General comment: This paper is interesting in bringing back the focus on the long term trajectory of growth in energy use, and how difficult it may be to change that, but lacking in several respects:

- the conflation of the method and its results with the functioning of reality,

Apologies, not sure we understand what is being proposed here.

- the lack of consideration of other parameters (population and GDP),

Although we understand why R2 thinks this is an important omission, we also think R2 has missed the point of the paper, probably highlighting our need to spell this out more clearly. Including an analysis of population and GDP may shed some light on why global energy use has strong systemic tendencies, but it is unlikely to given the fact that using these observations to explain patterns of global energy use has thus far offered little beyond specifying correlation (even Granger causality falls into this category). Understanding why global energy use may have long-wave dynamics requires something far more sophisticated than this because of the way these variables will co-evolve in a complex system such as the global economy. This is why we have adopted an econometric approach and simply identified systemic endogenous tendencies in the pattern of global energy use and used this as a basis for saying something about BAU. (see also response to Glen Peters on data availability for GDP and population)

- considering energy use itself as the ultimate parameter of interest. This is far from being obvious (or evidenced statistically, see David Stern's recent papers on this),

The focus of this work is to say something about CO2 emissions and the emissions landscape in 2020. As a result, focusing on global energy use is entirely rational and obvious. Again, we believe R2 is confusing the need to explain the behaviour of the world economy with our stated objective of forecasting patterns of energy use and emissions. Again this probably highlights our need to spell this out a little more clearly in the paper.

- assuming that past trends are unbreakable, despite the fact that these trends are not long term (in terms of human history), but represent a specific era. This means that transitions, which have occurred in the past, are not possible to "predict" with this type of analysis. That doesn't invalidate the analysis or BAU projections, but it does invalidate any discussion of possible future changes.

At no point do we state or assume these trends are unbreakable. We simply assert that until such a time that these patterns are known to have or observed to have changed, this is the BAU trajectory we are on. All we do assert in this regard is that the patterns of global energy use clearly demonstrate significant inertial timescales and these will dominate for a time even after the system has undergone transition. We are fully aware that the industrial revolution itself marked a transition and that our framework does not predict transitions (unless you believe global energy use is following Sornette's market failure dynamic!).

More specifically:

Top of page 3: Cite Peters et al 2012 NCC: 2008 crisis did not modify long term trajectories.

Happy to include.

Page 3 line 8: Can cite Jevons Coal Question and Ayres, Turton and Casten 2007 for more insights as to the mechanisms for energy use and demand.

Happy to include

Page 3 line 10: Well if methane hydrates become recoverable, we can use enough fossils to remove all the oxygen from the atmosphere (sky's the limit!) so dynamics could keep going a long time.

But they cannot persist indefinitely. Also, you can't assume they are bound simply by the availability of resource. Other factors could disrupt the evolution of the system including its own internal complexity or the detrimental consequences of resource exploitation e.g. climate change.

Page 4 line 10: Why not other source, IEA, EIA, or others?

Why not BP? As can be seen from Figure R2.1 below, bar the offset, it is remarkably similar to the IEA series (see below).

Page 4 line 13: Would want to know more about the systematics here: is the difference systematic during that time? is there a constant offset, or constant fraction missing? This is why might be useful to use other datasets as well to calibrate, for instance IEA or EIA.

Both the BP series and the IEA series (red below) have near constant offsets relative to the Grübler's series (see Figure R2.1 below). Beyond that, the EIA and BP series are very similar, with the merged Grübler-EIA series also resulting in a spectrum very similar to that shown in Figure 2.

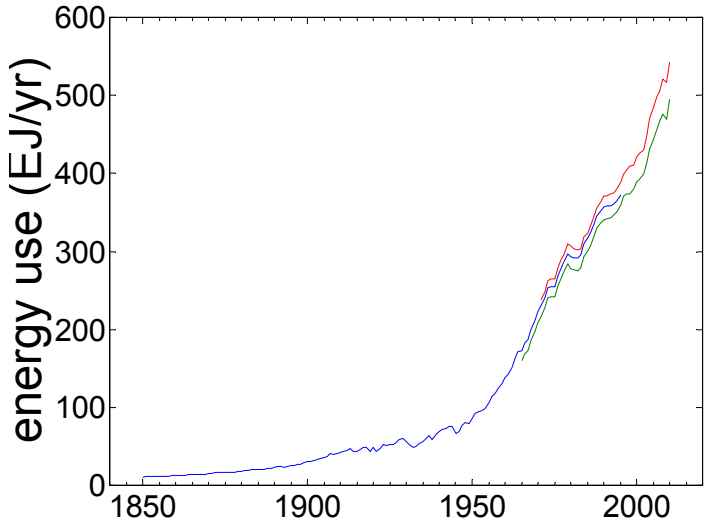

Figure R2.1. Grübler data (blue); BP data (green); IEA data (red).

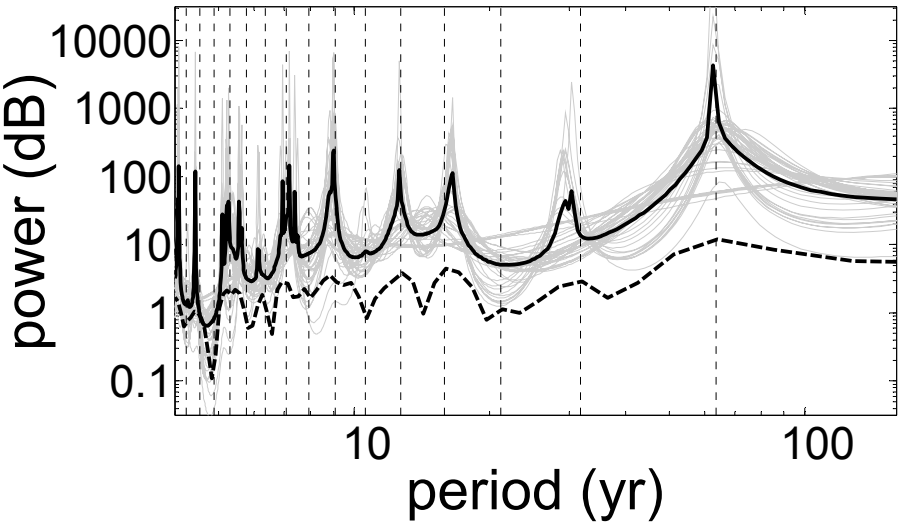

Figure R2.2. The period (frequency^{-1}) power relationship for the RGR estimates for global primary energy, 1850-2010 using the merger Grübler-EIA dataset shown in Figure R2.1. The grey lines are the spectra of all individual autoregressive models (5th to 50th order) fitted to these relative growth rate series of which the black line is the mean spectra. The vertical lines mark a 62 year cycle and its harmonics. The black dashed line is the spectra derived from the Fourier transform of the same data.

Line 14: what is the time span for the CO2 data?

1850-2010

Line 16: Why include land use change in energy centred analysis? Isn't land use change driven mainly by food/fibre demand?

No, wood fuel is also an important component even today. More importantly, this is very much the case for the period 1850-1900 where wood fuel is a vital part of global primary energy, forming a significant fraction of Grübler' estimates. It is true that today this is much less an important an contribution to global primary energy but it is a critical component to include in the 1850-2010 series for the reasons stated.

Page 5 line 3: Need a summary of the main features of this method in article itself, not just reference.

Happy to include.

Page 5 line 13: How does this compare with just doing a Fourier transform?

Figure R2.3 shows how FT compares to the AR method and data used in the paper. As can be seen the peaks line up showing the methods agree that there are frequency components and approximately on what the frequency components are. Not surprisingly, the AR method provides a clearer picture given the estimation of the AR model filters out noise that is

otherwise partially obscuring the FT result. These FT results will be added to Figure 2 in the manuscript.

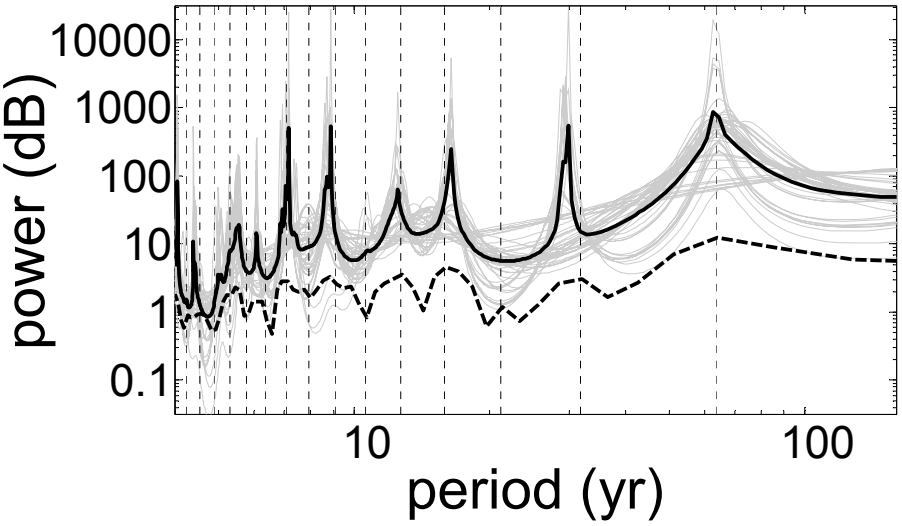

Figure R2.3. The period (frequency^{-1}) power relationship for the RGR estimates for global primary energy, 1850-2010. The grey lines are the spectra of all individual autoregressive models (5th to 50th order) fitted to these relative growth rate series of which the black line is the mean spectra. The vertical lines mark a 62 year cycle and its harmonics. The black dashed line is the spectra derived from the Fourier transform of the same data.

Page 6 line 5: say energy & co2 rather than x & y, throughout.

We have used x and y in the interests of brevity and precision but if the editor wishes us to change then we are happy to do so.

Page 6 line 24: I'd like to see a Fourier transform analysis as well (maybe on residuals from long term exp fit?). Also what is human population/GDP doing during this time, is long term periodicity visible at all there?

Why do you want to see the analysis done on the de-trended energy use data? In a system predicated on growth it is the relative growth rates that are key. The underlying dynamic in energy use will be obscured by the integration occurring between growth and energy use.

Page 7 line 16: What about time scales for technology cluster/infrastructure replacement? Pretty sure Grubler, Nakicenovic, and back in the day Marchetti had something to say about this.

Happy to include reference to the substantial amount of IIASA work on long-waves and innovation cycles but essentially this builds on the earlier work of Schumpeter as referenced.

Page 7 line 23: Isn't that just an artefact of the methodology used, rather than a compelling understanding and analysis of the ways economies function? Would be better to be a lot more modest about implications of findings.

It is only proposed as an "idea" that may "deserve attention" in the manuscript, nothing more. It may be an artefact of the analysis, but the mechanistic understanding of harmonic systems is much more developed and robust than our understanding of how the global economy works, which must rank as one of the most complex and poorly understood systems in the universe, hence why it is very difficult to find economists who agree. We are happy to be even more modest but don't feel we have overstepped the mark. Furthermore, from a position of parsimony (a tenant of science) this possible explanation has much to recommend it when compared to the somewhat convoluted and disjointed descriptions of economic cycles currently in play.

Page 8 line 4: There is a causal implication here which is cannot be justified by the analysis. in fact, as suggested, the analysis should be replicated with other long term growth variables (population, GDP) and those results discussed together.

The sentence in question reads:

"Also, because energy use is so fundamental to the operation of global industrial society, it is not surprising that equivalent periodicity is exhibited in the growth rates of other economic indicators, e.g. gross domestic product (Korotayev and Tsirel, 2010) as well as in primary energy use."

We are not using the analysis to substantiate this claim, we thought it was a widely accepted empirical observation that energy use is important to the global economy. Is R2 saying energy use is not fundamental to the functioning of the world economy? Also, as the reference shows, a frequency analysis of long run GDP data has recently been done by Korotayev and Tsirel (2010) and they too show long-wave and harmonic behaviour. If we had access to their data (we have asked) we would repeat our analysis on that. The public domain Maddison GDP data only goes back to 1950 for full global coverage as does the global population data.

Korotayev, A. V. and Tsirel, S. V.: A Spectral Analysis of World GDP Dynamics: Kondratieff 15 Waves, Kuznets Swings, Juglar and Kitchin Cycles in Global Economic Development, and the 2008–2009 Economic Crisis, Struct. Dynam., 4, 1, 2010.

Line 6: Need more than this : what does "nonlinear" mean in this context?

Simply that the linear system with its full set of harmonics is not observed and so by implication the system may be nonlinear. What form this takes we haven't got a clue.

Page 8 line 17: Or is your method merely picking up the world wars within its periodicity spectrum, but not the shocks? at least worth discussing.

It is most definitely a function of the method largely (but not exclusively) attributing deviations in the growth rate in energy use to endogenous, periodic components as opposed to exogenous, non-periodic components. Is this sensible? Well, although the wars were a big disturbance for many facets of life, in terms of energy, the data suggest they appear to represent switching from largely using energy for peaceful means to largely using it for unpeaceful means, we didn't stop using it. Perhaps a more detailed analysis could detect some further subtleties in the data, but our analysis would indicate energy use during the world wars was not far out of step with its systemic pattern during peacetime. Happy to expand the discussion.

Page 8 line 23: The causality assumptions here are if anything backwards. Your method is picking up (some) historical events and you are looking for patterns. History is not acting in order for your method to be vindicated.

Short of hedging our statements better to fully reflect the uncertainty in the analysis, we believe it is clear that this section is attempting to interpret the results presented in Figures 1 and 2 in relation to known historic events, not the other way around. However, the analysis, if correct, does have important implications for our interpretation of known events. The current narrative around the recent financial crash is that it was the result of human error and not part of the systemic re-adjustment of a global system. We propose that these data challenge this interpretation of events.

Page 8 line 29: Cite Peters et al 2012?

Happy to

Page 9 line 7: very short given time span of data analysed - why not go further?

Because 2020 is a meaningfully useful, politically inspired forecast and it is very unwise to stretch the past = future analogue quantitatively beyond this.

Line 19: wasn't 2010 a deviation year?

The spline only looks at the underlying trend. Also, 2010 followed the 2008-9 'crash' and so the two approximately cancel in the estimation of the spline node in 2010 which 'sees' data from 1990-2010.

Page 10 last sentence unclear

We agree will modify accordingly

Page 11: But that doesn't mean that transition or collapse are not possible: the time frame of study corresponds in very stable period of technological advance and growth in human societies, not a truly long term phenomenon.

We don't say that transitions are not possible, we just say they have to work against both the underlying systemic tendencies AND the inertia. We even refer to our previous work on systemic transition (Jarvis et al., 2012). We completely agree that collapse is possible and the conclusion needs to be clear on this, currently it is not. In a statistical sense we appear to live in a 'stable period' with respect to the growth in energy use. The fact that we say BAU will persist until something changes does not imply this state persists long term, such changes could be underway already, but not yet observable.

Jarvis, A., Leedal, D. T., and Hewitt, C. N.: Climate-society feedbacks and the avoidance of dangerous climate change, Nat. Clim. Change, 2, 668–671, 2012.

Line 21 line 10: Could argue this is already happening in many places, but not perceived or communicated clearly enough as related to climate change.

You could, but is there evidence it is resulting in "meaningful interventions in energy use"? The patterns of growth in global energy use would say not, and given it is at this scale where things matter in terms of climate this is what counts. That said, to be consistent with our earlier line of arguing, it is possible that society has transitioned but that we can't see it because of the inertial dynamics. We will make this point even though evidence on the ground is very scant indeed.

Authors oversimplify social (and economic) processes, and the power of vested interests within a technological and economic system to maintain the control over debate and decision making.

Firstly, the paper deliberately avoids getting into detail over processes. It is an econometric-type analysis of historical patterns. Where it is forced to say something about process clearly we agree we are simplifying many aspects of the behaviour of socio-economic processes in relation to global energy use. Are we oversimplifying? That is much less clear. If it is true that the world economy is in part determined by long-wave dynamics then this is in all likelihood a very poorly understood emergent property of a deeply complex system. As with all such systems, even complete understanding of the micro-interactions (which is unattainable) does not guarantee you understanding of the macro-behaviour. Again we ask, is there consensus amongst economists over how this system operates?

As for us underestimating the power of vested interests and decision makers. Maybe we have, but such interests have been seen to operate throughout the 160 years covered by the data analysed here and yet the systemic dynamics appear remarkably stationary. Stalin too thought his power and vested interests mattered more than long-wave dynamics, which is why he ultimately had Kondratiev killed. However, we present evidence that the pattern of global primary energy use suggests Kondratiev was right, and that there are forces at work that appear transcend our somewhat transient decision making machinery.