Jevons' Revenge – or why present carbon abatement strategies probably won't work.

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"Productivity has got to get ahead of production — or we're all buggered!"

In my soon-to-be-finished e-book, "Warming to You" those twelve words precipitate a sixty-thousand-word dialog between Bruce and Jane on how we explain and understand science. It started when Jane thought that the money saved from the superior fuel economy of their new hybrid car – with its low "carbon footprint"– could be put towards a family holiday in Phuket. Bruce wasn't so sure. Please explain, said Jane.

There's a lot to explain – and there's still a lot that isn't understood. The challenge of determining whether a hybrid car – with a fuel economy of 4l/100km has a smaller *total* carbon footprint than a similar sized turbo-diesel that does 5l/100km, but costs $10,000 less to purchase – is not easy. And it's a problem that pervades the whole debate on carbon-reduction measures. Let *me* try to explain.

Let's start in the middle, then go back to the beginning and finish at the end – just like a modern movie. I've found that that's the way to make the best sense of this perplexing issue.

In the middle: What we all *do* agree on is that the more carbon we burn, the more carbon-dioxide (CO_2) we put into the atmosphere – and, according to 97% – and maybe 99% – of climate scientists, the more we increase global warming. (We won't discuss here why more than half the mainstream media follow the views of the 1-3%.) So far, so good. Bruce and Jane's hybrid, *when on the road*, contributes less to global warming than the turbo-diesel alternative. Similarly, a natural gas-fired power station emits less CO_2 than a coal-fired power station per unit of electricity produced – and a nuclear or solar power station, none at all. So, if *on-the-road* emissions were the only ones, then we'd drive a hybrid, or generate electricity with natural gas – or nuclear or solar, if they were available. *But they aren't the only emissions.*

Back to the beginning: As everything takes energy to make or do, Bruce and Jane have to include the energy that it took to *make* their hybrid– and not just the energy to make the steel, aluminium, plastic and other materials in the car, but the energy that it took to make the things that made those materials. And the energy to dig the raw materials out of the ground and the energy to make the diggers and haulers. Similarly, all the energy and effort that goes into *making* the different power stations needs to be included with the energy consumed when they're *running*. And the energy to make the gas, coal or uranium useable. This becomes very complicated. It's called the "embodied energy". Not surprisingly, we haven't got very good data on this, both because it's complicated and nobody has bothered to try to do it comprehensively.

And later: Bruce and Jane know that even with the great fuel economy, the bills will keep rolling in for insurance, registration, tyres and repairs, to mention some of the big-ticket items. To them, they're just burdensome bills they pay on-line, *but those expenditures imply that effort and energy are happening elsewhere to keep them on the road.* And ultimately there will be the cost and effort of disposing of the worn-out car. Similarly, power stations cost money to maintain. Carbon capture and storage systems for coal and gas generators take money and therefore energy to build and maintain. Insurances for nuclear are being re-assessed in the wake of Fukushima and disposal costs are unknown or contentious. Insurance isn't just an energy-free abstraction – it's materials and movement elsewhere on our behalf. Whatever they might be, they imply that a lot of energy is needed to keep the generators running and dispose of them once their useful life has passed.

So – everything has a beginning, a middle and an ending. *Life-cycles*, they're called. Therefore, to make a full assessment of the energy embodied or consumed in their new hybrid, Bruce and Jane have to consider the *whole life-cycle costing* – in the same way that the NRMA assesses the "real" *financial* cost of acquiring and using a car over five or ten years.

With this brief example in mind, we can now look at the *first* dilemma– Jane and Bruce have reduced the carbon consumption during *their* stage of the hybrid's total life-cycle, but how do they know if there wasn't even more energy consumed to make their fancy car in the first life-cycle stage than they might save in its daily use? Answer– they don't know– *nobody knows*. Is there more energy being used in the auto factory in a smoggy Chinese city so that less energy can be used while Bruce and Jane drive their hybrid around an Australian city with clear skies?

Net energy analysis, as the scientists call it, is well-known in theory, but not used adequately or frequently in practice. Various vendors of "energy saving" goods make claims about the "energy pay-back time" of their product, but they are never substantiated and often absurd. Why? Because although the theory is not particularly complicated (compared with many modern scientific theories), it is very tedious to calculate in practice. One has to follow the energy trail for every piece of the product – which, in this era of globalized production, is even more difficult than ever. And further, for the analysis to be *done*, somebody has got to *do* it– bits of it are done by enthusiastic academics, but, to be useful, it must be comprehensive of all our goods and services, and complete in its detail. It would be a very expensive exercise, requiring sustained public resources.

Now – let's translate Bruce and Jane's problem to the owners of an electricity-generating power station. Take, for example, one in Victoria, burning brown coal, which produces 100 Kg of CO_2 for every GJ (278 kWh) of electricity produced. Most people want to see the power station's efficiency improved, but how can it be done? There are four main ways: it can build a state-of-the-art brown coal burning station; it can add on a "carbon capture and storage" system (CCST) to the existing station; it can switch to black coal or it can switch to gas. In all four cases, there would be *an increase in cost* to accompany the decrease in CO_2 emissions. So it is reasonable to ask: *would this increased cost also mean an increased use of CO_2 across the life-cycle and value-chains of the station?* The answer is not known, but the answer is probably "yes" if the life-cycle cost increases- which is expressed in the retail cost of each kWh of electricity. Overall- or globally- there would be *no* decrease in CO_2, although the power station could, perhaps, proudly say that *it* has decreased *its* emissions. Its lower emissions will be accompanied by greater emissions at the factory that produced the new brown or black coal or gas power station, the CCST system and/or the extra running cost involved in these new systems. We won't know for sure because the net energy analysis won't be done, for the reasons given above. *The only outcome that is likely to reduce CO2 emissions is a system that costs less to make, buy and run.*

This is a rather dismal prospect and applies equally to replacing the brown coal station with a nuclear or solar system- if these systems actually cost more.

The Jevons dilemma: But let us, for the moment, assume that our new system *does* cost less and therefore *does* emit less CO_2 into the global atmosphere. There is another problem- one that has been haunting us for almost two centuries- it is known as the *Jevons paradox*. Stated simply, it seems that if we make an efficiency gain (measured in either reduced energy use or reduced cost of production) we don't see the demand for energy going down. We simply use that "efficiency dividend" of spare energy to produce more of what we want- which is, basically, energy. In Bruce and Jane's case, Jane wanted to use the fuel savings to fly the family to Phuket. Bruce wasn't sure that there were actually any real savings, but even if there were, he foresaw that flying to Phuket would mean that they would burn up the saved energy and release the saved CO_2 anyway.

There really isn't a paradox- *this is actually the main way that we have increased our standard of living since the beginning of the Industrial Revolution*- we have opted to not decrease the amount of energy that we consume, but use the efficiency dividend to increase the goods and services that we can acquire. For example, if we improve efficiency so that we can now make 100 widgets with 99 units of energy rather than 100 units, we opt to make one more widget with the energy saved, rather than leave the energy in the ground. Or fly the family to Phuket.

Think back, for example, to the time that coal was first used to run an early-eighteenth century steam engine[1]. These steam engines were used in the first place in iron, copper and tin mines as well as coal mines, mainly to pump away unwanted water. Energy and effort were required to mine the coal, which in turn was used to both fire the steam engine and to do other things- mainly to smelt ores into metals like iron and copper and tin; in turn, some of which were used to make the steam engines. With ingenuity, the steam engines were actually made more efficient, so that they could mine more coal and ores with a given amount of coal for fuel, more of which were used to build bridges, grinding mills, wheels and other goods that improved public amenity. So standards of living increased across many countries as more coal, then oil, were extracted with increasing efficiency to provide more goods and services. It is important to note that part of the newly available energy from the efficiency dividend was diverted back to increased energy production, as well as moved forward in the life-cycle to produce more "end-user" goods and services like Bruce and Jane's car.

The *rate* of energy used to produce *all* the things we make and do in a country is called the "energy intensity". As discussed, while we don't know with sufficient precision the amount of energy used to make a *particular* thing, we have a better measure of the *total* used by each country and the amount of goods and services acquired- this is commonly called "the economy". The measure of energy intensity is dollars-per-megajoule (or dollars-per-BTU in the USA). An improvement in energy intensity means getting more dollars to spend for each unit (megajoule) of energy consumed. Fig 1 shows the improvement in energy intensity in many countries over the past 30 years- about 1% per year. But as the same graph shows, energy use *per capita* has remained fairly constant and total energy use has increased due to population increases. More people (on average at least) are enjoying an increased standard of living.

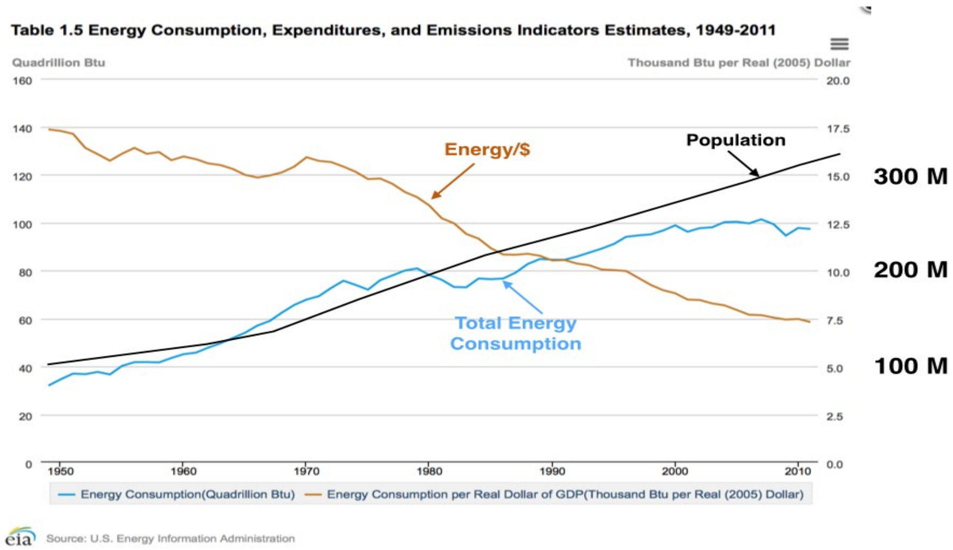

Fig 1 illustrates the point for the USA (where such data is easier to find than Australia's). Most OECD countries show a similar trend. Since 1950, the average energy intensity (AEI) has more than halved, while the total energy used has almost tripled. The population over that time has also more than tripled. So, **while there have been real efficiency gains, they have been more than outweighed by greater total energy consumption for the whole country.**

Importantly, the graph shows that *total* energy consumption has leveled off since 2000. While some of this may be real gains in carbon fuel reduction, there are very plausible claims that some of the reduction is due to "outsourcing" carbon-energy-intensive production to China and India [2]. Most of Australia's manufactured goods, including solar panels, are manufactured in China. This illustrates the point that we need to take into account all of the energy consumed along the whole life-cycle.

Policy responses: So where does this leave Bruce, Jane and the Australian Government's carbon abatement programs? In a word – "uncertain". Let's look at the two strategies that have been tried or proposed – *taxation* and *direct action*.

Carbon tax: The previous (Labor) Government's policy of taxing carbon use may have been an incentive for major carbon-energy users to improve their energy intensity. It had not been in place for long enough to tell, but all indications were that companies were responding positively. But there were two major defects: first, most of the tax money was ploughed back into the economy by way of compensation to consumers for increased prices due to the pass-through of most of the tax. This money was then used to purchase goods and services, which, as described, take energy to produce – producing a variant of the Jevons paradox. Bruce and Jane might have used the compensation to fly to Phuket. Secondly, although the companies may have responded by installing more carbon-energy efficient systems, there was no way of determining that these systems did not simply shift the energy use back along the life-cycle – ie, by acquiring efficiency systems from overseas, or from non-taxed local companies. **The only way to avoid this problem is to have a globally-implemented cap-and-trade system, where the total carbon use is fixed, then reduced, there is no capacity to life-cycle-shift the carbon use.**

Direct action has similar problems. It will be considered successful by the Government if the company installing the carbon-saving system actually *does* reduce its *on-site* carbon consumption. But, as explained above, it may well just simply displace the carbon consumption to elsewhere. As before, it may well lead to a nett reduction in global energy consumption, but this is not certain and not guaranteed.

Is there any solution to this problem? Yes – Bruce was right – *productivity has got to get ahead of production* – assuming that production and consumption are fairly equally matched. In other words, the improvements in *global* energy intensity have got to be greater than the increases in global production – *we've got to beat Jevons down*. There are two main ways that this can be done. The first is to have a robust net energy analysis system that takes into account all of the energy consumption along the whole product or service life-cycle. This would require a lot more energy economists in a lot more countries doing a lot more detailed analysis and subjecting it to a lot more scientific scrutiny. This is possible. The methodologies exist – the work just needs to be done and validated. Then purchase of goods and services could be done on a basis of knowledge, not assertion of opinions and naivety.

The second way, which is likely to be very unpopular*, would be to deflate the economy.* As described, money is a good proxy for energy use, so less money spent generally means less energy used. This does not have to be drastic – if real average energy intensity is improving at, say, 2% and rather than all of this being re-spent, a la Jevons, half of it is taken as a tax by government and not redistributed, but is used to create a "surplus"- ie the money supply is reduced. Although this could be "circumvented" by an increase in credit, as happened during the Howard years, Governments have a number of ways of curtailing credit demand. Understandably, if the community has an expectation of a standard of living always increasing at least at the rate of improvement of energy intensity, then this strategy would be unpopular. Further, as illustrated in the graph above, the total carbon energy use has to reduce, much of which is due to population increase. So the deflation would have to be at a rate at least equal to the rate of population increase – which in Australia is about 2% per year. *To be effective, Australia would have to deflate at a rate that would see absolute decreases in the standard of living, unless it stabilizes its population or finds some way of improving energy intensity by greater than the long term average of 1-2%.*

Are there any other options? I personally can't find them. Perhaps the decrease in solar photovoltaic costs provides some hope. Costs are already better than "plug parity" for mains electricity, but have to achieve "generator parity" or better to be significant in the long-run. There are also other energy efficiencies possible on a larger scale, both domestically and commercially. But with all of these measures, the dividends have to be saved, in an absolute sense, not used to "fly to Phuket" – either literally or metaphorically.

It's either "bugger Jevons" or Jevons will bugger us all.

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[1] http://en.wikipedia.org/wiki/Newcomen_atmospheric_engine
[2] http://www.theguardian.com/environment/2014/jan/19/co2-emissions-outsourced-rich-nations-rising-economies?CMP=ema_632