APPENDIX F | ECOSYSTEM SERVICES: THE NON-MARKET VALUE OF THE DESERT

Solar development in the California desert clearly will have an impact on the ecosystem but what does this mean from an anthropocentric perspective? Ecosystem processes provide critical services that benefit human existence including regulation of biogeochemical cycles, preservation of genetic diversity, conversion of solar energy to plant material, and even opportunities for spiritual or cultural enrichment. A better understanding of ecosystem service values in the California desert could greatly benefit the renewable energy siting decision-making process. The lack of complete information about ecosystem services and functions, the presence of environmental externalities, and market interventions are all contributing to an economic market failure, which results in continued land conversion and negative impacts on ecosystem services. The costs and benefits of solar development, in the dollar values often associated with land use decisions, are difficult to enumerate because many ecosystem services such as species preservation, habitat conservation, or aesthetics are non-market goods associated with non-use values. A calculation of ecosystem service values in monetary terms may never be absolute but an attempt to calculate their value to society in a common unit, the dollar, can help guide discussions and contribute to building a framework for evaluating the landscape-level impacts of various solar development scenarios.

Whether economic or ethical, systems of valuation exist in order to provide moral or normative frameworks for assigning importance and necessity to beliefs, actions, or objects.[629] Ecosystem services, whether considered from a use or non-use perspective, are public goods that are not typically traded in traditional markets despite the instrumental value they provide for human existence (Table F.1). This leads to the common misconception that services such as nutrient cycling or habitat provision are “free” or non-existent because they do not have a market value. Non-market, or public, goods are particularly vulnerable to degradation from environmental externalities, or indirect impacts of human activities on the environment not accounted for in our market-based economic system, are difficult to quantify outside of a market system. Research that reveals the value of the ecosystem services provided by the desert will give land managers and other stakeholders important new information for decision making.

The decision-making processes for renewable energy development requires new approaches to gathering data and quantifying the value of the ecosystem services in order to legitimately assess the costs and benefits to society. Criteria for evaluating the impact of solar facility siting decisions must include metrics for measuring instrumental values, but such metrics are incredibly difficult to define due to the incomplete, and often subjective, information available. This is an important area for future research because well-defined metrics for measuring the value of ecosystem services based on improved methods of data collection and analysis will improve the process of reaching a land use decision with the greatest net benefit to society.

In order to define or estimate the value of an ecosystem, a process of expressing a value for the goods or services that the ecosystem provides for human use is required. This is a critical distinction. We are not suggesting that future research on ecosystem services should determine the moral or ethical values inherent in habitat conservation or in land development choices, although policy choices must consider both. Rather, we see a need to determine the value of the "beneficial outcomes, for the natural environment or people, which result from ecosystem services."[630] This value is purely anthropocentric in that it measures instrumental value rather than the inherent value. Instrumental value is the difference something makes to the satisfaction of human preferences and is a reflection of how people allocate resources, or dollars, for a good or service.

In addition to the distinction between instrumental and inherent values made above, a second important distinction is that resources such as non-renewable minerals and oil, solar energy, wind, or the atmosphere are not included in these categories. Non-renewable resources such as fossil fuels or minerals sequestered underground certainly have a market value when they are extracted by people but, in their natural state, do not play a role in ecosystem functions. Renewable resources such as wind or solar energy are ubiquitous and have infinite value; the ecosystem functions, which regulate the atmosphere or convert solar energy into food, however, are providing a service that is of instrumental value to society.

Accounting for ecosystem services in dollar terms is controversial due to the difficulty in defining the boundary of the system, collecting data, and in assigning monetary value to environmental externalities. Although several methods for collecting data through surveys, purchase of goods and services, or real estate value exist, they rely on reported values or are otherwise not adequate for understanding the landscape-level values of multiple ecosystem services. This often results in undervaluing the service compared to established market goods and services. Estimating the economic value of ecosystem services is further complicated by uncertainty about how evolving human preferences about the utility of ecosystem services will affect the instrumental value of the ecosystem service at some point in the future.[631] For example, our preference for fossil-fuel based energy resources, is changing due to a better understanding of the risks associated with increased carbon emissions. Similarly, unrestrained land use and development is no longer a part of the American land ethic now that some unique ecosystems and habitats are threatened to the point of extinction. The nature of the conflict surrounding solar development in the California desert is rooted in human preferences and the uncertainty regarding which, habitat conservation or development of renewable energy resources, will be worth more in the future based on actions taken today. Most economic theory operates in the short-term and assumes fixed preferences. But human preferences do change in the long-term, the time frame over which we must consider ecosystem functions. In this sense, the moral and ethical goals of society are important for determining the appropriate time preference and discount rate for valuing ecosystem services in the long-term, which is one of the most controversial issues in developing methods for ecosystem service valuation.

An early attempt to determine the value of the world's ecosystem services estimated the value of 17 ecosystem services for 16 global biomes to be in the range of $16 to 54 trillion per year, or up to three times the global gross national product in 1997.[632] This study has many gaps and likely underestimates true value. The authors state that they could not find any data for desert ecosystem service valuation and attributed a value of $0 per hectare to this biome. Yet, clearly, there are recreational and cultural values among many other services discussed in this report including dust control, biodiversity, aesthetic value, and habitat connectivity. We had difficulty finding studies specifically estimating the value of ecosystem services in desert habitats with two notable exceptions: a 2007 Defenders of Wildlife report titled "Economic Benefits Provided by Natural Lands: Case Study of California's Mojave Desert" and a report published by the Wilderness Society in 2005 titled "The Economic Benefits of California Desert Wildlands: 10 Years Since the California Desert Protection Act of 1994." Although these reports specifically address the ecosystem service values within our study areas, we did not find enough data about ecosystem services to construct a spatial analysis of the impacts of solar development on ecosystem service values in the California desert. To build upon the existing knowledge of ecosystem service values in the California desert, we recommend using the following approaches to future research for this area.

GIS-Based Approaches

Although the availability of data layers for spatial analysis of landscape-level data has increased dramatically in recent years, valuation data about ecosystem services is limited. Environmental economists are working to improve the available data, but usually data are collected as needed for specific projects, which may result in discrepancies between data collection techniques and limitations in transferring values to areas outside the original study. To date, many of the studies applying this approach focus on forests, coastal areas, and climate change modeling. As the approach is applied more broadly and metrics for calculating values of a number of ecosystem services are expanded and standardized, this will be a valuable tool for decision makers in all sectors. As the data availability and connectivity improves, land managers, developers, and elected officials can use GIS models to more rapidly assess impacts under a number of scenarios both at the site level and at the landscape scale.

Early in this study, we imagined developing a cost-benefit analysis tool based on GIS data layers with quantified ecosystem service values. We were inspired by a study published in 2008 which created a semi-automatic modeling tool for valuing the effects of development on ecosystem services in the Swiss Alps.[633] Ultimately, development of a similar tool was beyond the capabilities of our project team.

Although we could not help further ecosystem service research, we believe future research should focus on developing a GIS-based tool that will allow decision makers to input information about a proposed facility's location, technology type, and capacity into an interface that will produce a balance sheet accounting of the project's net present value including ecosystem service values. Assets could include displacement of fossil fuels, number of jobs created, and lower energy costs. Liabilities could include depletion of water resources, impacts on air quality, habitat fragmentation, and loss of recreational space. Each of the line items will need a coefficient that monetizes the disturbance or benefit provided in order to calculate a net present value. The tool should also produce landscape models of the ecosystem service impacts at the site level and at the cumulative level. We realize that using a net present value calculation method to answer questions about the siting decisions does not fully account for ecosystem service values due to the difficulties in monetizing those services. However, this approach provides a framework for discussing the market and non-market values of solar energy development and can be used to enhance the decision-making process by providing an array of modeled scenarios based on a common set of data and calculation methods.

Market-Based Approaches

Payment for ecosystem services originated as a voluntary program in the agricultural sector when farmers were offered compensation from the government for adopting soil-conserving practices. Since the early days of agricultural conservation subsidies, the concept of rewarding landowners for sustainable land use practices has expanded to non-governmental or private investment in water conservation and wildlife stewardship projects around the world. The direct investment in conservation creates an immediate value for projects that protect a variety of ecosystem services. While the services themselves do not need to be measured and accounted for, the projects must be well defined in order to maintain the value of the investments. Spatial data will be an important tool in developing new investment and conservation incentive programs for the California desert. The models of landscape level impacts will create new information about how land use practices at the site level can create conservation value for broad ecosystem functions. Environmental economic research should employ spatial models in making a case for conservation values and conservation payment programs. These models can be used to support proposals for federal and state conservation expenditures and to define appropriate mitigation measures to offset the cost of damage to ecosystem services from solar power development.

Voluntary markets for greenhouse gas emissions trading, renewable energy credits (RECs), and RPS targets also help create a market value for carbon sequestration. While the market price of carbon or the cost of creating a REC may not reflect the true ecosystem service value, it does create a market signal for investors and businesses that generate, offset, or sequester carbon. Environmental benefits associated with solar energy market development arise when solar technologies are used to offset generation from new or existing fossil fuel facilities. For example, NREL estimates that "if 4,000 MW of CSP solar were deployed in the state in order to replace combined cycle natural gas production, carbon dioxide would be reduced annually by 7,600,000 tons."[634] However, disturbance to soil crusts in the desert reduces the ecosystem's carbon sequestration function and the lifecycle energy use of the materials required to build a solar facility contributes to carbon emissions. Conservation advocates and renewable energy developers should work with regulators and lawmakers to make sure the measurements for tracking carbon offsets and renewable energy credits account for land use disturbance as well as lifecycle assessments of material production for solar equipment and project development.

Table 1 Methods for Measuring Economic Value of Ecosystem Services.

Function	Ecosystem processes and components	Goods and Services (examples)
Regulation Functions	Maintenance of essential ecological processes and life support systems	
Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO_2/O_2 balance, ozone layer, etc.)	UVb protection by O_3 prevents disease Maintenance of good air quality Influence on climate
Climate Regulation	Influence of land cover and biologically mediated process on climate	Maintenance of a favorable climate (temperature, precipitation, etc.) for human habitat, health, and cultivation
Disturbance Prevention	Influence of ecosystem structure on dampening environmental disturbances	Storm protection by coral reefs Flood prevention by wetlands and forests
Water Regulation	Role of land cover in regulating runoff and river discharge	Drainage and natural irrigation Commerce and transportation
Water Supply	Filtering, retention, and storage of fresh water	Provision of water for consumptive use
Soil Formation	Weathering of rock, accumulation of organic matter	Maintenance of productivity on arable land

Soil Retention	Role of vegetation root matrix and soil biota in soil retention	Maintenance of arable land Prevention of damage from erosion and siltation
Nutrient Regulation	Role of biota in storage and recycling of nutrients	Maintenance of healthy soils and productive ecosystems
Waste Treatment	Role of vegetation and biota in removal or breakdown of xeric nutrients and compounds	Pollution control and detoxification Filtering of dust particles Abatement of noise pollution
Pollination	Role of biota in movement of floral gametes	Pollination of wild plant species Pollination of crops
Biological control	Population control through trophic-dynamic relations	Control of pests and diseases Reduction of herbivory (crop damage)
Habitat Functions		Maintenance of biological and genetic diversity
Refugium Function	Suitable living space for wild plants and animals	Maintenance of commercially-harvested species
Nursery function	Suitable reproduction habitat	Maintenance of commercially-harvested species
Production Functions	Provision of natural resources	
Food	Conversion of solar energy into edible plants and animals	Hunting, gathering of fish, game, fruits, etc. Small-scale subsistence farming and aquiculture
Raw Materials	Conversion of solar energy into biomass for human construction and other uses	Building and manufacturing Fuel and energy (fuel wood, organic matter Fodder and fertilizer
Genetic Resources	Genetic material and evolution in wild plants and animals	Improve crop resistance to pathogens and pests
Medicinal Resources	Variety in biochemical substances in, and other medicinal uses for, natural biota	Health care, drugs and pharmaceuticals Chemical models and tools Test organisms

Ornamental resources	Variety of biota in natural ecosystems with potential ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration, and souvenirs
Information Functions	Providing opportunities for cognitive development	
Aesthetic Information	Attractive landscape features	Enjoyment of scenery
Recreation	Variety in landscapes with potential recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
Cultural and Artistic	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architecture, advertizing, etc.
Spiritual and Historic	Variety in natural features with spiritual and historical value	Use of nature for religious of historic purposes (heritage value)
Science and Education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research