

Part	Comment #	Comment	Authors' response
1	1	The budget constraint (4) would be easier to understand if it stuck to “primitives” – total income must equal the costs of buying the device and of disposing of it (both multiplied by annuitisation factors), of (non-energy) operation and maintenance, the amount spent on all other goods and services (perhaps with no explicit price needed, since it's normalised to 1) and the cost of energy bought for the device. But that energy cost should be written as the amount of energy service consumed, divided by the	Equation (4) is stated in terms of costs only, which, as we explain fully in the response to Comment 3, we desire to leave in cost terms only, for simplicity. We implemented this helpful suggestion in Equation (5). Thank you for this suggestion.
1	2	There's no need for the initial budget constraint to contain the “savings” $N$ (which is zero, anyway)	Thanks for this comment. We deleted the net savings term from Equation 4.
1	3	creating new versions of your cost variable $C$ , each with another subscript to be memorised, just raises the cognitive load	<p>Thanks for this comment. Respectfully, it is our opinion that using <math>C_{\dot{}}</math> consistently for all cost rates reduces cognitive load. The reader knows that all <math>C_{\dot{}}</math> values are cost rates, and the subscript indicates which cost is represented by a particular variable.</p> <p>Specifically, in the beginning of this paper Equation 4 provides the budget constraint exclusively in terms of cost rates. Equation 5 following provides further explication of those cost rates by substituting for each cost rate.</p>
1	4	<p>I'd strongly recommend using <math>G</math> for the quantity of other goods and services, just to reduce the number of <math>C</math>-subscript variables the reader has to keep track of. I realise that you assign that letter to a different concept towards the end of the paper, but equation 36 relies on a very odd assumption in any case – surely any reduction in energy prices would overwhelmingly affect energy consumption!</p> <p>I've also now spotted the use of <math>G</math> in section 2.5.3, but I don't think it's actually giving you anything important in understanding the derivation.</p>	<p>Thanks for this comment. As discussed below, we converted subscript “o” (other goods and services) to lowercase “g” everywhere.</p> <p>An aside: We believe that freed cash (<math>G_{\dot{}}</math>, Section 2.5.3) is a very important concept. Freed cash respent in the economy is the source of indirect rebound.</p>

1	5	Five appendices is more than enough for most papers, and so I'd drop appendix F and just leave it as a topic for further research.	<p>Thanks for this comment.</p> <p>We respectfully note that the reviewer said the following in the first round of reviews: "I think the authors need to think about the effects of reducing the demand for energy on its price in a world where supply is not perfectly elastic. That effect is likely to be much more direct, and hence easier to measure, than the indirect and longer-term effects of greater energy productivity or real-terms consumer spending. A partial equilibrium model of the energy sector ought to be sufficient to capture the size of such price changes, which can then be fed into the rest of the analysis."</p> <p>In response to this helpful comment, we developed and analyzed the energy price rebound effect as detailed in Appendix F of Part I and in Section 4.5 of Part II. Those sections demonstrate the utility and extensibility of the framework elucidated in the two papers.</p> <p>We were grateful for the insightful first-round comment from the reviewer and respectfully prefer to retain Appendix F of Part I and Section 4.5 of Part II in the papers.</p>
1	6	Engineers may like dots to denote a flow, but economists often use lower case letters, with capitals for stocks.	<p>Thanks for this comment.</p> <p>We acknowledge that the overdot notation may be unfamiliar for economists. However, the goal of this paper is to bridge disciplines, and the chosen nomenclature will necessarily have unfamiliar elements to both disciplines.</p> <p>To be clear, there are already many aspects of the nomenclature in these papers that are unusual for engineers [G (usually a flux), I (usually mass moment of inertia), p (usually pressure), Re (usually Reynolds number), S (usually surface area), u (usually internal energy), etc.]. So these papers are equal-opportunity offenders.</p> <p>Furthermore, economists are already inconsistent in their use of uppercase and lowercase characters: u or U for utility, I or L for labor, etc.</p> <p>In response to this comment, we added the following sentence to footnote 4: "As the goal of this paper is to bridge disciplines, the nomenclature will necessarily have unfamiliar elements to each discipline involved."</p>

1	7	Annuity factors preceding a capital cost would be lower case. Is that convention clearer? It may be more familiar to your readers.	Thanks for this comment. We have replaced the uppercase R values with the lowercase Greek letter tau everywhere. We chose tau, because it has a connotation of "t" for time. We did not choose $R \rightarrow r$ due to conflict with r meaning interest rate in the papers.
1	8	Please be very careful to ensure that you define every term before it is first used in an equation – I don't think you do so before using $q_{sub O}$ and $p_{sub O}$ in equation 5.	Thanks for this helpful comment. All terms are defined before Equation (5) now.
1	9	Using $p_{sub G}$ alongside G (or g) will reduce the risk that readers start thinking that your current "sub O" variables refer to the original values of energy service consumption and its price.	Thanks for this comment. We have replaced the subscript "o" with subscript "g" everywhere in both papers.
1	10	Where parameters only change once in your analysis, why not just have the original value and a changed rate (perhaps superscripts "o" and "*" or a prime marking)?	<p>The reviewer is correct that parameters change only once. But it matters <b>when</b> the change occurs with reference to Figure 1. Furthermore, different parameters change at different places, as shown in Table B.1. It is our belief that it would create confusion for the reader if the same decoration applied at different stages of Figure 1. Indeed, a goal of this paper is to be very precise when describing rebound effects to, as we say, bring clarity to the field.</p> <p>This comment prompted us to review our nomenclature, and we noted that we were creating confusion with the nomenclature around efficiency (<math>\eta</math>). In particular, we use <math>\eta_{\text{tilde}}</math> for <math>\eta_{\text{star}}</math>, <math>\eta_{\text{hat}}</math>, and <math>\eta_{\text{bar}}</math>. We defended this decision in Footnote 9, citing consistency with Borenstein (2015). However, looking at this again, we realize that decision could create confusion for the reader of the kind we are trying so hard to avoid! So in response to this comment, we now use specific efficiency (<math>\eta</math>) terms in the framework throughout both papers. Furthermore, we deleted footnote 9 in Part I.</p> <p>We are grateful for this insightful comment.</p>
1	11	And if they [parameters] don't change at all (income and the price of energy), you don't need any superscripts.	<p>Thank you for this helpful comment. Table B.1 shows that the following parameters never change: income (<math>M_{\text{dot}}</math>), the price of other goods (<math>p_o</math>, now <math>p_g</math>), and the price of energy (<math>p_E</math>). That said, we allow <math>p_E</math> to vary via the energy price effect.</p> <p>In response to this comment, we removed all decorations from <math>M_{\text{dot}}</math>, <math>C_{\text{dot}_o}</math>, and <math>p_o</math> (now <math>C_{\text{dot}_g}</math> and <math>p_g</math>).</p>

1	12	<p>You might get a nice result if you introduced the Compensating Variation into the analysis of your income effect – I think that the “net savings” that are going to create this effect are going to be equal to the monetary value of the initial emplaced energy saving, less the increase in the cost of owning and operating the device (or plus any saving), plus the Compensating Variation for the “price” change of the energy service, which is linked to the two substitution effects you’ve just calculated. Indeed, you show this Compensating Variation in the expenditure diagrams (figures 3 and 6) of Part II.</p>	<p>Thank you for this comment. Indeed, the compensating variation is defined as <math>N_{\dot{hat}} - N_{\dot{star}}</math>. To make this clearer we have added the following line to the financial analysis of the substitution effect "The difference <math>N_{\dot{star}} - N_{\dot{hat}}</math> is the compensating variation from microeconomic analysis that allows the consumer to reach the pre-price change utility after a price change. It is negative as the energy service prices declines."</p>
1	13	<p>I’m not sure what the convention on discounting in studies looking at energy savings and embodied energy – if you wanted to use your numbers to get a cost per MJ actually saved, it would be essential to discount everything, for consistency. It could also be argued that emissions in the near term are worse than those occurring later, since they will be in the atmosphere for more of the period most relevant to those currently alive. (The counter-argument that the carbon per unit of energy may fall over time is probably too speculative for more than a footnote.) It’s a bit odd to discount decommissioning costs but to ignore the issue for the initial purchase of the device.</p>	<p>Thank you for this perspicuous comment. It is a very interesting idea that carbon emissions could be discounted as later emissions are less bad thanks to arriving there later (and perhaps being subject to better abatement technology). We have added a footnote to that effect that says:</p> <p>"We are only discounting monetary magnitudes to reflect the time value of money. We thank an anonymous reviewer for the insight that, in principle, the carbon content of energy could also be discounted, as near term emissions are worse than later emissions."</p> <p>We strongly agree that the initial capital cost must be discounted and do so, using the letter <math>\tau_{\alpha}</math> in equation 5.</p>

1	14	<p>I don't think you need the parts of the appendix that prove that the annuity factor is one over the device lifetime when the interest rate is zero – that's a standard result in economics, and entirely intuitive (since the annuity factor combines depreciation and the return on outstanding capital, and a zero interest rate gives no return on capital).</p>	<p>Thanks for this comment. Perhaps it is interesting to know how these derivations came about. When the reviewer suggested that we include discount rates for money, we searched the literature and found a paper that purported to account for time value of money with an annuity factor. The equation was clearly incorrect. So we (economist and energy analysts) had to derive these factors ourselves. Given that other papers in this space have done this calculation incorrectly, we needed to prove our approach to ourselves before we introduced our approach in the paper. Thus, we believe there is value in including these proofs in an appendix.</p> <p>Also, we point out that our papers have two stated audiences, economists and energy analysts. Parts of the papers will seem obvious to energy analysts. Other parts of the papers will be obvious to economists. Our stated goal is to write papers that bridges disciplines. A way to achieve that goal is to provide derivations and further additional details in appendices for consultation by both energy analysts and economists. Thus, there may be more appendices than typically seen in such papers, but this owes to the need to serve and join two research communities.</p> <p>This point has reinforced the importance of highlighting our objectives. In response, we which you added a new footnote in Section 1.4 of Part I: "This objective may mean that some aspects of the development of the framework will seem obvious to energy analysts while other aspects will seem obvious to economists."</p>
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1	15	The assumption that device installation will be spread evenly over time ignores the well-known S-curve pattern with which most innovations are adopted.	<p>Thank you for this insightful comment. We agree with the reviewer that in the aggregate, technology adoption usually follows a logistic (or s) curve. However, our framework is focused on individual machines. So the original sentence and the S-curve adoption are not really applicable.</p> <p>To address this comment, we deleted the text justifying our approach, namely "A justification for spreading embodied energy and purchase costs comes from considering device replacements by many consumers across several years. In the aggregate, evenly spaced (in time) replacements work out to the same embodied energy in every period." We already say our approach is a simplification ("For simplicity, we spread all embodied energy over the lifetime of the device for a constant embodied energy rate (<math>\text{\\$rate}\{E\}_{\text{emb}}\%</math>).")</p> <p>Then, we modified the sentence in question to the following: "For simplicity, we spread all embodied energy evenly over the lifetime of the device which gives a constant embodied energy rate (<math>\text{\\$rate}\{E\}_{\text{emb}}\%</math>)."</p> <p>We trust this addresses this comment.</p>
1	16	Is there a problem with the N (or its description) in line 403 – is it all income, or all of the change in income after spending on energy?	Thanks for this comment. The reviewer correctly surmised that something was amiss. The word "net" was omitted. The sentence now reads "Under the bounding satiated utility model, all <b>net</b> income ( $\text{\$}\text{\textit{r}}\text{\textit{a}}\text{\textit{s}}\text{\textit{u}}\text{\textit{b}}\{N\}\text{\$}$ ) is spent on other goods"
1	17	I suspect footnote 20 is a bit strong – the rise in efficiency does make the energy available to the economy go further, and there's probably some scope for substituting between energy and other inputs, but as those other inputs remain constrained, I suspect there could still be crowding out.	<p>Thank you for pointing out that our wording in footnote 20 is strong. We insist that crowding out as defined in macroeconomic policy cannot apply as a result of a technology shock, since crowding out is defined as "'Crowding out' refers to all the things which can go wrong when debt-financed fiscal policy is used to affect output." (Blanchard, 2008, "Crowding Out", in: Durlauf &amp; Blume, The New Palgrave Dictionary of Economics), and there is no debt-financed fiscal policy involved. However, your point about limited abilities to substitute is very well taken. In response we have added a sentence to the footnote that reads:</p> <p>"Nevertheless, as long as the energy efficiency improvement is the only one in the economy, the further output growth may be constrained to the extent that the other inputs into production remain constrained at the original levels and substituting energy for these is limited by the prevailing technology."</p>
1	18	Table A.1 should not be defining something (m) to equal two different things, but I don't think there's any point in having an equation with mass in it, so that's another distraction to cut...	Thanks for pointing this out. We have removed all mention of m as mass.

1	19	<p>Appendix B.1 is much fuller than it needs to be – there are a lot of expressions that you’re writing out in full that economists would just “take as given”, and if you feel you must derive them for one cost category, you should still just add a sentence which lists the categories that are analogous. I realise that “space” may be cheap in an online appendix, but readers’ attention is a scarce commodity.</p>	<p>Thanks for this helpful comment. You are correct!</p> <p>In response, we now have only 3 equations where previously there were seven.</p>
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