

**Author Response to Manuscript “Diurnal land surface energy balance partitioning estimated from the thermodynamic limit of a cold heat engine” by Kleidon and Renner**

Dear Editor:

We would like to submit our revised manuscript to Earth System Dynamics. In the revision, we addressed the main points raised by the reviewers along the lines described in our response in the discussion forum (apart from a few, minor cosmetic changes). In the submitted manuscript, we highlighted the modified text passages in blue, so that they are easy to identify.

The points raised by the reviewers were dealt with as follows:

**1. Better motivation/explanation for the term “cold heat engine” (response to Reviewer 1 Comment 1 and Reviewer 2 Comment 1)**

We explain our motivation for referring to the limit derived in the manuscript as the limit of a cold heat engine in greater detail and made it clearer that this is a new term, and not an established term. We changed part of the abstract to clarify this, and added text at the end of page 2 in the introduction (using the explanation from the discussion forum) and at the end of Section 2.1 on page 6.

We also included Reviewer 1’s point that despite the difference between where the heat storage change is located, the power output of the heat engine is the same (page 7, line 24).

**2. Confirm derived power with data (Reviewer 1 Comment 2)**

We included this point as a possibility for future research in the discussion section (page 11, line 24-26).

**3. Emphasize utility of Eq. 2 (Reviewer 1 Comment 3)**

We followed Reviewer 1’s suggestion and emphasised more the utility of the simple estimate for turbulent heat fluxes. To do so, we first numbered the two approximations (Eq. 8 and 9 on page 7) and describe the constant offset, as described by the reviewer. In the discussion section, we also refer to the utility of this estimate (page 11, line 16-17).

**4. Restriction of applicability of the approach for values  $R_s < R_{s,avg}/2$  (Reviewer 1 Comment 4)**

During the revision, we actually noticed that the argumentation of the reviewer was not quite correct. The expression for power does not turn negative for  $R_s < R_{s,avg}/2$ , but the power always stays fixed at a value of  $R_{s,avg}/2$ . It is thus not a physically implausible case, and so we decided to not change the text in the manuscript. (That the approach likely does not apply during nighttime conditions due to stability (and lack of heating) is already discussed in the discussion section).

5. **Fix text (Reviewer 1 Comment 5) — Done**

6. **Explain blue boxes in Figure 2 (Reviewer 1 Comment 6) — Done**

7. **Enlarge Figure 3 for visibility (Reviewer 1 Comment 7) — Done**

8. **Setup of heat engine shown in Figure 1 (Reviewer 2 Comment 2)**

We modified Figure 1 so that the heat flux  $J_{out}$  does not go into the free atmosphere, but rather into the radiative-convective layer.

9. **Improved description of entropy budget (Reviewer 2 Comment 3)**

We extended the description of the entropy budget (Eq. 2) in Section 2.1 (page 5, lines 12 - 19) to address this point.

10. **Difference between  $J_{in}$  in Eq. 1 and  $J_{opt}$  (Reviewer 2 Comment 4)**

As described in our reply in the discussion forum, this apparent difference is due to a somewhat altered atmospheric energy budget (and thus an altered formulation of the first law) that needs to account for  $RI_{net}$ . We renamed the heat storage change inside the engine to  $dU_e/dt$  in Sect. 2.1 and added an Appendix in which we describe that the limit derived in Sect. 2.1 still applies when the net exchange of longwave radiation between the surface and the atmosphere is added in the derivation. We also included  $dU_e/dt$  in Table 1.

11. **Calculate difference between  $J_{opt}$  and  $J_{in}$  (Reviewer 2 Comment 5)**

As described in our response, there is no difference between these two expressions (related to the term  $RI_{net}$ , related to Comment 4 of Reviewer 2). We hence did not change the manuscript.

12. **Improved explanation of Figure 2a regarding the shape of storage changes (Reviewer 2 Comment 6)**

We added a reference to Figure 2A in Sect. 3 and added a brief explanation of the profiles in the caption of Figure 2.

With these modifications, we hope that we addressed all points raised by the reviewers in a satisfactory way.

Best regards,

Axel Kleidon  
on behalf of the authors