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Entropy, pumped-storage and energy system finance

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Pumped-storage holds a key role for integrating renewable energy units with non-renewable fuel plants into large-scale energy systems of electricity output. An emerging issue is the development of financial engineering models with physical basis to systematically fund energy system efficiency improvements across its operation. A fundamental physically-based economic concept is the Scarcity Rent; which concerns the pricing of a natural resource's scarcity. Specifically, the scarcity rent comprises a fraction of a depleting resource's full price and accumulates to fund its more efficient future use. In an integrated energy system, scarcity rents derive from various resources and can be deposited to a pooled fund to finance the energy system's overall efficiency increase; allowing it to benefit from economies of scale. With pumped-storage incorporated to the system, water upgrades to a hub resource, in which the scarcity rents of all connected energy sources are denominated to. However, as available water for electricity generation or storage is also limited, a scarcity rent upon it is also imposed. It is suggested that scarcity rent generation is reducible to three (3) main factors, incorporating uncertainty: (1) water's natural renewability, (2) the energy system's intermittent components and (3) base-load prediction deviations from actual loads. For that purpose, the concept of entropy is used in order to measure the energy system's overall uncertainty; hence pumped-storage intensity requirements and generated water scarcity rents.

Keywords: pumped-storage, integration, energy systems, financial engineering, physical basis, Scarcity Rent, pooled fund, economies of scale, hub resource, uncertainty, entropy

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