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Dynamic Exergy Analysis for the Built Environment: Fixed or Variable Reference State

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Abstract : Exergy analysis successfully helps optimizing processes in various sectors. In the built environment, a second-law approach can enhance potential interactions between constructions and their surrounding environment and minimise fossil fuel requirements. Despite the research done in this field in the last decades, practical applications are hard to encounter, and few integrated exergy simulators are available for building designers. Undoubtedly, an obstacle for the diffusion of exergy methods is the strong dependency of results on the definition of its 'reference state', a highly controversial issue. Since exergy is the combination of energy and entropy by means of a reference state (also called "reference environment", or "dead state"), the reference choice is crucial. Compared to other classical applications, buildings present two challenging elements: They operate very near to the reference state, which means that small variations have relevant impacts, and their behaviour is dynamical in nature. Not surprisingly then, the reference state definition for the built environment is still debated, especially in the case of dynamic assessments. Among the several characteristics that need to be defined, a crucial decision for a dynamic analysis is between a fixed reference environment (constant in time) and a variable state, which fluctuations follow the local climate. Even if the latter selection is prevailing in research, and recommended by recent and widely-diffused guidelines, the fixed reference has been analytically demonstrated as the only choice which defines exergy as a proper function of the state in a fluctuating environment. This study investigates the impact of that crucial choice: Fixed or variable reference. The basic element of the building energy chain, the envelope, is chosen as the object of investigation as common to any building analysis. Exergy fluctuations in the building envelope of a case study (a typical house located in a Mediterranean climate) are confronted for each time-step of a significant summer day, when the building behaviour is highly dynamical. Exergy efficiencies and fluxes are not familiar numbers, and thus, the more easy-to-imagine concept of exergy storage is used to summarize the results. Trends obtained with a fixed and a variable reference (outside air) are compared, and their meaning is discussed under the light of the underpinning dynamical energy analysis. As a conclusion, a fixed reference state is considered the best choice for dynamic exergy analysis. Even if the fixed reference is generally only contemplated as a simpler selection, and the variable state is often stated as more accurate without explicit justifications, the analytical considerations supporting the adoption of a fixed reference are confirmed by the usefulness and clarity of interpretation of its results. Further discussion is needed to address the conflict between the evidence supporting a fixed reference state and the wide adoption of a fluctuating one. A more robust theoretical framework, including selection criteria of the reference state for dynamical simulations, could push the development of integrated dynamic tools and thus spread exergy analysis for the built environment across the common practice.

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