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Solar resource-reserve classification and flow-based economic analysis

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Abstract

A framework is defined for the flow-based analysis of the solar resource by adapting established mineral economic methods, categorizing the joint degree of uncertainty for the solar resource and the degree of economic risk of project development. Solar energy is expressed as a raw energy commodity (an identified resource). Subsequent classification of the identified resource reflects the degrees of confidence in the meteorological data (measured, indicated, and inferred classes). The reserve base at the locale in question is then assessed for the economic viability for potential to be converted into a diversity of useful goods and services. Two example cases are examined for Andhra Pradesh, southern India. The solar resource-reserve system has been applied to a common product of electricity derived from photovoltaic (PV) technologies here, but the method is sufficiently broad to encompass economic utility derived from any conversion of a flow-based resource. This dynamic classification and analysis method establishes a foundation for communicating the confidence in project development from solar energy conversion, constrained not only by the confidence in the data describing the solar resource, but also in accordance with the technoeconomic feasibility for available conversion technologies, and the elasticity of demand for the solar commodity identified by investor/developers. The resource-reserve framework provides a foundation for solar resource economics; upon which individuals, firms, government agencies, and investors can make rationalized decisions on the allocation of the solar resource for high solar utility.

Keywords: Solar energy; Flow-based; Mineral economics; Commodity

1. Introduction

Energy economics is emerging within the broad field of solar energy conversion, primarily associated with energy products such as heat and electric power, each highly substitutable commodities demanded in society. Solar systems design is linked with the surrounding environment (ecosystems services, meteorology, microclimate) as well as with any social constraints of the client (Brownson, 2013). The dynamic environment–society relationship in sustainable energy drives solutions to be case-dependent, particularly for flow-based resources such as light from the Sun. In order to make more use of the Sun (marginally), we require skill to measure, understand, and communicate the scale and the variability of solar irradiance, where time and space are coupled (Rayl et al.; Brownson, 2013).

For solar energy, our raw mineral “resource” is the photon. Solar design and development teams put forth technologies and skilled effort to first explore for energy, then deploy technologies to convert the available photons into a diversity of marketable goods. The task of the emerging generation of entrepreneurial solar designers is to strengthen and expand a business model of sustainable energy exploration and environmental technology deployment. This raises questions about how we estimate and

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communicate the effective size of the solar resource within a given locale, as well as communicating the technoeconomic feasibility of project success to investors, developers, and policy makers, given a real demand for a substitute to purchased fuels for electricity, heat, light, or even food.

This paper defines the process of flow-based solar economics founded on the client-specific and locale-specific constraints. The question arises, why would one even need an economic foundation when a fiscal approach for economic feasibility for the electricity products from solar power farms is rapidly becoming commonplace for developers, financiers, and banks? In answer, project finance is built upon a simplified portion of energy economics (Life Cycle Cost Analysis, time value of money, metrics of evaluation, etc.), but the risk embedded within the financial data does not fully encompass the scope of limitations in the quality of information, or the degree of uncertainty, regarding the resource itself. In essence, the uncertainty of the applied resource data is typically not classified in project finance, joint with the risk of financial development and economic viability. Due to the increasing rate of expansion of national and international solar projects, practical methods are emerging to define the criteria for solar resource risk and *bankable* data as superior measurable data (McMahan et al., 2013; Vignola et al., 2013). However, the two topics: *economic risk* and *uncertainty in the measurable data*, are typically treated as distinct entities, where the focus of financial analyses are shifted from the flow of the solar *resource* (per the established field of mineral economics) to the *products of solar conversion* (U.S. Bureau of Mines, 1980).

We propose a methodological shift of measuring and classifying that which we value in the renewable energy industries: the viability of accessing and converting the flow of a variable and locale-specific resource into *any* diverse solar good or service found to have high *solar utility* to society or a group of stakeholders. Here, economic *utility* refers to client preference within a set of goods and services, and *solar utility* refers to the set of goods/services that originate from the solar resource, rather than a non-solar good/service (Brownson, 2013). While examples of analysis for the products of energy resource conversion are essential parts of systems design, here we have chosen to focus on the flow of the solar resource as the commodity of interest.

For commodities, the amount of the good or service accessible is dependent on the economic viability of that good or service (Brownson, 2013). Light from the Sun, with the potential to be converted into useful forms, is a commodity: it can be marketed as a good or a service to satisfy the needs and wants of individuals and society. And as with any commodity, the value of light varies with the demand for light technologies as a good or service and the costs of alternatives. This of course indicates that the value of an unconverted photon is a variable quantity. The technology to convert a photon to a useful form is also a commodity with some variable value.

Here, the language of mineral resource commodity assessment is adapted as a flow-based analysis from existing language used in mineral economics, well known to the traditional energy industry. This method addresses the valuation criteria and thresholds for decision-making in solar resource development when one is provided the option to make use of the flow of photons from the Sun. We consider the photon or the flux of photons (irradiance, in W/m^2) as a mineral commodity, just as traditional geofuels (the class of geologically derived fuels, including fissile materials; e.g. coal, petroleum, natural gas, gas hydrates, U, and Pu nuclides) have been considered mineral commodities in traditional resource assessment (Brownson, 2013).

1.1. Concept: light as commodity

First, we explain the shift from stock-based resource assessment (common to mineral economics) to flow-based resource assessment. In considering “collection” of light for use in society and the environment, we observe that photons can be harvested via a solar energy conversion device, e.g. a photovoltaic technology. However, photons are not actually *extracted* as geofuels are, then stored or collected like fuel in a tank, like a stock. Rather, light is *converted* from radiant energy form to another energy form with proper technologies. Once absorbed, the photon is lost, converted into a new form of energy. From a systems dynamics perspective of stocks and flows, a flow is a rate of exchange with a stock, which can diminish stocks through outflows, build up stocks via inflows, or flows can be converted as they pass (Meadows, 2008). In comparing energy sources, renewable resources are stock-abundant (the Sun is effectively a limitless stock) but flow-limited, while non-renewable resources are stock-limited while being flow-abundant. The term of a “reserve” can first be thought of as a type of economically accessible stock within a larger stock—the physically limited reservoir in the Earth’s crust (Daly and Farley, 2011). This is the traditional view for geofuels and other mineral commodities. In turn though, with sufficiently large scales, the economic analysis of flow-based systems (e.g. products derived from solar irradiance) will benefit from an analogous flow-based economic classification approach. For example, a flow-based economic classification approach specifies the confidence in our knowledge of risk as defined by the full probability distribution of irradiation with respect to the time intervals of import (e.g. subhourly distributions that are non-normal, defined by climate regime/seasons, and locale-specific). Hence, the term of a reserve can also be considered as an economically accessible flow within a larger flow—the physically limited flow of light from the Sun.

The “quantity” of accessible light for a solar energy conversion system (SECS) is variable, but it depends on more than just the annual irradiation in a given locale. It also depends on the economic viability of the technologies to convert a photon into a useful form of energy for the client.