



Comparisons of Energy Efficiency for Evolved and Human Designed Systems

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Metabolic pathways for individual organisms and groups of organisms have evolved through natural selection for as much as 3 billion years. Thus, it may seem that the evolved biotic systems for capture and use of energy must approach the upper thresholds of efficiency with reference only to thermodynamic constraints. Nevertheless, information on energy efficiencies in nature shows surprisingly low efficiency for many processes. For example, natural photosynthesis typically has efficiencies well below 1% in nature, and efficiency of energy use by consumer organisms in creation of new biomass typically is no greater than 40%. Even under artificially optimized conditions, natural processes are below the thresholds that are targets for renewable energy technologies.

For individual organisms, which are the direct products of natural selection, explanation of surprisingly low energy efficiencies is in part an outcome of the diversity of selective forces that affect an organism: optimization occurs through natural selection, but optimization is not focused exclusively on energy efficiency. At higher levels of organization, including populations, communities, and ecosystems, the association between selection pressure and a specific function, such as energy efficiency, is even more indirect than it is for individuals. Multispecific combinations of organisms that are subject to distinctive evolutionary selection pressures show inefficiencies that are caused by interspecific interactions, including especially competition and predation.

Spatial dispersion of energy consuming processes offers explanations of inefficiencies that are common to both evolved and designed energy systems, thus leading to more valid comparisons and some narrowing of gaps between energy efficiency in evolved and designed systems. Also, evolved and designed systems may become progressively more similar through increasing human tendencies to assign values other than cost per unit energy to specific modes of energy production. Multivariate valuation systems lead to discounts on energy efficiency similar to the ones that appear through natural selection, which simultaneously optimizes multiple factors, only one of which is energy efficiency.

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