Recent Evidence for Large Rebound: Elucidating the Drivers and their Implications for Climate Change Models

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The International Energy Agency has recently identified energy efficiency as the "hidden fuel" that has become the "first fuel" in IEA countries, delivering energy savings that in 2010 "exceed the output from any other fuel source." The clear inference the authors of this report would like us to draw is that future investments in energy efficiency will result in massive energy savings, with all its attendant positives for climate change mitigation and resource conservation. This is a highly seductive proposition, promising as it does a future bereft of thorny political tradeoffs and requiring no sacrifice in economic welfare (or even gains) even while radically reducing assaults on the natural environment. A nostrum to be cherished by any politician or environmentalist worth their salt.

Unfortunately, this proposition is highly problematic and the present article demonstrates why. Fundamentally, the proposition is at odds with both economic principles and meticulously-developed empirical evidence from studies examining hundreds of years of energy efficiency history.

At the center of it all is a stubborn misconception of how economies respond to energy efficiency gains. This misconception has found its way not only into the methodology employed by the IEA but also models relied on by the Intergovernmental Panel on Climate Change (IPCC) for forecasting energy use. The simplistic view is that an x% improvement in energy efficiency (the savings potential derived from engineering calculations) will lead to an x% reduction in energy use (or nearly so when penetration barriers are taken into account). But in reality so-called "rebound" effects will prevent this from happening. At root, energy efficiency rebound effects arise because energy efficiency gains reduce the effective price of energy, and economic agents, both producers and households, will respond by increasing energy use in various ways. A vast and rapidly-growing peer reviewed literature on rebound provides abundant detail on these mechanisms.

The article examines evidence from recent studies showing that this effect has historically been very large indeed. A study that analyzed lighting efficiency improvements over 300 years, 6 continents and 5 technologies showed that rebound effects "ate up" all the efficiency gains – the introduction of more efficient lighting technologies reduced energy use for lighting not at all, a condition known as 100% rebound. A study that analyzed transport energy demand in the UK over 150 years found a rebound magnitude of 70%. A study that analyzed lighting demand in the UK over 200 years found 60% rebound. A study that analyzed overall energy use in Sweden over 200 years shows rebound of 50-60%. In contrast, the IEA assumes a global rebound magnitude of only 9% in its projections. Clearly, forecasts that ignore or greatly understate such effects will substantially overstate future energy savings from energy efficiency investments.

The article also examines methodology issues surrounding the IEA approach and in the models relied on by the IPCC. A central methodological issue with the IEA's historical measurement showing it has become the "first fuel" in IEA countries is that the authors rely on an extremely problematic method involving the historical evolution of energy intensity (the ratio of total primary energy consumption to GDP). Their calculation of "avoided energy use" uses as a primary reference point a projection of energy use assuming this ratio had remained unchanged between 1974 and 2010. Importantly, as the present article shows, this ignores the contribution to observed energy intensity decline arising from efficiency gains for other economic inputs – labor productivity improvements, capital efficiency improvements and improvements in the efficiency of materials use – implicitly assuming that all these gains in GDP per unit energy input arose from energy efficiency alone. The article shows that for Sweden, these non-energy efficiency gains contributed vastly more to the decline in the energy intensity ratio than did energy efficiency gains. Accordingly, the IEA estimate of historical "avoided energy use" due to energy efficiency gains is greatly overstated.

The article also argues that the presence of rebound effects means it is improper to treat energy efficiency as a "supply" source as assumed in the "energy efficiency cost curves" employed by the IEA and others. The potential energy savings derived from engineering calculations used to develop these curves will be eroded in various ways by rebound effects, meaning the x-axis quantities used in such efficiency "supply" curves are not reflective of real energy savings potential. These are not legitimate supply curves in any neoclassical economics sense. Fundamentally, energy efficiency is a demand-side, not a supply-side phenomenon.

The article takes a deep dive into the models relied on by the IPCC, reviewing 25 of these models for which documentation is available. Here, it is found that technical limitations related to the absence of mechanisms allowing for rebound phenomena abound. Most of these models incorporate remarkable detail and are quite sophisticated, but they often use functional forms that do not have the capability to accommodate rebound dynamics, assume values for unmeasured parameters that essentially pre-determine the energy results, or ignore key drivers such as prices and non-energy technology gains. The article offers 8 technical improvements that will allow these models to overcome the inherent limitations arising from improper specification. A model that is improperly specified in a way that is at odds with economic principles relating energy efficiency to energy use, no matter how detailed, will not provide reliable energy use forecasts, nor properly reveal the role of energy efficiency in restraining energy use. The article urges modelers to incorporate such improvements.

[Note: since the time this article was accepted for publication, both the IPCC and the IEA have at last acknowledged the importance of considering rebound effects. However, it is to be hoped that both organizations will accordingly call for the necessary improvements in the models used for forecasting energy use prior to releasing their next round of forecasts. Policy makers need a realistic picture of the consumption-reducing effects practically attainable from energy efficiency initiatives.]