fitness	1105 E. 2nd Ave.	2,556	112.52		82.97	680	195.49	2330.05
Station 2	830 S. Stapley	9,081	594.81		500.93	5,760	1095.74	11911.50
Station 3	1340 W. University	3,601	460.13		479.37	5,308	939.50	8877.91
Station 3 Fitness					35.40	168	35.40	1011.47
Station 4	1426 S. Extension	6,284	602.61		480.66	5,440	1083.27	12355.02
Station 5	730 S. Greenfield	4,663	227.71		678.12	7,440	905.83	9399.25
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	1,359.29		1,113.78	13,920	2473.07	22256.34
Station 7	2505 S. Dobson 35% Fire/65% Police	3,374	261.17		318.38	16,720	579.55	5743.60
Station 8	4530 E. McKellips	13,515	490.58		1,109.01	13,120	1599.59	18370.83
Station 9	7035 E. Southern	8,268	206.07		660.18	8,000	866.25	12280.67
Station 10	1502 S. 24th St.	4,730	180.13		1,161.13	14,720	1341.26	11434.46
Station 11	2130 N. Horne	4,862	661.48		404.30	4,480	1065.78	7444.02
Station 12	2430 S. Ellsworth 25% Fire/75% Police	5,148	105.52		651.66	32,160	757.18	8078.15
Station 13	7816 E. University	4,534	150.71		724.08	7,920	874.79	7978.15
Station 14	5950 E. Virginia	6,186	584.38		502.86	6,000	1087.24	8771.77
Station 15	5945 S. Sossaman 49% Fire / 51% Police	16,130	127.11	1812.86	956.18	16,880	2896.15	15162.31
Station 16	7966 E. McDowell	9,012	625.98		488.79	5,640	1114.77	9958.74
Station 17	10434 E. Baseline	10,284	265.98	559.33	714.38	8,880	1539.69	15998.32
Station 18	845 N. Alma School		449.60				449.60	490.66
Substation	2507 S. Dobson		73.11				73.11	2613.98
Council Chambers	57 E. 1st St. 2% Fire		19.47				19.47	199.06
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur 6% Fire	16,753	138.06				138.06	1572.04
Training Facility	3260 N. 40th St. 52% Fire / 48% Police		843.66		1,342.65	29,920	2186.31	26025.06
Resource Test Pit	7121 E. Adobe		43.13				43.13	258.32
Substation	4534 E. McKellips		85.72				85.72	600.04
Total		**194,398**	**13,333.09**	**2,372.19**	**12,404.83**	**203,156**	**28110.11**	**271175.58**

Note: Yellow-highlighted fields indicate shared facilities. Percentages charged are reflected in address field. Dollar amount shown reflects our share, but the actual kilowatt hours reflects the total for the entire facility.

2009/2010 Utility Expense Report — Feb

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st St./64 N Center	21,588	1,381.32				1381.32	18855.43
Station 1	360 E. 1st St.	26,565	2,814.64				2814.64	35394.39
Health & Fitness	1105 E. 2nd Ave.	2,556	114.96		69.80	560	184.76	2514.81
Station 2	830 S. Stapley	9,081	616.00		512.97	5840	1128.97	13040.47
Station 3	1340 W. University	3,601	346.55		452.89	4988	799.44	9677.35
Station 3 Fitness					46.24	293	46.24	1057.71
Station 4	1426 S. Extension	6,284	518.03		500.93	5760	1018.96	13373.98
Station 5	730 S. Greenfield	4,663	233.22		677.90	7160	911.12	10310.37
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	949.49		1,114.37	14000	2063.86	24320.20
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	232.85		348.42	18720	581.27	6324.87
Station 8	4530 E. McKellips	13,515	225.47		1,075.53	12560	1301.00	19671.83
Station 9	7035 E. Southern	8,268	199.15		734.27	8880	933.42	13214.09
Station 10	1502 S. 24th St.	4,730	173.24		899.67	10960	1072.91	12507.37
Station 11	2130 N. Horne	4,862	507.34		348.57	3760	855.91	8299.93
Station 12	2430 S. Ellsworth 25% Fire/75% Police	5,148	117.21		642.65	31520	759.86	8838.01
Station 13	7816 E. University	4,534	150.71		683.15	7360	833.86	8812.01
Station 14	5950 E. Virginia	6,186	506.16		440.75	5000	946.91	9718.68
Station 15	5945 S. Sossaman	16,130	138.02	1,838.98	764.54	12880	2741.54	17903.85
Station 16	7966 E. McDowell	9,012	486.51		485.19	5760	971.70	10930.44
Station 17	10434 E. Baseline	10,284	227.87	463.30	655.78	7560	1346.95	17345.27
Station 18	845 N. Alma School		182.07				182.07	672.73
Substation	2507 S. Dobson		52.35				52.35	2666.33
Council Chambers	57 E. 1st St.		20.05				20.05	219.11
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	143.77				143.77	1715.81
Training Facility	3260 N. 40th St. 50% Police/Fire		623.01		1,349.45	31760	1972.46	27997.52
Resource Test Pit	7121 E. Adobe		33.90				33.90	292.22
Substation	4534 E. McKellips		85.72				85.72	685.76
Total		**194,398**	**11,079.61**	**2,302.28**	**11,803.07**	**195321**	**25184.96**	**296360.54**

Note: Yellow-highlighted fields indicate shared facilities. Percentages charged are reflected in address field. Dollar amount shown reflects our share, but the actual kilowatt hours reflects the total for the entire facility.

2009/2010 Utility Expense Report

Mar

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st St.(64 N Center)	21,588	1299.44				1299.44	20154.87
Station 1	360 E. 1st St.	26,565	2703.70				2703.70	5218.51
Health & Fitness	1105 E. 2nd Ave.	2,556	118.49		66.58	520	185.07	2699.88
Station 2	830 S. Stapley	9,081	383.99		558.54	6080	942.53	13983.00
Station 3	1340 W. University	3,601	326.90		437.66	4588	764.56	10441.91
Station 3 Fitness					59.86	294	59.86	1117.57
Station 4	1426 S. Extension	6,284	471.20		543.34	6000	1014.54	14388.52
Station 5	730 S. Greenfield	4,663	259.89		498.14	5360	758.03	11068.40
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	992.37		1,091.83	13640	2084.20	26404.40
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	196.54		324.87	16640	521.41	6846.28
Station 8	4530 E. McKellips	13,515	281.35		1,123.91	13520	1405.26	21077.09
Station 9	7035 E. Southern	8,268	209.52		740.44	9120	949.96	14164.05
Station 10	1502 S. 24th St.	4,730	154.61		807.26	9600	961.87	13469.24
Station 11	2130 N. Horne	4,862	400.15		359.90	4000	760.05	9059.98
Station 12	2430 S. Ellsworth 25% Fire/75% Police	5,148	123.39		629.91	29600	753.30	9591.31
Station 13	7816 E. University	4,534	159.50		532.49	5440	691.99	9504.00
Station 14	5950 E. Virginia	6,186	384.32		465.84	5280	850.16	10568.84
Station 15	5945 S. Sossaman	16,130	124.39	736.21	817.52	14000	1678.12	19581.97
Station 16	7966 E. McDowell	9,012	535.22		484.73	5520	1019.95	11950.39
Station 17	10434 E. Baseline Rd	10,284	238.65	346.17	619.86	7200	1204.68	18549.95
Station 18	845 N. Alma School		394.41		861.90	9520	1256.31	1929.04
Substation	2507 S. Dobson		45.43				45.43	2711.76
Council Chambers	57 E. 1st St.		20.51				20.51	239.62
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	2146.36				2146.36	3862.17
Training Facility	3260 N. 40th St. 50% Police/Fire		632.93		1,358.87	31680	1991.80	29989.32
Resource Test Pit	7121 E. Adobe		33.90				33.90	326.12
Substation	4534 E. McKellips		85.72				85.72	771.48
Total		194,398	12722.88	1082.38	12383.45	197602.00	26188.71	289669.67

2009/2010 Utility Expense Report

Apr

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st St./64 N Center	21,588	1,345.13				1345.13	21,500.00
Station 1	360 E. 1st St.	26,565	3,263.66				3263.66	8,482.17
Health & Fitness	1105 E. 2nd Ave.	2,556	111.19		74.09	520	185.28	2,885.16
Station 2	830 S. Stapley	9,081	314.13		625.55	7040	939.68	14,922.68
Station 3	1340 W. University	3,601	247.25		449.17	4788	696.42	11,138.33
Station 3 Fitness							0.00	1,117.57
Station 4	1426 S. Extension	6,284	513.34		663.37	7600	1176.71	15,565.23
Station 5	730 S. Greenfield	4,663	473.22		533.96	5520	1007.18	12,075.58
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	703.30		1,080.19	13440	1783.49	28,187.89
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	176.32		370.90	18560	547.22	7,393.50
Station 8	4530 E. McKellips	13,515	179.24		1,210.11	14240	1389.35	22,466.44
Station 9	7035 E. Southern	8,268	247.55		754.78	9600	1002.33	15,166.38
Station 10	1502 S. 24th St.	4,730	288.40		379.17	4320	667.57	14,136.81
Station 11	2130 N. Horne	4,862	260.85		409.75	4640	670.60	9,730.58
Station 12	2430 S. Ellsworth 25% Police/Fire	5,148	191.18		625.18	31360	816.36	10,407.67
Station 13	7816 E. University	4,534	231.78		420.03	4320	651.81	10,155.81
Station 14	5950 E. Virginia	6,186	309.21		491.18	5520	800.39	11,369.23
Station 15	5945 S. Sossaman	16,130	127.11	108.28	859.82	13360	1095.21	20,677.18
Station 16	7966 E. McDowell	9,012	310.11		533.56	5880	843.67	12,794.06
Station 17	10434 E. Baseline	10,284	425.80	159.95	665.09	7560	1250.84	19,800.79
Station 18	845 N. Alma School		353.87				353.87	2,282.91
Substation	2507 S. Dobson		63.88				63.88	2,775.64
Council Chambers	57 E. 1st St.		28.90				28.90	268.52
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	1,479.69				1479.69	5,341.86
Training Facility	3260 N. 40th St. 50% Police/Fire		472.30		1,329.96	29520	1802.26	31,791.58
Resource Test Pit	7121 E. Adobe		33.90				33.90	805.38
Substation	4534 E. McKellips		85.72				85.72	857.20
Total		194,398	12,237.03	268.23	11,475.86	187788	23981.12	314,096.15

2009/2010 Utility Expense Report — May

Facility	Address	Square Footage	City of Mesa	Southwest Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st St./64 N. Center	21,588	1,490.78				1,490.78	**22,990.78**
Station 1	360 E. 1st St.	26,565	4,100.53				4,100.53	**12,582.70**
Health & Fitness	1105 E. 2nd Ave.	2,556	177.76		153.59	1080	331.35	**3,216.51**
Station 2	830 S. Stapley	9,081	376.74		1,045.08	10000	1,421.82	**16,344.50**
Station 3	1340 W. University	3,601	249.91		624.93	5668	874.84	**12,013.17**
Station 3 Fitness							0.00	**1,117.57**
Station 4	1426 S. Extension	6,284	563.58		1,018.31	9760	1,581.89	**17,147.12**
Station 5	730 S. Greenfield	4,663	559.88		723.50	6320	1,283.38	**13,358.96**
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	825.74		1,570.74	17400	2,396.48	**30,584.37**
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	218.43		521.07	22480	739.50	**8,133.00**
Station 8	4530 E. McKellips	13,515	206.10		1,727.73	16640	1,933.83	**24,400.27**
Station 9	7035 E. Southern	8,268	294.79		1,164.87	11680	1,459.66	**16,626.04**
Station 10	1502 S. 24th St.	4,730	587.02		474.77	4960	1,061.79	**15,198.60**
Station 11	2130 N. Horne	4,862	260.91		565.58	4880	826.49	**10,557.07**
Station 12	2430 S. Ellsworth 25% Police/Fire	5,148	235.25		826.59	32640	1,061.84	**11,469.51**
Station 13	7816 E. University	4,534	467.43		688.28	5880	1,155.71	**11,311.52**
Station 14	5950 E. Virginia	6,186	287.98		797.04	7480	1,085.02	**12,454.25**
Station 15	5945 S. Sossaman	16,130	136.42	79.94	1,210.42	15920	1,426.78	**22,103.96**
Station 16	7966 E. McDowell	9,012	401.73		890.94	8400	1,292.67	**14,086.73**
Station 17	10434 E. Baseline	10,284	652.66	142.68	1,122.28	10560	1,917.62	**21,718.41**
Station 18	845 N. Alma School		269.65		1,242.24	11120	1,511.89	**3,794.80**
Substation	2507 S. Dobson		263.23				263.23	**3,038.87**
Council Chambers	57 E. 1st St.		23.60				23.60	**292.12**
East Mesa Serv. Ctr. *(Res. Mgmt. & F. Prev.)*	6935 E. Decatur	16,753	1,704.18				1,704.18	**7,046.04**
Training Facility	3260 N. 40th St. 50% Police/Fire		614.31		2,101.81	37920	2,716.12	**34,507.70**
Resource Test Pit	7121 E. Adobe		33.90				33.90	**839.28**
Substation	4534 E. McKellips		85.72				85.72	**942.92**
Total		**194,398**	**15,088.23**	**222.62**	**18,469.77**	**240788**	**33,780.62**	**347,876.77**

Note: Yellow-highlighted fields indicate shared facilities. Percentages charged are reflected in address field. Dollar amount shown reflects our share, but the actual kilowatt hours reflects the total for the entire facility.

2009-2010 Utility Expense Report

June

Facility	Address	Square Footage	City of Mesa	SW Gas	SRP	KW Hours	Monthly Total	Year-to-Date Total
Fire Prevention	13 W. 1st/64 N Center	21,588	1792.44				1792.44	24,783.22
Station 1	360 E. 1st St.	26,565	5221.52				5221.52	17,804.22
Health & Fitness	1105 E. 2nd Ave.	2,556	163.29				163.29	3,379.80
Station 2	830 S. Stapley	9,081	683.29		1259.32	11920	1942.61	18,287.11
Station 3	1340 W. University	3,601	260.38		733.79	6708	994.17	13,007.34
Station 3 Fitness							0.00	1,117.57
Station 4	1426 S. Extension	6,284	639.86		1142.03	10800	1781.89	18,929.01
Station 5	730 S. Greenfield	4,663	686.55		917.05	8320	1603.60	14,962.56
Station 6 & Connector Bldg.	815 N. Lindsay	17,264	920.23		1956.36	19040	2876.59	33,460.96
Station 7	2505 S. Dobson 25% Fire/75% Police	3,374	256.47		608.76	25520	865.23	8,998.23
Station 8	4530 E. McKellips	13,515	246.72		2348.87	23440	2595.59	26,995.86
Station 9	7035 E. Southern	8,268	305.16		1684.31	16320	1989.47	18,615.51
Station 10	1502 S. 24th St.	4,730	540.34		578.44	5680	1118.78	16,317.38
Station 11	2130 N. Horne	4,862	317.08		629.63	5680	946.71	11,503.78
Station 12	2430 S. Ellsworth 25% Police/Fire	5,148	279.69		885.78	35520	1165.47	12,634.98
Station 13	7816 E. University	4,534	629.01		898.86	8080	1527.87	12,839.39
Station 14	5950 E. Virginia	6,186	395.18		1067.33	10440	1462.51	13,916.76
Station 15	5945 S. Sossaman	16,130	187.26	75.95	1589.53	21280	1852.74	23,956.70
Station 16	7966 E. McDowell	9,012	493.29		1191.64	11280	1684.93	15,771.66
Station 17	10434 E. Baseline	10,284	787.71	162.34	1272.03	12120	2222.08	23,940.49
Station 18	845 N. Alma School		280.60		1217.06	10800	1497.66	5,292.46
Substation	2507 S. Dobson		418.77				418.77	3,457.64
Council Chambers	57 E. 1st St.		23.73				23.73	315.85
East Mesa Serv. Ctr.	6935 E. Decatur	16,753	2137.24				2137.24	9,183.28
Training Facility	3260 N. 40th St. 50% Police/Fire		785.19		2427.69	43760	3212.88	37,720.58
Resource Test Pit	7121 E. Adobe		33.90				33.90	873.18
Substation	4534 E. McKellips		85.72				85.72	1,028.64
Total		194,398	18570.62	238.29	22408.48	286708	41217.39	389,094.16

Appendix B

Facilities Rating Low (1-3) for Rooftop Solar Feasibility

Facility	Rating	Aerial Image	Comments
Station 202	3		N-S facing metal-clad sloped roof. Flat roof stores mechanical equipment. HVAC and parapets present a shading issue. S-facing along street view may present aesthetic concerns for neighbors. Landscape shades portions of the S-facing roof.
Station 204	2		E-W facing metal-clad sloped roof. Flat roof stores mechanical equipment. HVAC and varying roof elevations present shading problems. E-facing roof along street view may present aesthetic concerns for neighbors. Landscaping south of station shades portions of the roof and is not part of the city's property.
Station 205	2		N-S facing pitched roof over apparatus bay; E-W over living quarters. Tile roof. HVAC presents shading issue. Total suitable area only 575 s.f. Older facility.
Station 207	3		Large, flat roof divided into 3 areas. One section heavily shaded by landscaping. Another is small with HVAC equipment. Largest portion presents possible site. Some HVAC and parapet shading areas to contend with. Estimate as much as 2500 s.f. of rooftop space could be made available for solar PV.

Station 208	3		Three flat roof areas. Smaller area heavily shaded by landscaping. HVAC dominates central roof area over apparatus bay. Section over living quarters presents some opportunity, though it contains HVAC and assorted penetrations. Large open space estimated 2800 s.f. suitable for solar PV.
Station 209	3		Three flat roof areas. N-facing heavily shaded by higher roofline over living quarters. Living quarters roof area dominated by HVAC and roof penetrations. Four HVAC over apparatus bay. Potential for 1400 s.f. of area for solar PV.
Station 210	1		Two flat roof areas. Too many shading issues, HVAC equipment, and roof penetrations.
Station 211	2		E-W facing tile roof. Flat roof contains HVAC equipment. E-W roof heavy shading at times due to higher roof over apparatus bay.

Station 213	1		N-S tile pitched roof with heavy landscape shading. South-facing roof presents under 200 s.f. of appropriate surface.
Station 214	3		N-S facing tile pitched roof. Some landscape shading on-site. 3200 s.f. of south facing roof could be suitable for PV. However, S-facing area is street-side and may present aesthetic concerns for neighbors; upper-middle class neighborhood.

Note. Images are not to scale.

Appendix C

Fire Station 206 and Volunteer Center

Fire Station	206	Aerial Image.
Address	815 N. Lindsay Road Mesa, AZ 85213	
Facility Area (s.f.)	17,264	
Est. solar ready roof area (s.f.)	7100	
Roof type	Metal clad, pitched	
Annual Energy Consumption (kWh)	238,160	
Annual electricity cost ($)	22,164.12	
Avg. Elec. Rate ¢/kWh	9.30	
Solar suitability rating (1-5)	4	
Peak kWp A-Si 0° tilt Annual kWh A-Si 0° tilt	47.06 82239.3	
Peak kWp A-Si 18° tilt Annual kWh A-Si 18° tilt	42.03 79576.8	Notes.
Peak kWp P-Si 0° tilt Annual kWh P-Si 0° tilt	71.57 117000.9	
Peak kWp P-Si 18° tilt Annual kWh P-Si 18° tilt	63.62 112975.2	
Peak kWp P-Si single axis Annual kWh P-Si single axis	63.62 149781.6	
Peak kWp M-Si 0° tilt Annual kWh M-Si 0° tilt	94.57 154638	
Peak kWp M-Si 18° tilt Annual kWh M-Si 18° tilt	84.06 149270.4	
Peak kWp M-Si single axis Annual kWh M-Si single axis	84.07 197948	
Notes. Large facility. Two buildings. Fire station has multiple rooflines, Volunteer Center has E-W facing sloped, metal-clad roof. Few penetrations.		

Appendix D

Fire Station 212 and Superstition Patrol Division

Fire Station	212	Image. 
Address	2430 S. Ellsworth Mesa, AZ 85208	
Facility Area (s.f.)	17,818	
Est. solar ready roof area (s.f.)	5400	
Roof type	Flat	
Annual Energy Consumption (kWh)	430,560	
Annual electricity cost ($)	39,654.50	
Avg. Elec. Rate ¢/kWh	9.20	
Solar suitability rating (1-5)	5	
Peak kWp A-Si 0° tilt Annual kWh A-Si 0° tilt	55.28 96138.9	
Peak kWp A-Si 18° tilt Annual kWh A-Si 18° tilt	49.14 93026.4	Aerial Image. 
Peak kWp P-Si 0° tilt Annual kWh P-Si 0° tilt	83.66 136775.7	
Peak kWp P-Si 18° tilt Annual kWh P-Si 18° tilt	74.37 132069.6	
Peak kWp P-Si single axis Annual kWh P-Si single axis	74.37 175096.8	
Peak kWp M-Si 0° tilt Annual kWh M-Si 0° tilt	110.56 180774	
Peak kWp M-Si 18° tilt Annual kWh M-Si 18° tilt	98.27 174499.2	
Peak kWp M-Si single axis Annual kWh M-Si single axis	98.27 231404	
Notes. Large, unobstructed roof area over police patrol division. Very limited shading issues or roof penetrations. Newer facility. Mechanicals concentrated off to the side.		

Appendix E

Fire Station 216

Fire Station	216	Image. 
Address	7966 E. McDowell Rd Mesa, AZ 85207	
Facility Area (s.f.)	9,012	
Est. solar ready roof area (s.f.)	5400	
Roof type	Low-pitch E-W	
Annual Energy Consumption (kWh)	101,640	
Annual electricity cost ($)	9,991.06	
Avg. Elec. Rate ¢/kWh	9.98	
Solar suitability rating (1-5)	4	
Peak kWp A-Si 0° tilt Annual kWh A-Si 0° tilt	23.31 40540.5	
Peak kWp A-Si 18° tilt Annual kWh A-Si 18° tilt	20.72 39228	Aerial Image. 
Peak kWp P-Si 0° tilt Annual kWh P-Si 0° tilt	35.28 57676.5	
Peak kWp P-Si 18° tilt Annual kWh P-Si 18° tilt	31.36 55692	
Peak kWp P-Si single axis Annual kWh P-Si single axis	31.36 73836	
Peak kWp M-Si 0° tilt Annual kWh M-Si 0° tilt	46.62 76230	
Peak kWp M-Si 18° tilt Annual kWh M-Si 18° tilt	41.44 73584	
Peak kWp M-Si single axis Annual kWh M-Si single axis	41.44 97580	
Notes. Low-sloped E_W facing roof (almost flat). Some roof penetrations and four HVAC units along the corners of the apparatus bay roof. Some shading from parapet.		

Appendix F

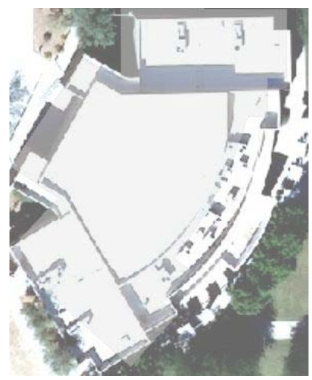
Fire Station 217

<table>
<tr><td>Fire Station</td><td>217</td><td rowspan="10">Image.
</td></tr>
<tr><td>Address</td><td>10434 E. Baseline Rd
Mesa, AZ 85212</td></tr>
<tr><td>Facility Area (s.f.)</td><td>10,284</td></tr>
<tr><td>Est. solar ready roof area (s.f.)</td><td>3000</td></tr>
<tr><td>Roof type</td><td>Flat to low-pitch</td></tr>
<tr><td>Annual Energy Consumption (kWh)</td><td>144,240</td></tr>
<tr><td>Annual electricity cost ($)</td><td>13,821.61</td></tr>
<tr><td>Avg. Elec. Rate ¢/kWh</td><td>9.58</td></tr>
<tr><td>Solar suitability rating (1-5)</td><td>4</td></tr>
<tr><td>Peak kWp A-Si 0^{o} tilt
Annual kWh A-Si 0^{o} tilt</td><td>19.98
34749</td></tr>
<tr><td>Peak kWp A-Si 18^{o} tilt
Annual kWh A-Si 18^{o} tilt</td><td>17.76
33624</td><td rowspan="7">Aerial Image.

</td></tr>
<tr><td>Peak kWp P-Si 0^{o} tilt
Annual kWh P-Si 0^{o} tilt</td><td>30.24
49437</td></tr>
<tr><td>Peak kWp P-Si 18^{o} tilt
Annual kWh P-Si 18^{o} tilt</td><td>26.88
47736</td></tr>
<tr><td>Peak kWp P-Si single axis
Annual kWh P-Si single axis</td><td>26.88
63288</td></tr>
<tr><td>Peak kWp M-Si 0^{o} tilt
Annual kWh M-Si 0^{o} tilt</td><td>39.96
65340</td></tr>
<tr><td>Peak kWp M-Si 18^{o} tilt
Annual kWh M-Si 18^{o} tilt</td><td>35.52
63072</td></tr>
<tr><td>Peak kWp M-Si single axis
Annual kWh M-Si single axis</td><td>35.52
83640</td></tr>
<tr><td colspan="3">Notes. Large flat roof over apparatus bay with some penetrations and HVAC near corners. Slight E-W pitched roof over living quarters. New facility.</td></tr>
</table>

Appendix G

Public Safety Training Facility

Fire Station	Training Academy	Image.
Address	3260 N. 40th St Mesa, AZ 85215	
Facility Area (s.f.)	24,235	
Est. solar ready roof area (s.f.)	5800	
Roof type	Flat	
Annual Energy Consumption (kWh)	518,960	
Annual electricity cost ($)	53,321.16	
Avg. Elec. Rate ¢/kWh	10.28	
Solar suitability rating (1-5)	5	
Peak kWp A-Si 0° tilt Annual kWh A-Si 0° tilt	38.46 67181.4	
Peak kWp A-Si 18° tilt Annual kWh A-Si 18° tilt	34.34 65006.4	Aerial Image. 
Peak kWp P-Si 0° tilt Annual kWh P-Si 0° tilt	58.46 95578.2	
Peak kWp P-Si 18° tilt Annual kWh P-Si 18° tilt	51.97 92289.6	
Peak kWp P-Si single axis Annual kWh P-Si single axis	51.97 122356.8	
Peak kWp M-Si 0° tilt Annual kWh M-Si 0° tilt	77.26 126324	
Peak kWp M-Si 18° tilt Annual kWh M-Si 18° tilt	68.67 121939.2	
Peak kWp M-Si single axis Annual kWh M-Si single axis	68.67 161704	
Notes. 24,235 square feet total over multiple buildings in a campus setting. The auditorium is approximately 15,000 s.f.; which 5800 s.f. of rooftop space is free of rooftop equipment or shading and suitable for PV installation.		