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Optimizing Sustainable Geothermal Heat Extraction

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Geothermal heat, though renewable, can be depleted over time if the rate of heat extraction exceeds the natural rate of renewal. As such, the sustainability of a geothermal resource is typically viewed as preserving the energy of the reservoir by weighing heat extraction against renewability. But heat that is extracted from a geothermal reservoir is used to provide a service to society and an economic gain to the provider of that service. For heat extraction used for market commodities, sustainability entails balancing the rate at which the reservoir temperature renews with the rate at which heat is extracted and converted into economic profit. We present a model for managing geothermal resources that combines simulations of geothermal reservoir performance with natural resource economics in order to develop optimal heat mining strategies. Similar optimal control approaches have been developed for managing other renewable resources, like fisheries and forests. We used the Non-isothermal Unsaturated-saturated Flow and Transport (NUFT) model to simulate the performance of a sedimentary geothermal reservoir under a variety of geologic and operational situations. The results of NUFT are integrated into the optimization model to determine the extraction path over time that maximizes the net present profit given the performance of the geothermal resource. Results suggest that the discount rate that is used to calculate the net present value of economic gain is a major determinant of the optimal extraction path, particularly for shallower and cooler reservoirs, where the regeneration of energy due to the natural geothermal heat flux is a smaller percentage of the amount of energy that is extracted from the reservoir.