Examining the Growing Renewable Resource Energy Landscape in California's Mojave Desert

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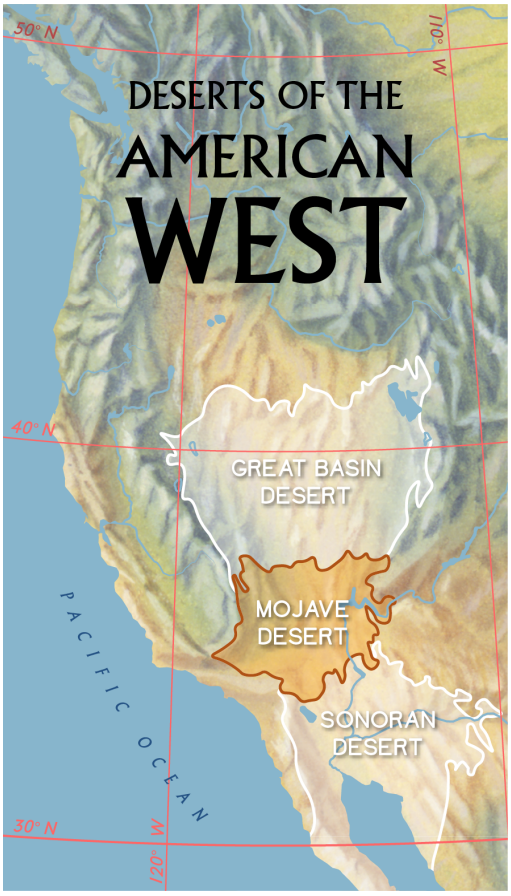
Abstract:
My research and this subsequent project will examine the Mojave Desert as an energy resource landscape, and specifically, discuss the history of the desert and its development as well as the impacts of energy infrastructure on biodiversity, native peoples, the economy, public lands, and water use. A natural history of the area will be given, as well as an explanation of many of the factors that affect the potential energy development of the area. A large component of this project was compiling geospatial data, and the maps produced help to show the infrastructure that exists within the desert as well as some of the conflicts that are going on. In addition to the paper, a poster was created with all of the final maps produced for the project.

Introduction to the Desert:



Physical Geography / Geology:
The Mojave Desert is a rain-shadow desert in the Southwest United States. Most of the topography is classified as mountain-and-basin, with long mountain ranges trending north to south and big deep basins that separate them. The desert sits primarily in Southeastern California but extends into Southern Nevada, Northern Arizona, and a small corner of Southwest Utah; occupying well over 20,000 square miles. The Mojave is bordered by the Great Basin Desert in the North, The Sierra Nevada and Southern California Ranges in the West (including the Tehachapi, San Gabriel, and The San Bernardinos), The Colorado Plateau in the East, and the Sonoran Desert in the South. The Mojave is also defined by the presence of Joshua Trees, an indicator species that is native only to the area.

Climate:
The climate in the Mojave Desert is well known to have some of the most extreme conditions in North America. There is extreme daily temperature variation with record high temps of 137° Fahrenheit (recorded in Death Valley NOAA) in the summers and record lows of -11° in the winter (recorded on Mount Charleston NOAA). Part of this temperature variation is due to the wide range of elevations found in the region, from -280 feet at Death Valley, all the way up to 11,918 feet at Mount Charleston. The area receives very little rainfall, at an average of 2 inches of precipitation a year. Many of the valleys are internally drained, and what little precipitation the area does receive often never makes it to the Pacific. The desert experiences approximately 300 clear days each year. Wind is an incredibly prominent weather feature due to the

consistent rushing of air from the high pressurized Great Basin, towards the Coast, being funneled by the area's many mountain ranges, which results in pockets and valleys of consolidated strong winds. Spring tends to be the windiest season. The consistency of sun and wind in the Mojave is one of the reasons the area has such high potential for harnessing renewable energy resources.

Biota:
While at first glance, the Mojave seems like a dry and desolate region, the area is actually springing with life, and is an incredibly important ecosystem, both in terms of biodiversity and preservation, and the desert is believed to hold over 2,000 species of plants, as well as countless animals, all of which are well adapted to desert living. Some of the native species that the Nature Conservancy is advocating to protect within the Mojave are the Desert Bighorn Sheep, Mountain Lions, Burrowing Owls, Desert Tortoises, Gila Monsters, and Horned Lizards.

Cultural Geography:
Much of the desert is sparsely populated, but there are specific areas, including Las Vegas, St George, and Lancaster, that have become increasingly more urban. Las Vegas specifically, is growing at a rate of over 3% a year and is currently sitting at almost 2.3 million people, with new development sprawling further and further out into the desert, affecting native plants and animal habitat. In Southern California, several large military bases also occupy a large portion of land. With a steadily growing population, in the Mojave, and also in the surrounding metropolitan areas of Southern California, Arizona, and Utah, the energy needs of the area are also increasing.

Natural History of the Mojave:
The Mojave is the smallest desert in North America, but its vastly unique surfaces are intertwined with a vast and complicated history. The oldest known rocks are Precambrian in age, and were formed about 1.8 billion years ago (Walker 2018). From 800 to 300 mya, where the Mojave Desert sits now, was a coastline where sediments accumulated and compacted as sea levels shifted. This was followed by several periods of volcanism, and a series of colliding and subducting faults led to the upheaval of many of the larger mountain ranges we see today. The faults we see today in the Mojave, the San Andres, and Garlock Faults, became active during this time, and are still moving at rates of about 0.5" a year. The compression and release of these faults stretched and thinned the continental crust, and helped to shape the distinct north to south mountain ranges, and long basins interspersed by long basins. During the Jurassic period, large sand dunes occupied much of the desert and were compressed into bright orange Aztec (or Navajo) Sandstone, which is now visible near Red Rocks, just outside of Vegas, or many locations in Utah and the Grand Canyon. Around 20,000 years ago, during the last glacial maximum the climate was much cooler in the Mojave region, water was abundant, with glacial melt and rainwater filling many of the basins with large lakes. During this time, wooly mammoths, sloths, saber-tooth cats, wolves, and even flamingos occupied the Mojave region.

Around 10,000 years ago, the lakes began to dry up, and as climates shifted towards what we know today, dry salinated lake beds were left behind. This is also the time period where the first record of early humans is recorded, and groups of native people living in the area at the time were believed to be mostly nomadic, with some permanently settled farming communities. Many native groups have lived in the desert over time, and while in this paper, only two main groups will be discussed, it is important to note that many others have occupied the area and can for the most part collectively be known as part of the Colorado River Tribes.

The namesake people of the desert, the Mojave Indians, were incredibly well adapted to the environment and had their own systems of mostly sedentary living along the Colorado River and established trade routes with other tribes. The Chemehuevi Indians were more nomadic than the Mojave, consistently moving around to attain the resources needed to survive. In addition to these two tribes, many others also lived or used resources in the area, including the Paiute, Shoshone, Kawaiisu, Vanume, Serrano, and Cahuilla. The Mojave region and the native peoples living within it were essentially left alone until explorers began coming through in the late 1700s. The Gold Rush jump started real development in the Desert and after the Mojave Road was finished, more and more land was taken from native peoples', relationships worsened rapidly. Railroads sprung up in the desert, and many small railroad towns came into fruition along their tracks. Las Vegas and Barstow originally were founded as railroad stops. Grazing animals were allowed to roam free in the desert, and their presence ended up causing fairly permanent damage to many of the plant ecosystems. Because the Mojave is so arid, the recovery after disturbance of plant and animal life is difficult if not impossible. In 1994, Congress passed the California Desert Protection Act and Death Valley, Joshua, Tree, and the Mojave Reserve all became protected nationally managed areas shortly thereafter.

The Mojave as an Energy Resource Landscape:

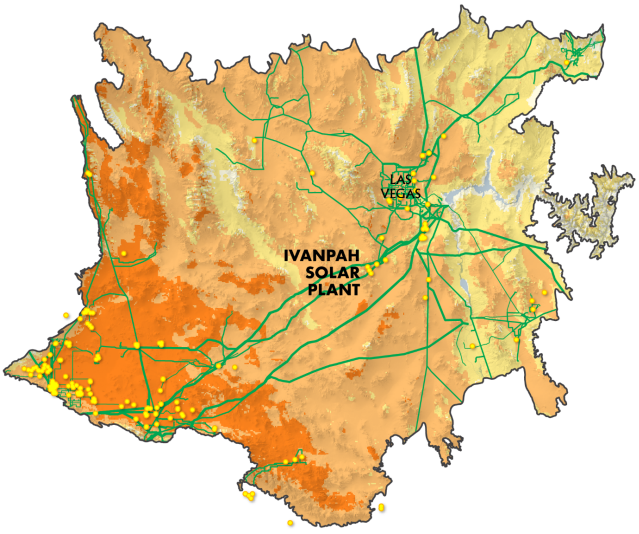
An energy resource landscape is defined by (defined by Bridge et al. pg 16) "The constellation of activities and natural and socio-technical relations through which energy production and/or natural consumption are achieved within a given space."

Major energy infrastructure and development in the Mojave didn't really kick off until large natural gas and oil reserves were found in California's central valley, and the state became a nationwide crude-oil supplier (Tanaka 2020). In 1936, the Hoover Dam was constructed; the hydrology of the Colorado River was forever changed, and hydroelectricity generation began. Large scale renewable energy didn't pop onto the scene until around the 1980's. After the passing of the Public Utilities Regulatory Policy Act in 1978 the country's very first utility scale wind farms popped up in Northern California at Altamont. Not long after Tehachapi, and then San Gorgonio Passes were developed. By 1986 4,200 wind turbines had been installed at San Gorgonio Pass, but the technology was still young and many of them failed within a few years. Most of the original turbines at both of these locations have since been replaced (Gipe 2013). Solar development began in the desert in 2002, following an electricity crisis that cost California billions, and spurred industry-wide change (Chiaro 2017). Since then, solar development has continually increased in the region, with several huge projects being spurred on by updated policy in recent years.

In the year 2000, California only received 11% of it's energy supply from renewable resources, with that percent of the mix growing to 35% by 2018. But the state has big clean energy goals and plans to be using strictly clean energy by 2045 (California Energy Commission). With these ambitious goals comes the need for rapid development of renewable energy facilities, or the acquisition of reliable sources for import. Several regulations have been put into place around planning these goals, including the Renewable Portfolio Standard, which requires retail sellers of electricity to continuously increase the share of renewables in their portfolios (CA PUC Article 16 Section: **399.11 - 399.33**). Internally would require public lands to support up to 8,000 Megawatts of energy demand by 2040, with the potential to be built up to a 27,000 capacity (DRECP Renewables Fact Sheet). For the Mojave, being a seemingly perfect place to develop many of these renewable energy resources, the Desert Renewable Energy Conservation Plan, was written into effect in 2016, as a collaboration by the California Energy Commission, California Department of Fish and Wildlife, the U.S. Bureau of Land Management, and the U.S. Fish and Wildlife Service. According to the BLM, it is a "landscape-level plan that streamlines renewable energy development while conserving unique and valuable desert ecosystems and providing outdoor recreation opportunities" (BLM California DRECP). It focuses on 10.8 million acres of public lands in the California portion of the Mojave Desert and specifically identifies 388,000 acres of development focus areas, that are "areas with high renewable energy potential and transmission access where sensitive ecological and cultural resources impacts can be avoided, minimized, or mitigated" (DRECP Renewable Fact Sheet). Several, big 500 kV transmission lines already run through the desert, but with large scale planned growth, will also come the need for more transmission lines connecting these renewable energy projects to the metropolitan areas that will be using the resource.

Currently, in the Mojave, many huge renewable energy plants exist, including both the world's third-largest wind farm; the United State's largest, (Alta Wind Energy Center), and the world's largest solar thermal plant (Ivanpah Solar Electric Generating System).

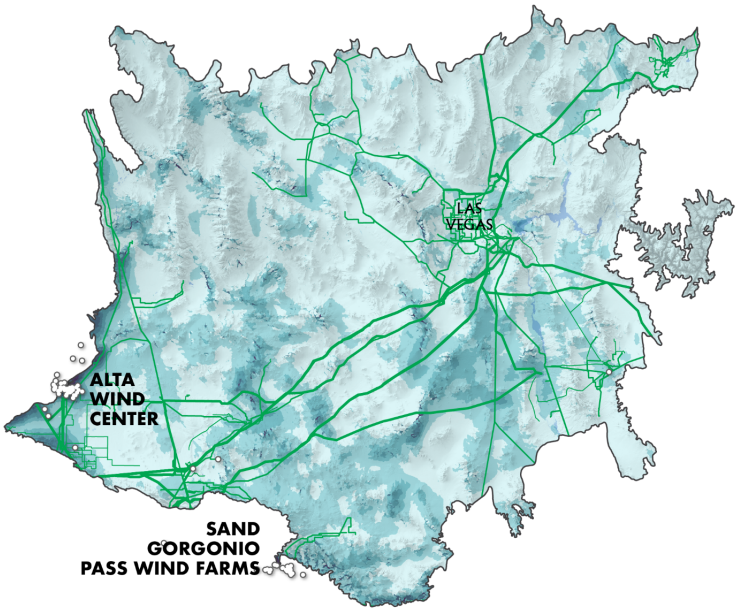
SOLAR RESOURCES



The highest areas of Solar Intensity exist in the Southwest corner of the desert, In Antelope Valley. That being said, in comparison to the rest of the country, the Mojave Region hosts the highest concentration of Photovolatic Energy potential in the United States.

SOLAR PLANT	COMPANY	STATE	AREA (ACRES)	OPERATING CAPACITY (MW)	STATUS	TYPE	YEAR OPENED
Nevada Solar One	Acconia Energy	NV	400	64	operational	CSP Parabolic Tough	2007
Copper Mountain	Sempra Generation	NV	4000	552	operational	PV Flat-panel	2010
Antelope Ranch	Exelon	CA	2100	230	operational	PVFlat-panel	2014
Mojave Solar Project	Abengoa	CA	1765	250	operational	CSP Parabolic Tough	2014
Ivanpah	BrightSourceEnergy	CA	3500	392	operational	CSP Power Tower	2014
Genesis	NextEra	CA	1950	250	operational	CSP Parabolic Trough	2014
Desert Sunlight	NextEra	CA	4084	550	operational	PV Flat-panel	2015
McCoy/Arlington	NextEra	CA	4282	750	operational	PV Flat-panel	2016
Blythe Mesa	NextEra	CA	4318	485	operational	PV Flat-panel	2016
Palen	EDF Renewables	CA	3140	500	under construction	PV Flat-panel	NA
Desert Quartzite	First Solar	CA	3800	450	under construction	PV Flat-panel	NA
IP Athos	Intersect Power	CA	3600	500	under construction	PV Flat-panel	NA
Desert Harvest	EDF Renewables	CA	1412	150	under construction	PV Flat-panel	NA
Crimson Solar	Recurrent	CA	2500	350	proposed	PV Flat-panel	NA
Victory Pass	Clearway Energy Group	CA	2000	200	proposed	PV Flat-panel	NA
Arica	Clearway Energy Group	CA	2000	265	proposed	PV Flat-panel	NA

WIND RESOURCES



Wind resources are primarily located on tight mountain passes where wind is funnelled through mountain topography.

The two primary wind energy farm areas are located at Tehachapi Pass, and San Gorgonio Pass right outside of the Mojave Desert Ecoregion boundary, but still considered part of the area.

WIND PLANT	COMPANY	STATE	AREA (ACRES)	OPERATING CAPACITY (MW)	STATUS	TYPE	YEAR OPENED
San Gorgonio Pass (just_outside the mojave)	Shared Ownership	CA		615	operational	460	1982
Tehachapi Pass	Shared Ownership	CA		1244	operational		1986
Sky River	NextEra	CA		76	operational	342	1994
Pine Tree	LA Dpt. of Water & Power	CA		135	operational	90	2009
Manzana	Avangrid	CA		340	operational	126	2013

The area is a major frontier for big investors in new renewable energy. Google has invested $168 Million into the Ivanpah plant (Meyers, The Guardian), and Amazon announced their investment into purchasing 47 megawatts of energy from wind farms in the Tehachapi Mountains in 2019 (Douglas, CNBC).

In the Mojave, there is a tricky balance between energy development to serve a rapidly growing population, and conservation values of trying to at the same time, maintain biodiversity and preserve natural lands and recreation opportunities. One of the paradoxes of this issue and region, is that production of renewable energy, and conservation, are essentially fighting for the same goal, of a cleaner, and more sustainable planet, while at the same time being in complete opposition, with both values negatively affecting the other when coexisting in the same space. This is one of the more interesting things about the region as an energy resource landscape, and something that is quite often applicable to many other areas where renewable energy is being developed. One of the reasons that this is such a tricky problem, is because, while the goal of renewable energy development has good intentions, oftentimes the companies and stakeholders involved are thinking strictly in terms of profit, and their own margins. The initial goal of why we need to develop renewable energy resources is lost. Inefficient distribution networks, or poorly placed or thought out projects, are often favored in terms of higher profits.

Effect of Development on Biodiversity:

The Mojave Desert is a hotspot for desert biodiversity, thus leading to a significant amount of controversy and opposition around development. While not as biologically distinct as some of the other American deserts, the Mojave has an impressive assortment of distinctive endemic communities, that are put at risk in areas where development is occurring (World Wildlife Organization). A study published in *Diversity*, identified 10 evolutionary hotspot zones within the Mojave desert and concluded that 17% of the total land area for these zones also coincided with renewable energy development areas. They also concluded that transmission corridors were contributing more to this disturbance than the solar and wind sites themselves (Vandergast et al. 2013). Two species that have been studied closely, in correlation to energy development, are the Desert Tortoise, and the California Condor.

The Desert Tortoise; a slow-growing species with a low reproductive rate was placed onto the threatened species list in 1990 (FEIS), they live up to 80 years old, and they are one of the primary concerns of conservationists when it comes to development. In a study done looking at desert tortoises and wind farms in the Sonoran Desert, it was concluded that while new development and habitat destruction leads towards increased mortality rates of the desert tortoise during development, the population can restabilize, and adapt to man-made features in their habitat after development has concluded (Lovich et al 2011). Hina Gupta, proposed some interesting new citing regulation requirements that would help manage the development of renewables while incorporating wildlife concerns to save the Desert Tortoise (Gupta 2014). Many of the wind farm facilities in the Mojave have not been fenced off, and the protected nature of the sites and the relative low impact on vegetation area could actually benefit tortoise recovery, although site operations at the facility could counteract this (Price 2020). During the environmental review for Ivanpah, Fish and Wildlife Services estimated there to be 38 tortoises on the site that would need to be relocated. But when biologists did a sweep in 2009 before construction, there were 173 found, much

higher than the original estimate. Brightsource; the company that owns and operates Ivanpah has spent over 60 million on tortoise research and relocation (Mulvaney 2017).

Avian death from renewable energy plants is also a major environmental concern. Wind turbines have always been known to be a threat to birds, but the more recently popularized style of solar "power towers" comes with a new set of challenges. Instead of a low-lying field of solar panels across a large geographic area, a series of mirrors reflects high-intensity sun to heat a receiver that generates electricity atop the tower. But the problem with this system; which has been especially publicized at Ivanpah, is that the high concentrated heat coming off the mirrors has the ability to incinerate, or vaporize birds in a matter of seconds. The issue is worsened by the fact that the light coming off the central tower is thought to attract an unusually large amount of insects, which in turn, brings more birds in, whose dead carcasses draw in predators. Essentially the whole system acts as a sort of mega trap for the desert community (Phil Taylor, E&E News). A conclusive study has not been done recently, but in the second year of operation, the Ivanpah plant killed over 6,000 birds, more than any other plant has ever reported. In response to the outcry over bird deaths, the Ivanpah developers pointed out how many more birds are being killed by buildings, cars, and house cats.

At the Manzana Plant; Avangrid, the company that owns and operates the wind farm, is investing half a million dollars ahead of time to raise 6 California Condors to maturity. The wind farms on their property have not caused any Condor deaths yet, but the company is taking precautions in case they do put any birds in danger (Casey 2021).

Public Lands Access:

Public lands, and many protected and accessible wilderness areas, are a huge part of what makes the Mojave special. The Desert Renewable Energy Conservation Plan has attempted to address many of the concerns related to both public lands access and ecology, The plan excludes BLM lands that are valuable for public recreation from the development focus areas. But controversy still remains. In the early 2010's a 2,000-acre solar facility (Soda Mountain Solar Plant) was almost approved less than a mile from Mojave National Preserve, threatening recreation values as well as an already threatened Bighorn Sheep population that used the area as a travel corridor (Schmidt 2015). It was concluded that the plant would have led to some fairly serious habitat fragmentation in the area, and protests from several groups eventually shut the project down.

A section of the Pacific Crest Trail, which runs 2,600 miles from Mexico to Canada, crosses a 30-mile waterless stretch of the Mojave Desert in Antelope Valley. When the trail heads back up into the Tehachapi Mountains on the North end of the desert, it crosses through two major wind farm properties, (Manzana and Alta Wind Center) where developers have allowed a public access corridor for hikers traveling through the wind facility sites. 4 miles of the trail run through the Manzana wind farm, and they not only maintain and improve that section of trail, but they also provide a 110-gallon water tank for hikers to use as drinking water. This cooperation between energy developers and the outdoor recreation community in the Mojave is a step in the right direction for everyone and a good example of how energy projects and outdoor recreation can coexist.

Water Use at Solar Plants:
Another major constraint of solar energy in the Mojave that is less publicized is the water consumption used during energy production. A 2013 study published by NREL, found that for every operational hour at solar plants with cooling towers, around 800 gallons of water per MW was being used. This is more water than consumed at most fossil fuel plants and is an especially pressing issue in the Mojave, where water resources are incredibly scarce. Dry cooling systems have been proposed to reduce water use up to 95%, but these systems are expensive, and take a longer time to install. Currently, the Ivanpah and the Genesis Plants in the Mojave use dry cooling systems (Macknick et al. 2011).

Opposition from Native Peoples:
Native peoples' have inhabited, and harnessed the natural resources of the Mojave Desert far longer than anybody else, and did so in an incredibly low impact way. Before railroads, gold miners or any white men came through the desert, the people living on and along the Colorado River lived peaceful lives, without the constant threat of railroads or military bases, or large-scale energy utilities and transmission lines taking control of their land.

Throughout the history of energy development in the Mojave the voices and concerns of native peoples have been largely ignored. Many of these cases are well documented, with protests and opposition coming from native peoples' who are worried about the destruction of native sites and sacred animals. In most cases, Native opposition has been largely ignored by developers. The Chemehuvi people have had a particularly harsh battle with energy over the last century. Their traditional land was declared as public domain in 1853. In 1907 they were relocated to 36,000 acres of reservation land, and their legal status as a tribe was revoked. In 1940, 8000 of these acres were unlawfully flooded in the construction of a new hydroelectric project, the Parker Dam, during the height of the push for hydroelectric energy in the west. This was the first, but not the last time that Chemehuevi People had their native land destroyed for energy development that provided little to no benefit to their community (*History & Culture*, n.d.). The Genesis Solar Project was constructed in 2012 directly on top of a pre-contact trade route that the Colorado River Tribes had utilized for centuries. The developers failed to consult with the tribe until after the project was sited and approved. Construction of the solar plant destroyed burial sites, sacred cultural artifacts, and thousands of years of native history in the area (Krol 2021).

One of the most depressing things about the situation is that the Chemehuevi people, even with all the energy development on their land, live in one of the highest areas of energy poverty in the region. Triple-digit temperatures are common for well over half the year, energy prices are high, and outages are frequent due to high winds and seasonal flooding. In addition to this, the whole reservation is only connected to the electricity grid by a single transmission line. In recent years there has been progress forward for native people (*Chemehuevi Community Center Microgrid - Clean Energy Group*, 2018). The Genesis project ended up sparking a national debate that concluded in the Solar Energy Programmatic Agreement being established. This new legislation requires for developers to consult with native tribes throughout the process of energy planning and construction, as well as better address tribal input and environmental concerns (Krol 2021). The Chemehuevi people were recently given a $2.6 million dollar

grant from California's EPIC Program to build and operate a solar microgrid to operate their community center. While this is a step forward in the right direction, there is still much work that needs to be done to make reparations to Native People in the Mojave, and give them a real voice on energy development on their traditional lands.

Economic Impacts:

There are many positive impacts that have come or will come from renewable energy development in the Mojave. Temporary and permanent jobs brought to small communities is a major positive effect CNBC wrote an interesting article on the town of Tehachapi, and how wind development in the area has brought in many new jobs for local residents, as well as business from outside contractors who are temporarily living in the area (Douglas 2019). The Ivanpah plant alone created 1,000 temporary construction jobs, and about 60 temporary positions. Construction on the Alta Wind Energy Center was reported to provide 3,000 domestic jobs (Power Technology). In addition to the positive economic impact that energy development has had on jobs, the availability of clean energy resources also benefits the cities and regions that the utilities serve. As more solar and wind resources are being developed in the Desert, electricity prices coming from renewables are also dropping for consumers and becoming more affordable for utilities to acquire.

The easier access to clean energy, and the regulations that California has put in place around it, have also incentivized big companies to invest, and make more efforts, in aiding in the development of new renewable resources, and putting money into the industry.

Discussion and Conclusion:

There is no perfect way to manage energy development, and even with renewables, there will always be groups of people or regions that are disproportionately affected when development does occur. Dustin Mulvaney has written some very insightful literature on Solar resources and development in the American Southwest. In a paper published in 2017, he refers to the conflict going on between utility-scale renewable development, and environmental groups as the "Green Civil War". The changing of land use, even drawn out over a long period of time, will inevitably cause conflict and leave certain groups unsatisfied.

In the Mojave Desert, the development of renewables has happened so fast, and at such a large scale, that oftentimes community involvement and feedback from those with different opinions aren't always considered. In addition, management policies and private utilities fighting to develop on public lands does not always lead to the smartest most efficient decisions in the long run.

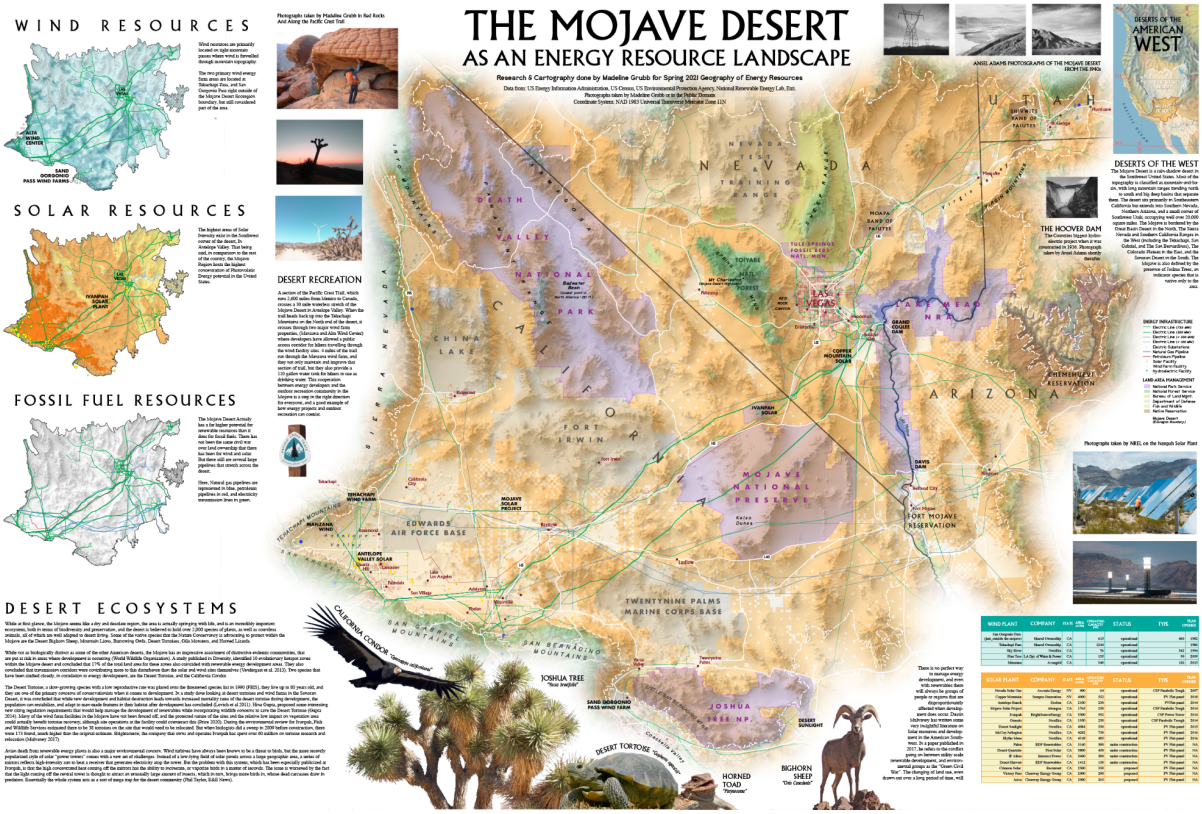
Even though the BLM is sometimes perceived as careless with its development decisions, from 2016 - to 2020, there were 93 renewable energy development applications were denied.

The Nature Conservancy recently proposed a plan that would encourage and streamline the process of renewable construction on "brownfields" or tracts of land that have previously been used for mining and development. These areas already exist in the Mojave, and if companies and government agencies can develop energy in the smartest way possible, on land that has already been degraded, the destruction of

further habitat can be minimized (Nature Conservancy, Solar Energy in the Mojave). A study conducted by the Rocky Mountain Institute found that if the already degraded areas in Nevada (more than one million acres) were used for renewable energy extraction, Nevada could reach its 50% Renewable Portfolio Standard several times over, and entirely power the four largest cities in the state. A formal study has not been done, but the same would likely be true in California. And because many of the mining sites that could be used for energy development also have established infrastructure, this would also minimize the need to build new road networks and transmission lines to support development. The EPA has estimated that there are around 43 million acres of brownfields nationally that could be considered for renewable development (Nature Conservancy, Mining the Sun).

The Mojave Desert is always going to be a special place to many people and creatures, and there are ways that sustainable energy development can occur with minimal impact to these groups. Given the physical properties of the desert that make it so lucrative for energy systems, we need to figure out a better land management system. A way to sustainably and efficiently manage the inevitable renewable energy development that needs to occur there with the least amount of negative impact.

Map Poster of the Energy Infrastructure in the Mojave.



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