The Fifth Headwind: Will Moving Towards Energy Sustainability Really Inhibit Industrial Productivity Growth?

By Michael C. Overturf*

Industrial productivity is a social dynamic that has brought great benefit to society in general, raising the standard of living, life span, and the quality of life in general. We are learning that the byproducts of industrial activity are exerting such harm on the local and global environments that some change must occur to mitigate these effects.

In particular, energy inputs take the form of hydrocarbon fuels. The term sustainable energy means that energy consumption can occur indefinitely (which I arbitrarily pegged at 10,000 years) without ill effect, and that it can support the necessary perpetual dynamic of productivity growth.

A survey of literature finds that energy sustainability today is, by and large, a political topic, supported in part by truisms and in part by a misunderstanding of how industrial energy use actually works. If the desired consumption shift is indeed to occur, it must clearly and demonstrably achieve its environmental gains while also maintaining or accelerating productivity growth rates. Is this possible? In this opinion piece, I take a look at how this might occur.

Sustainability isn't the Worst Thing in the World

This question first formed in my mind as I was listening to Steve Dubner of Freakonomics in one of his podcasts. In this particular issue he examined the work of Robert J Gordon and Tyler Cowen, both of whom claim that the United States, and possibly the industrialized world, is doomed to low productivity growth for the foreseeable future, or to put this to greater rhetorical effect, "our golden age is behind us". However, by Mr Cowen's own admission: "Our [economists] ability to predict future growth has never been that great". And then Dubner, in conversation with Kai Ryssdal, said this: "It may be time to think of the U.S. economy not in terms of never-ending growth, which we have been trained to do, but in terms of sustainability, *which isn't necessarily the worst thing in the world*".

Aw, shucks. Is sustainability a good in and of itself, unrelated to productivity growth? Anybody who's sat down with a CFO or CEO of an industrial corporation knows: if an investment does not improve productivity, or revenues, in some way, it's not going to be done.

As an energy professional myself, I know that the value chain of sustainable energy sources is mostly shorter than that of conventional energy, and their capital barriers are lower than ever. So why the down-beat ambiguity, the noble readiness to sacrifice by turning away from the magic productivity engine crank and head into the uncertain forest of sustainability?

The Fifth Headwind

Gordon's paper[1] asserts that all fundamental innovations in communication, transport, and manufacturing technology have been invented, and it is unlikely that anything further will engender growth rates akin to that during the deployment of electricity. He concludes that the United States has six headwinds that will dampen economic growth rates (GDP) for the foreseeable future:

1. Declining Demographics – fewer people working fewer hours;
2. Educational attainment – fewer people completing higher education;
3. Stasis in income inequality – the bottom 99% will not experience significant income growth;
4. Globalization–a nearly infinite[2] source of foreign cheap labor will compete with the U.S. uneducated;
5. Climate change – the cost of reversing past environmental changes
6. And finally, household and government debt.

Although skeptical, I'm not qualified to properly grapple with most of these. The fifth headwind, however, caught my interest, though, as I've seen this in variation from others. Here is the original text from his paper:

> *"Energy and the environment represent the fifth headwind. Part of any effort to cope with global warming represents a payback for past growth. In 1901 the environment was not a priority and the symbol of a prosperous city was a drawing of a factory spewing pure black smoke out of its chimneys. The consensus recommendation of economists to impose a carbon tax in order to push American gasoline prices up toward European levels will reduce the amount that households have left over to spend on everything else (unless it is fully rebated in lump-sum or other payments). India and China are both growing more rapidly than the U.S. and taken together those two na-*

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tions are responsible for double the carbon emissions of the U.S., but they resist suggestions that their growth to high-income status should be curtailed by energy restrictions, since today's rich nations of North America, Europe, and Japan were not regulated in the same way during their 20th century period of high growth."[3]

Apparently economists are now imbued with legislative powers. Anyway, ignoring the crankiness about China and India not stepping up to the plate, the essence of the fifth headwind is this: a cost that is a hangover for past growth, with no current benefit. Does this really stand up to scrutiny?

Energy Consumption and Emissions

The U.S. consumed around 100 quadrillion btus of energy, with only about 10% of this from renewable, or sustainable, sources. Another 8% comes from nuclear power, which many do not classify as sustainable, because of its radioactive waste. The balance, 82%, comes from combusted hydrocarbons.

There are no 'centrally administered' plans to change this mix in the foreseeable future. There are plenty of hydrocarbons available for many more human lifetimes – we can literally cook the planet with the balance of reserves. The EIA forecasts renewable generation growth of 1.9% per year from 2010 through 2035, which does significantly exceed forecast demand growth (0.3% per annum in aggregate), but isn't enough to substantially change the mix.[4]

Yet, emissions are declining, and there is evidence that further reduction in emissions will come about as a *result* of more economic activity, not the other way around.

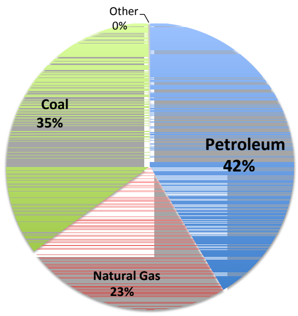

Figure 1, Percentage of Carbon Dioxide Emisssions from U.S. Fuel Consumption in 2012. Total:5.6 billion tons.

Emissions

In 2012 the U.S. emitted 5.6 billion tons of carbon dioxide, with transportation – petroleum combustion – making up the largest share, Figure 1. CO_2 Emissions are currently (2010-2012) on a *downward trend* – the consequence of shifting consumption behavior patterns. The EIA anticipates that that emissions will decline by 0.1 percent per year from 2005 to 2035, as compared with an average increase of 0.9 percent per year from 1980 to 2005.

What are these shifts? On a macroeconomic level we can measure the carbon intensity of an economy, i.e., how much carbon dioxide is emitted per GDP dollar. For the United States, there has been a long term decline in this measure, Figure 2. Over time each financial transaction causes less and less fuel to be combusted. Reasons for this may include a steady shift away from fuel-intensive activities such as manufacturing towards services, which tend to involve more transportation, with less per capita emissions. As this may be, even the most casual observer will detect an inverse relationship between GDP growth and carbon intensity.

The period between 2007 and 2011 is of particular interest, not only because it was a recessionary period, but because other fundamental, unprecedented changes are occurring. Most previous recessions resulted naturally in a flattening or temporary reversal of CO_2 emissions growth.

Since in 2006 - before the most recent recession - gasoline sales in the U.S. have been on a precipitous decline, causing unprecedented refinery closures, and price spikes due to shrinking refinery capacity, Figure 3. An *entire generation of Americans* is combusting less petroleum. But are they emitting more CO_2 through electricity consumption instead?

A similar, but broader trend is taking place in the electric power sector. The exploitation of shale deposits have put large reserves of natural gas on the market at a long term, stable price. Historically, coal has been stable and cheap, but is now being replaced by natural gas[5]. Conventional coal plants emit around 1,200 kilgrams of CO_2 per MWh[6], natural gas emits around 500 kilograms. This represents a nearly 60% emissions reduction while also reducing generating costs and consumer prices. Figure 4 shows new energy generation capacity coming online in the U.S. year-to-date 2012. Led by natural gas, the va-

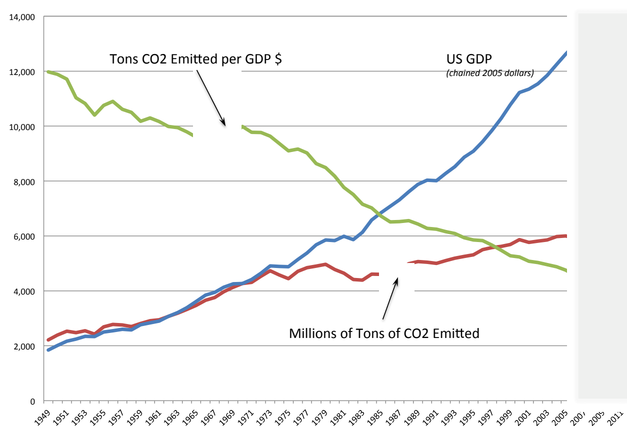

Figure 2, Changes in historical 'Carbon Intensity' of U.S. GDP. Source: EIA & BEA riety of lower emissions technology is increasing significantly, with coal in third place behind wind generation.

Long term capacity plans continue this trend, as can be seen in Table 1, from 2010, projecting registered or intended generation capacity (Megawatts) through 2015. Coal use for power generation is in serious decline; note the higher variance between what was planned for coal in late 2010 (4,304 MW), and the actual 2012 figure in the pie chart above (1,385 MW) in comparison to other fuel sources.

While this organic substitution towards lower emissions is taking place, prices remain flat. Overnight spot prices in the PJM as recently as June 2012 were below $20 per MWh; the year-to-date realtime LMP for the entire PJM region averaged 3.2 cents/kWh. Electricity markets are regional, of course. Unregulated markets will continue to see low electricity prices due to lower natural gas costs and supply competition. Regulated markets are likely to see small price hikes due to investment requirements.

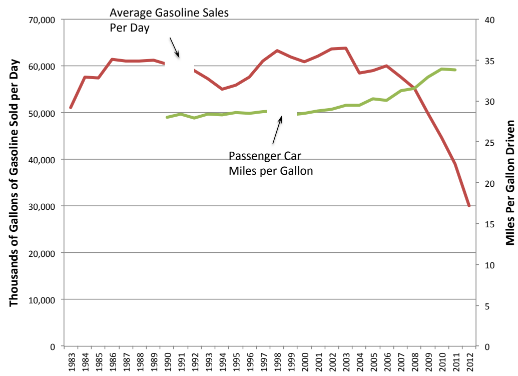

Figure 3, Average Gasoline sales/ day, Passenger car miles/gallon. Source EIA, DOT

Zero Emissions?

Awareness of excessive CO_2 emissions as an adverse pollutant is a recent phenomenon. CO_2 is different than other emissions, such as Nitrous or Sulfur Oxides, in that it is not inherently unhealthy. CO_2 is a volume problem, not a toxicity problem. The ecosphere readily absorbs a certain amount of CO_2, but it appears we are producing more than that.

Therefore, sustainability can be achieved by fractionally reducing CO_2 footprint, not eliminating it - there is probably a floor to the emissions volume cut. I will not hazard a guess what that is, some estimates advocate around 2 billion tons, depending on what other countries do[7]. This would imply a reduction of about 70%.

The U.S. may be able to achieve this level organically, without regulatory mandates, but with technology development, opportunity awareness and prudent investment. Why? Because reduced CO_2 emission is plainly a *byproduct* of cost reductions and productivity improvement – economic stimulants, not depressants.

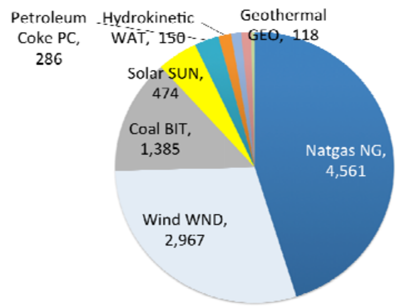

Figure 4, New generation capacity 2012, in MW

Industrial Energy Productivity

In my work I'm not as much focused on residential energy consumption, but rather large commercial and industrial. Industrial energy consumption is about a third of the total, across all uses. Will making these 30 quads of energy supply sustainable lead to productivity growth, stagnation, or reduction?

U.S. Industrial[8] Energy Productivity, also called Energy Intensity, historically somewhat follows the CO_2 emissions per GDP trend:

Interestingly, the correlation between prices and energy intensity is not terribly strong: other factors[9] contribute for this continuous improvement, namely, the introduction of JIT[10] material flow, 'instant' information about demand and supply, and automation. In short, a combination of enlightened management and information technology, the IR3, as Dr. Gordon refers to it. IR3 improved industrial energy productivity by an entire order of magnitude over 50 years – this without knowing or caring about CO_2 emissions, but certainly while suffering SO_2 and NO_x abatement policies, Figure 5.

Fuel	*2011*	*2012*	*2013*	*2014*	*2015*
Natural Gas	11,256	8,756	6,028	4,291	7,387
Wind	7,972	4,711	2,221	349	
Coal	4,873	4,304	290	515	41
Solar Thermal and Photovoltaic	586	2,717	2,673	1,848	471
Petroleum	548	70			
Wood and Wood Derived Fuels	155	485	206		
Other Biomass	128	86	171	93	65
Hydroelectric Conventional	33	155	224	263	22
Geothermal	31	144	185		460
Other	20				
Other Gases		808	4	840	
Nuclear		1,270			
Pumped Storage					

Table 1, Planned electrical production capacity for the U.S., release date 2011. Source: EIA

Lean Meets Mean

The energy industry is not known for its flexibility. No wonder: highly politicized, capital-intensive, millions of customers – these are not attributes that lend itself to quick, adaptive change. But the advantage

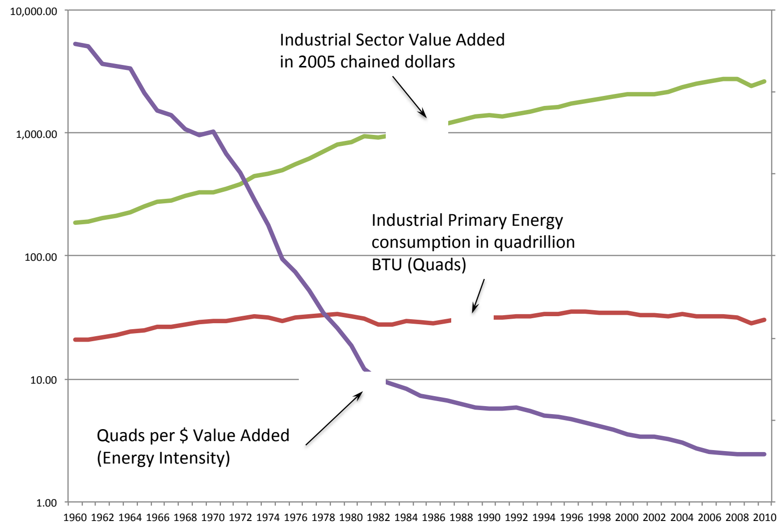

Figure 5, Industrial Energy Intensity over 50 years, Source: BEA, EIA. Note logarithmic y axis.

of latency/waste reduction is powerful – our entire modern material supply was created by the disruptive effects of wide variety, small lot production.

Lawrence Livermore Laboratory estimates that the productivity potential, i.e., the amount of energy wasted (rejected energy) in the current energy infrastructure, is 57% of actual consumption.

This means efficiency alone could make up more than half of desired emissions cuts, while reducing corporate input cost.

The intelligent grid movement, another IR3 offshoot, promises more efficient load balancing, with large scale distributed generation (thousands of more efficient small energy generation systems), to replace the monolithic, central plant.

Why is this interesting? Because onsite generation is a natural 'lean management' approach to energy generation, and the old economics of input fuel volume no longer apply. Energy conversion at the time and place of demand, instantaneously adjusted to either need or market pricing options, could move rejected energy from 57% to 10% or less[11]. Further, intelligent load management accommodates the asynchrony between ambient energy conversion and actual demand.

Although capital requirements can be high, the value chain for distributed energy is shorter and absorbs less cost than the traditional energy portfolio. Industrial firms are installing micro-grids, with CHP plants, renewable energy components, and gas-electric hybrid transportation not because it's a neat thing to do, but because it cuts energy input costs by as much as 50% over delivered market rates. And the by-product, trumpeted by marketers, not CEOs, is reduced atmospheric emissions.

The mean energy input cost reduction afforded to industrial clients by my energy firm is 40%, while reducing CO_2 emissions, by 10%, 15%, or more. Other toxic emissions, such as Mercury, are eliminated wholesale, or completely.

Energy Density

Hydrocarbon fuels such as coal, oil, and gas have a critical advantage over ambient energy such as solar or wind: they meet the energy density requirements of industrial demand. Energy density the amount of energy required per surface area, Watt per square meter (I use kW/m^2).

Why this measure? Because JIT logistics is all about minimizing material and people movement (distance), while maximizing value (what the customer wants). This means that the less area used for production, the more efficient the processes, and the higher labor density (value added motion divided by expended motion) becomes. Surface area is an important measure for an industrial facility.

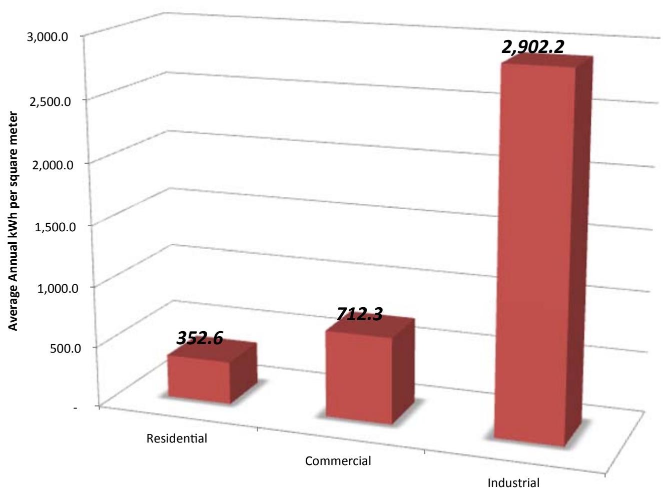

Figure 6, Annual total energy consumption per square meter, by sector. Source: EIA, Overturf (Industrial is small sample set from Food Industry)

Energy demand density is also important in the sustainability discussion because that's how the earth receives its energy from the sun: spread over half the sphere. Hereabouts we can expect anywhere between 360 to 1,800 kWh/m^2 per year, depending on location and weather. Current technology only allows us to harvest roughly 12% of that economically, so that brings the yield down to 40 to 210 kWh/m^2, which is fine for residential or some commercial purposes, as shown in Figure 6.

But solar energy per se is irrelevant, or inconsequential, for industrial purposes: for a median intensity industrial plant one would have to capture solar flux from around 25 square meters for every one square meter used in production. A small 25,000 square meter plant (250,000 square feet) would consume 625,000 square meters of land just for energy generation – 6 acres, under favorable circumstances. Larger plants or more intensive industries have energy density much, much higher than that.

One of the causes of this high density is that industrial plants require temperatures anywhere from 200ºC to 3000ºC to manufacture goods. On a good day, for a short period, the sun is able to convert water into steam for practical purposes, at about 110ºC or so. Large concentrating solar thermal can deliver oils or steam higher than that – for a few hours per day. There is simply no way conceivable at the moment how to continuously power industrial processes with direct solar capture.

Technological substitution is, therefore, a real challenge for the industrial and large commercial sector. Does this mean that there are no lower cost paths that also offer lower emissions? Of course not.

Capital and Sparks

The cost of energy generation plants is hard to pin down from year to year. A coal-fired power plant, that costs around $1,100 per kW of capacity one year, costs nearly $3,000 per kW two years later. Solar PV installations, soaring at $8,000 per kW STC one year, drop to $2,000 three years later.

My perception is that energy conversion technology prices are increasingly volatile, due to fuel shifts, innovations, and regulatory burdens such as emissions controls. A California Energy Commission study in 2010[12] forecast the installed cost of solar PV around $4000 per kW in 2012. It actually came in around $2000 per kW as of this writing.

The recent Prairie State coal powerplant in Kentucky, which went live in June 2012, is an Advanced Simple Cycle system that will deliver 1,600 megawatts of electricity into the Kentucky grid. The plant cost $5 billion to build, at a cost ratio of $3,125 per kilowatt – a number shared with many other peer projects in the western world. The California Energy Commission study baselined the cost at around $1,400 per kW. This is an upward, not downward trend. Plus, like all coal combustion, it puts out a nearly unmanageable amounts of coal ash.

These are big central plants, built by public utilities. Distributed generation is small, costs less, but still consumes capital like any other equipment. Just as this technology has now matured, cash reserves of U.S. companies have exceeded $5 trillion, and interest rates remain at historic lows. At payback rates of less than 36 months, private energy investments offer above average returns at low to moderate risk, and should, therefore, be an attractive investment. Again, regardless of who finances this development, investing in energy emissions reductions provides attractive returns on capital.

The Future Past Gas

Distributed generation technologies offer the lowest LCOE rates of all alternatives, and at the same time afford low and decreasing emissions rates. Current technology offers at least another ten years or more of continuous reduction in cost and emissions for the industrial sector, during which time further cost-reducing technological innovation – in early development now - will become available.

I'm not pretending everything is fine. There are all kinds of structural problems in the energy industry. But change is just starting to accelerate here also, from policy, to technology, to capital intensity – powered by a continually unfolding IR3. Also, very important, the U.S. leads the world with open energy markets: electricity (mostly), natural gas, and oil are deregulated, competitive markets, which quickly expose customers to shifts in cost.

As James Conca at Forbes points out: "The financing issue is key…" Free market forces may be excellent for short-term profits and innovation but cannot address long-term non-market requirements for stability, security and environmental sustainability." Corporations will continue to reduce their costs AND emissions, but capital requirements, although modest on a macro-economic level, will be high. But those investments will be recovered from current and future productivity improvements, not past.

Footnotes

[1] "Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds", Robert J. Gordon, Working Paper 18315, Nation Bureau of Economic Research, Cambridge, MA

[2] The end, or diminishment of growth, of course, means poverty is here to stay for billions of people

[3] Reprinted with permission from 1

[4] It should be said that EIA forecasts beyond a 5 to 8 year timeframe are mathematical, i.e., not based on structural effects

[5] The politics surrounding this shift would lead one to conclude a regulatory force, but, in fact, it is cost that is driving this. It is more profitable to export coal.

[6] http://www.lngfacts.org/resources/PACE_White_Paper.pdf

[7] If the planet absorbs around 11 billion tons, and we're around 25% of global GDP, our 'fair share' would be 2 – 3 billion.

[8] The Industrial sector is comprised of manufacturing, agriculture, mining, and construction

[9] "Explaining Long-Run Changes in Energy Intensity of the U.S. Economy", Wing/Eckhaus, Report 116, September 2004, MIT Program on the Science and Policy of Global Change

[10] JIT – Just in Time

[11] I include transportation in this: electric/hybrid vehicles are charged in time for consumption, the latency time for that energy is much shorter than that of oil, which is captured months, or even years, before ultimate consumption.

IAEE/Affiliate Master Calendar of Events

(Note: All conferences are presented in English unless otherwise noted)

Date	Event, Event Title and Language	Location	Supporting Organizations(s)	Contact
2013				
April 8-9	4th ELAEE Conference *Energy Policy in Latin America: Regional Integration and the Promotion of Renewables*	Montevideo, Uruguay	LAAEE/IAEE	Marisa Leon melon@adme.com.uy
April 22-23	6th NAEE/IAEE International Conference *Energy Resource Management in a Federal System: Challenges, Constraints & Strategies*	Lagos, Nigeria	NAEE/IAEE	Adeola Adenikinju adeolaadenikinju@yahoo.com
June 16-20	36th IAEE International Conference *Energy Transition and Policy Challenges*	Daegu, Korea	KRAE/IAEE	Hoesung Lee hoesung@unitel.co.kr
July 28-31	32nd USAEE/IAEE North American Conference *Industry Meets Government: Impact on Energy Use & Development*	Anchorage, Alaska	USAEE/IAEE	USAEE Headquarters usaee@usaee.org
August 18-21	13th IAEE European Conference *Energy Economics of Phasing Out Carbon and Uranium*	Dusseldorf, Germany	GEE/IAEE	Georg Erdmann georg.erdmann@tu-berlin.de
2014				
June 15-18	37th IAEE International Conference *Energy and the Economy*	New York City, USA	USAEE/IAEE	USAEE Headquarters usaee@usaee.org
September 19-21	4th IAEE Asian Conference *Economic Growth and Energy Security: Competition and Cooperation*	Beijing, China	CAS/IAEE	Ying Fan yfan@casipm.ac.cn
2015				
May 24-27	38th IAEE International Conference *Energy Security, Technology and Sustainability Challenges Across the Globe*	Antalya, Turkey	TRAEE/IAEE	Gurkan Kumbaroglu gurkank@boun.edu.tr