How Greater Efficiency Increases Resource Use

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by

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Statement of the Problem

Most environmentalists believe that increasing the efficiency of a process minimizes the material flowing through that process (throughput) because less waste requires fewer resources. This paper states that our environment does not benefit from greater efficiency but from less material throughput. Greater efficiency justifies greater material throughput.

Clarifying the Definition of Efficiency

Efficiency is a ratio of input to output that compares one process with another. Common usage has distorted this definition to include productivity, but productivity is a rate of output *per unit of time*. Examples of productivity are the amount of product manufactured per year and occupancy rates for hotels.

Another distortion suggests that efficiency is a ratio of costs to benefits, but costs and benefits are usually stated *in monetary terms*. Our government uses cost benefit analyses to judge the worthiness of environmental projects. The inputs and outputs in most processes are not monetary. Hundreds of definitions and viewpoints concerning efficiency are on my website www.efficology.com.

Each sector of commerce has efficiency ratios such as fish caught per trawl, or timber harvested per acre. With energy in particular, examples of efficiency ratios include miles driven per gallon of fuel consumed and lumens of light generated per watt of electric input. Some efficiency ratios are expressed as percentages, such as the efficiencies of boilers and electric motors.

What Efficiency Does

Efficient processes can produce materials faster, better and cheaper than inefficient processes. Efficient processes help businesses successfully compete with one another. Products that are more efficient than their counterparts can be faster, smaller, lighter, cheaper, more predictable, reliable and uniform. They usually are heavily advertised, widely-available and machine-made.

In these ways, efficiency works to our advantage. As time has passed, almost every mechanical and chemical process has become more efficient – wireless communication, medical technology, computers, lasers, microwaves – the list is huge. On face value, improving the efficiency of processes and products seems to be our nature – a celebration of progress.

Increased efficiency necessitates comparing an input/output ratio in one process with that of at least one other process. One ratio is judged more efficient than another when:

a. Output is greater for the same input.
b. Output is the same with less input.
c. Output increases at a greater rate than the input.

Increased Efficiency Correlates with Increased Resource Input

Among all resources, energy use is very important for three reasons:

1. We are burning up non-renewing energy resources.
2. Products of combustion are globally warming our climate.
3. Products of combustion are poisoning our water and air.

Given energy's importance, let's start by looking at how much energy the United States consumes in comparison to citizens of other countries. In his 1974 book *Energy, Man, Society*[1], the late Professor Earl Cook, Dean of the College of Geosciences at Texas A&M University, explained that an advanced industrial society, perhaps like the former USSR, was about 3% less efficient than an industrial-technological society, such as the United States.

	Per Capita Daily Energy in kcal			
Type of Society	Gross input	Relation to average	Gross output	Approximate aggregate efficiency
Subsistence agricultural	5,000	6%	500	10%
Advanced agricultural	20,000	23%	3,000	15%
Emerging industrial	60,000	70%	15,000	25%
Advanced industrial	120,000	140%	42,000	35%
Industrial technological	225,000	262%	81,000	36%
Averages	86,000	100%	28,300	

The approximate aggregate efficiency is the gross output divided by the gross input. Note that Professor Cook writes that an advanced industrial country would use more than two and a half the average kcal input. The 3% increase from 35% to 36% efficiency requires an increase of about 88% in per capita energy input from 120,000 kcal to 225,000 kcal.

Have Professor Cook's proportions withstood the test of time? Using data from the International Energy Agency and the World Resources Institute[2], the following table shows the per capita energy consumption for four countries. The units of consumption are not the same, but the proportions are similar:

Per Capita Annual Kilograms of Oil Equivalent

	Gross input	Relation to average
Bangledesh	133	5%
China	861	33%
Russian Federation	4,124	156%
United States	8,095	306%
Averages	2,643	100%

Note how close the year 2000 relationship to the average per capita energy input for these four countries compares to Professor Cook's more theoretical relationship. The per capita outputs, unfortunately, seem skewed by exports of energy; I wish I could find and include the net energy output per capita. With those numbers, the aggregate efficiency could be estimated.

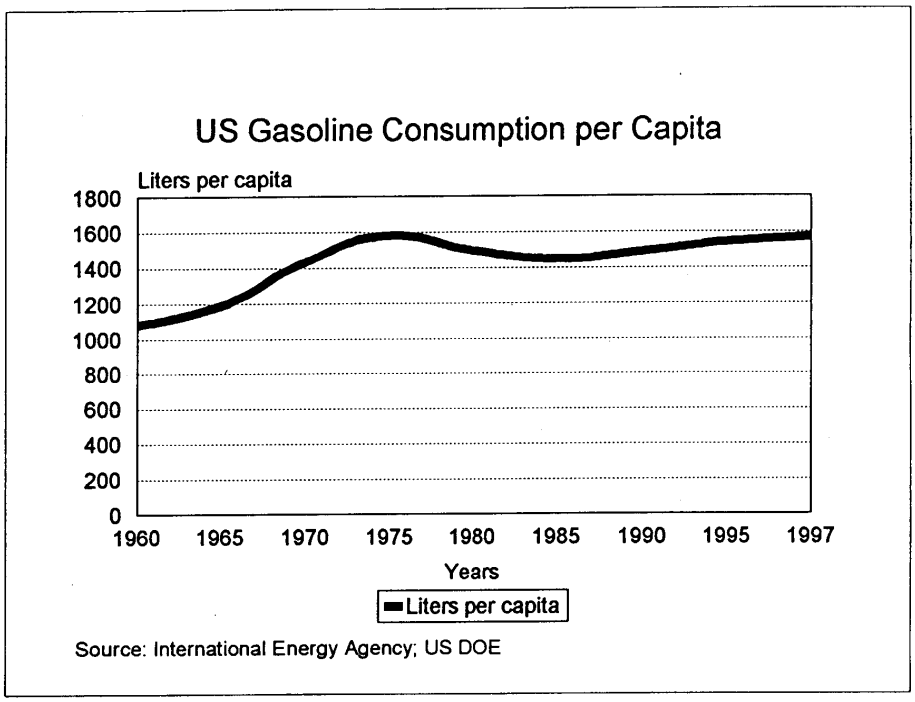
Are the choices of countries meaningful? I don't think there currently are any hunter-gatherer societies. Is Bangladesh a good agricultural choice? According to the Bangladesh government[3], "agriculture is the single largest producing sector of economy since it comprises about 30% of the country's GDP and employing around 60% of the total labour force. The crop sub-sector dominates the agriculture sector contributing about 72% of total production."

Three Examples of Per Capita Resource Consumption

Each of the following three examples has two parts – a chart that shows an increase in a rate of per capita consumption of a resource in the United States, and an associated table below it that lists the mechanisms, or techniques, to increase efficiency of resource use. In each example – gasoline, paper and electric consumption – US per capita consumption increased as consumption became more efficient.

A popular comment about this observation is that the rate of consumption would have been greater without increased efficiency. This reply is moot because the consumption would have been reduced absolutely by not consuming (conserving) paper, gasoline or electricity in the first place. Increased efficiency coincides with, and likely rationalizes, increased consumption of the resource.

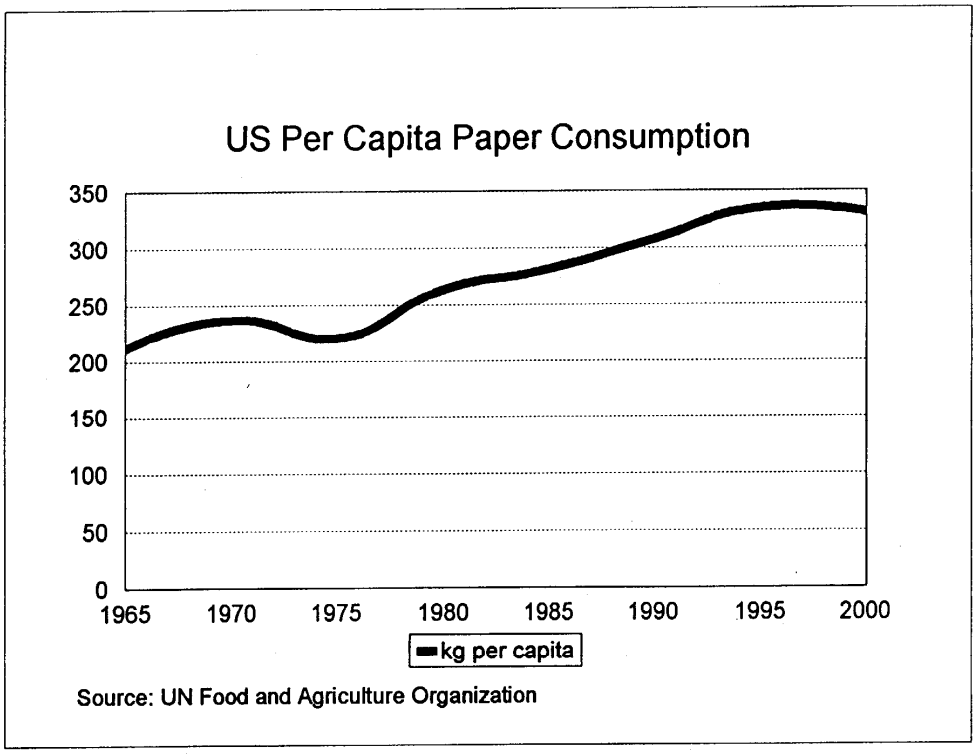
To this response, a common retort is that we should be free to consume what we wish, as long as we consume efficiently. This reinforces to my basic point – greater efficiency rationalizes greater use of resources.



Transportation Efficiency Improvements

Lighter bodies and frames – plastics and fiberglass
Aerodynamic body shape
Aluminum engine blocks
Fuel injection
Turbocharging
Overhead cams
Better carburetors
Automatic speed controls
V6 and V4 engines
Multi-speed automatic transmissions
Electronic controls
Torque converter lockups to prevent slippage
Transverse direction of motor rotation

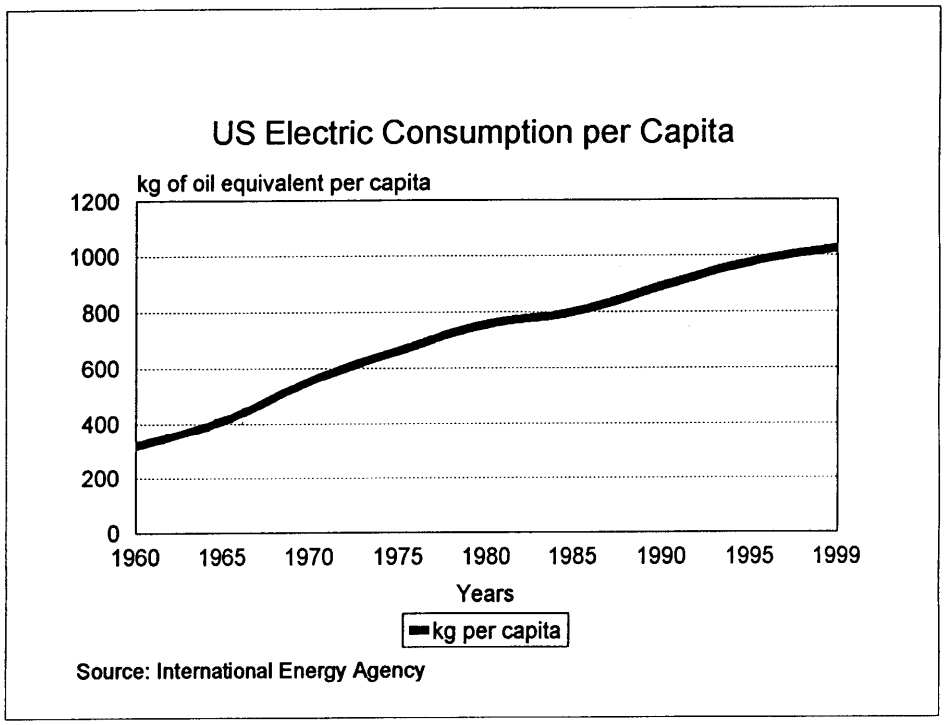
Mandated periodic emissions tests
Steel belted radial tires
Front wheel drive
Antilock disk brakes
Sealed beam halogen lighting
Light emitting diodes rear and indicator lighting
Interstate highway system
55mph speed limits
CAFE Standards
Right Turn on Red
Carpooling
The internet, email, telecommuting
Instantaneous information about traffic conditions



Paper Efficiency Improvements

Paperless communication
- Email
- Internet
- Faxes between computers
- Cellphone communication
- Portable Document Format (.pdf)
- Compact Disks
- Scanners
- Huge capacity hard drives
- Phone answering machines
- On-line publications

Duplex (two-sided) copying
Junk mail minimization programs
Increased postal rates
Increasing storage and disposal costs
Microfiche
Government paperwork reduction acts
Document routing
Self-mailing documents
Notepaper with removable adhesives
Cloth bags
Electric hand dryers
Recycling



Electrical Efficiency Improvements

More efficient motors and heating systems
Direct and indirect domestic water heaters
Variable speed drives
Variable volume HVAC
Microwave, laser and fiber optic technologies
Personal computers
Digital communication
The Internet
Direct digital control
Energy management systems
High pressure sodium street lighting
Metal halide, compact fluorescent lamps
Light emitting diodes
T8 fluorescent tubes and electronic ballasts
Reflective internal fixture surfaces
Better light diffusers
Daylight and occupancy sensors
Higher SEER air conditioning with economizers
Double-bundle condensers on chilled water systems
Air-to-air, and now ground source heat pumps
Department of Energy, State energy offices and the EPA
Commercial and Apartment and Conservation Services
Photovoltaics, with tax credits and accelerated depreciation
On-site cogeneration
Energy efficiency tax credits
The Model Energy Code
ASHRAE Standard 90
The shared savings industry

How Greater Efficiency Increases Resource Use

Here are a dozen ways that the increased efficiency increases our consumption of resources:

1. Efficiency disconnects the problem from the solution. If we recover from a disease merely because we change our lifestyle, we have a clear relationship between diagnosis and cure. We diagnose environmental diseases by measuring the accumulation of poisons in our environment. The toxins accumulate because we dump them into our air, soil and water faster than natural processes can absorb and neutralize them. The term "faster" means that environmental problems are usually expressed as rates. To heal our environment, we need to slow the rates.

One example of such a rate is the tons of CO_2 that accumulate in our atmosphere per year. Another is catching fish at a rate faster than a fishery can replenish. To succeed, we would slow or reduce the absolute rates of resource use. We would reduce our consumption of fish from depleting fisheries and reduce our CO_2 production from transport and from electric generation. Each of us would have to change our lifestyle to do so. Or, maybe efficiency can allow us to eat our fish and preserve them too.

If we could ingeniously reduce the resources put into a process or product, we might produce the same, or even more output. We could lower our consumption of resources and not have to change our resource-intensive lifestyles. We could enjoy our car trip and reduce CO_2 at the same time. This is the seduction of increased efficiency – we get a better deal, bigger yield, more options, features, benefits, advantages – while our use of resources is supposed to decrease.

Since greater efficiency is supposed to reduce resource input, the rate of gasoline, paper and electric consumption should have been reduced, but the opposite happened. As the increased efficiency of each mechanism succeeds in achieving greater output per input, consumption and harm to our environment continue to increase in spite of, and perhaps justified by, greater efficiency.

Efficiency ratios seem successful because they disconnect from the rates that originally diagnosed the problem that increased efficiency was supposed to solve. The ratio of tons of fish per trawl is disconnected from the rate of fishery depletion. The efficiency of harvesting trees is disconnected from the rate of depletion of old growth forest. Lumens per watt are disconnected from kilowatthours generated per year. Btus per square foot per year are disconnected from the rate of household energy use. And the ultimate disconnection – energy used per dollar of Gross Domestic Product decreases as we degrade our environment. We can easily improve efficiency ratios without reconnecting them to the rates that originally diagnosed the environmental problems, and harm to our environment continues. As we succeed, we fail.

2. Efficiency emphasizes output. Increased efficiency emphasizes outputs from a process more than inputs into the process. Inputs don't promote sales of products. Advertisements for more efficient processes and products describe increased speed, additional options, more compact size and other advantages over less efficient antecedent or competing products. The features, benefits and advantages of outputs outshine the inputs. The value of the inputs associated with consumed products are diminished by discounting the environmental harm associated with their

production and disposal. Monetary prices are discounted by rebates, coupons, sales, credit, small print, and so on. Efficiency makes products cheaper as long as (a) inputs to processes discount the artificially cheap cost and high replacement value of non-renewing resources, and (b) as long as the outputs from processes exclude the pollution of our atmosphere, landfills and water. The outputs seem more worthy relative to the inputs; our harm to the environment is hidden by emphasizing the outputs and discounting the inputs.

3. Optimization is not minimization. To slow a rate of environmental degradation directly means setting limits. By their structure, efficiency ratios have nothing to do with limits. Increased efficiency is a means with no goal because the efficiency of a process can be infinitely increased. We don't know what a "most efficient" process or product is.

While increased efficiency may be measured in more miles traveled per gallon of gasoline burned, for example, consumption limits would ration gasoline, raise the price of oil from its extraction cost to its replacement cost, set limits for the number of vehicles owned per family, and so on. Current similar debates about limits involve fishery and old growth forest depletion.

Promoting limits on consumption and challenges to our resource-extravagant lifestyles is not deemed politically correct, even though it would benefit our environment. In contrast, promoting increased efficiency is more fundable, politically correct, and seemingly without any negative consequences. We can consume all the natural resources we want, as long as we consume them efficiently, even if the result is increased resource use and environmental degradation.

4. Efficiency has greater value with greater consumption and use. The more we use a resource efficiently, the more of that resource we 'save.' In replacing incandescent lamps with lower wattage compact fluorescent lamps, we 'save' more electricity as the lower wattage lamp burns for more hours. Likewise, a relatively fuel-efficient car 'saves' more gasoline the more we drive it.

On the other hand, not driving and turning off lamps has less, or no, value in an energy efficiency ratio. Greater savings results from turning off more inefficient lamps and not driving large, inefficient cars. In other words, the more inefficient a process or product is, the greater the savings from not using it. Not using products and processes has far more value for our environment because the savings are not incremental estimates based on disconnected ratios, but are absolute instead.

5. Efficiency breeds discontent. Usually, we judge less efficient processes or products as inferior when compared to more efficient ones. Since increased efficiency has no goal and sets no limits, we expect most or all products and processes to evolve into more efficient ones. Increasingly efficient products and processes foment discontent with what exists; nothing seems good enough. Everything seems to have the potential for 'improvement' and a reason to discard it for a more efficient product.

6. Everything seems prototypical, temporary. Increased efficiency compares at least two processes or two products to determine which is more efficient. Such redundancy occurs not only in comparing the inputs and outputs of one process with another, but in comparing the efficiencies of all antecedent processes in the evolution of those products and processes. For example, the antecedent processes for developing one specific type of DVD include comparing the efficiencies of many varieties of compact disks, magnetic tape, vinyl records, stereo systems, televisions, and DVD players. As less efficient products and processes are discarded, all preceding and unsuccessfully competing prototypes seem to lose value as well.

7. Obsolescence flourishes. With each more efficient product or process, the less efficient ones are discarded. Over time, the more efficient process gains market share. Efficiency motivates us to discard one car for another that can travel more miles per gallon, or one lamp another with more lumens per watt. The improvements in computers and cell phones provide excellent examples. While all cell phones are judged adequate at the time of purchase, over a million less efficient cell phones are discarded each week, even though most still function adequately. Buying more efficient ones increases material throughput, but is justified by the increased efficiency of additional features, options, compact size, faster operating speed, increased clarity, picture-taking features and expanded range. We look forward to more efficient consumption.

8. Personal behavioral responsibility decreases. Increased efficiency instructs us what to buy, not how to use it. Other people design and engineer efficient processes into products that are manufactured by machines or cheap foreign labor as much as possible. As increasingly efficient digital electronics, fiber optics, lasers and microwaves have gained market share, the products that contain them become less transparent. They cannot be understood, diagnosed, maintained or repaired as easily as their analog predecessors. Examples include digital thermostats replacing analog ones containing bimetallic strips, digital watches replacing wind-up watches, and DVDs replacing vinyl records. We can't understand, maintain, diagnose or repair the new products without using technology as complex as that used to manufacture them. While the additional advantages, options and benefits lead to a greater dependence on newer technology, the inability to maintain and repair them necessitates their disposal to the detriment of our environment.

9. Efficiency overvalues the quantifiable. We can increase the efficiency of a process only if we can quantify inputs and outputs. Attributes that cannot be so quantified seem to have less value. Do they really have less value?

The products and processes that are the most valuable to us are, by necessity, inefficient. Examples are democracy, raising children, learning, loving, art, manners, and even nature itself, which H.T. Odum estimated was only 2% efficient[4]. Respectively, we can make each of these more efficient through dictatorship, child labor, cheating, pornography, mass production, selfishness and genetic engineering – all with repercussions. Increased efficiency destroys the things we value most and yet adds value to the more quantifiable products and processes that harm our environment.

10. Increased efficiency lowers the cost of consumption. Increasing the efficiency of a process usually lowers costs and increases consumption. The benefits of the output of processes are attractively described, and competition, mass production, mass marketing, political lobbying, and the many ways of discounting costs, including environmental costs, are continually increased. As prices fall, consumption and disposal are increasingly justified. Lower cost electricity, gasoline and paper stimulate their consumption. At the World Resource Institute, Emily Matthews shows that more efficient nations have greater material throughput. Her book, *The Weight of Nations*[5], is on the WRI website.

11. Efficiency disconnects us from natural systems. Input output ratios describe a linear process. In contrast, more natural processes are cyclical with outputs that later become inputs, such as leaves becoming fertilizer for the plants that sprouted them. Material throughput results in products with value and waste with no value. In their 2000 book, *Cradle to Cradle*[6], William McDonough and Michael Braungart write,

> Eco-efficiency is an outwardly admirable, even noble, concept, but it is not a strategy for success over the long term, because it does not reach deep enough. It works within the same system that caused the problem in the first place, merely slowing it down with moral proscriptions and punitive measures. It presents little more than an illusion of change. Relying on eco-efficiency to save the environment will in fact achieve the opposite; it will let industry finish off everything, quietly, persistently, and completely….
>
> Eco-efficient factories are held up as models of modern manufacturing. But in truth many of them are only distributing their pollution in less obvious ways. Less efficient factories, instead of sending emissions through high smokestacks into other areas far from the site (or importing them), tend to contaminate local areas. At least local destruction tends to be more visible and comprehensible: if you know what you are dealing with, you may be horrified enough to do something about it. Efficient destruction is harder to detect and thus harder to stop. In a philosophical sense, efficiency has no independent value: it depends on the value of the larger system of which it is a part. An efficient Nazi, for example, is a terrifying thing. If the aims are questionable, efficiency may even make destruction more insidious.
>
> Last but not least, efficiency isn't much fun. In a world dominated by efficiency, each development would serve only narrow and practical purposes. Beauty, creativity, fantasy, enjoyment, inspiration, and poetry would fall by the wayside, creating an unappealing world indeed. Imagine a fully efficient world: an Italian dinner would be a red pill and a glass of water with an artificial aroma. Mozart would hit the piano with a two-by-four. Van Gogh would use one color. Whitman's sprawling "Song of Myself" would fit on a single page. And what about efficient sex? An efficient world is not one we envision as delightful. In contrast to nature, it is downright parsimonious.

12. The investments in efficient processes require rapid returns. In competitive business contexts, more efficient processes require continual retooling and upgrading. Continual investments are required to successfully compete with less efficient processes from competitors. As one car manufacturer adds more sophisticated robots and automation, others

must add them as well to remain competitive. Since they are on the cutting edge, more efficient processes come at a premium cost because they are unique. Returns on the investments in such technology require mass production, advertising and growth, all of which stimulate consumption and increase in environmental degradation. Selling to larger national or international markets may increase sales, but also increases energy/transportation costs.

Alternatives to Increased Efficiency

In spite of its failure to reduce consumption, increased efficiency has become the mantra of most environmental groups. Perhaps they assume that alternatives to efficiency will marginalize their efforts and reduce their funding streams. Here are nine alternative behaviors and affirmations, in contrast to increased efficiency, that promote a healthier environment. My proposed solutions are more sociological than technical:

1. Turn things off. If increased efficiency claims considerable resource savings, a great deal more resources are saved by not consuming them at all. With energy, this is called 'conservation.' If increased energy efficiency 'saves' more energy with greater use, conservation saves even more with no use. Almost everyone understands this concept because most lights and appliances are off; if they were all turned on, the electric utilities would crash under the load. Most cars are parked; otherwise, our roads would be totally congested; there would be no room to drive. Not using things appeals to the best of human nature that admires frugality and thrift. Nothing is better for our environment than turning things off.

2. Preserve non-renewing resources. We preserve older buildings and antiques. We find greater meaning in things with a history. We admonish those who destroy our heritage. We value endangered species and habitats. Non-renewing fossil fuel is a similar heritage worth preserving. We revere obsolete technology through museums and interest in antiquities. And we admire many aspects of inefficiency. For example, the past has always seemed slower. Efficient technology comes with a premium price and landfills its worthless predecessors – the effluence of affluence. Inefficient technology, on the other hand, seems more nostalgic, romantic. Each piece of old technology provides an alternative to more efficient successors and came from a time when we used less non-renewing energy.

3. Accept limits as positive. We accept limits in everything we do. Otherwise, we would overdose. We accept speed limits and thousands of other laws. We understand limits on fisheries and the logic of fishing licenses. We have little or no tolerance for other forms of harm – like child pornography, adults selling illegal drugs to kids, killing innocent people, or stealing from the poor. We have reduced other pollution from second-hand tobacco smoke, and similarly attempt to reduce pollution of our atmosphere. To a great extent, our religions are based on limits – "Thou shalt not…." And, if we understand and accept the experience of the Amish, self-imposed limits on connection to the electric grid, car ownership, mechanized farming, and other forms of extreme resource use improve family and community life, while lessening environmental damage.

Richard Heinberg has written an excellent book[7] that discusses the importance of diminishing oil resources. Here is his take on accepting limits as positive:

> The inescapable implications of these findings are first, that many efforts toward energy efficiency actually constitute a kind of shell game in which direct fuel uses are replaced by indirect ones, usually in the forms of labor and capital, which exact energy costs elsewhere; and second, that the principal factor that enabled industrial countries to increase their energy efficiency in the past few decades - the switch to energy sources of higher net yield - does not constitute a strategy that can be applied indefinitely in the future. Thus the curtailment of energy usage offers clearer benefits than improved efficiency. … Given that, from a historical and cross-cultural perspective, Americans' average standard of living is lavish, it would seem that some curtailment of consumption may not be such a bad thing. After all, people currently have to be coaxed and cajoled from cradle to grave by expensive advertising to consume as much as they do. If the message of this incessant propaganda stream were simply reversed, people could probably be persuaded to happily make do with less. Many social scientists claim that our consumptive lifestyle damages communities, families, and individual self-esteem; a national or global ethic of conservation could thus be socially therapeutic.

4. Resurrect symbols of conservation. We can communicate the values of responsibility that come with freedom to use natural resources. Smokey Bear tells us "Only you can prevent forest fires." We have Woodsy Owl's "Give a hoot, don't pollute." We can popularize symbols like electric switches in the off position. We can change our message and goal from "Use Energy Efficiently' to 'Use Less Energy.' We can give new meaning to Dr. Seuss' *Lorax* who wants more and bigger Thneeds and to Aesop's fable in which the tortoise beats the hare.

5. Emphasize the inefficiency of the best things in life. The activities that are the most valuable to us happen to be inherently inefficient. Efficiency promotes growth, uniformity, passivity and non-human automation. Inefficiency flatters depth, color, texture and independence in our lives. Culture itself – with art, religion, democracy, knowledge, health and an appreciation of natural systems – flourishes with restraint. We need to describe these many aspects of our culture as having greater value with less efficiency, and we must promote that increasing their efficiency destroys what we value most, including the natural systems on which we depend.

6. Honor and emulate more sustainable energy users. Less efficient societies provide us with many examples of alternatives to efficient consumption. Almost every society other than the United States is less efficient and uses fewer resources per capita <u>because</u>, by my reasoning, they are less efficient. Hunter-gatherers, for example, provide net positive food calories to their society, while it takes four calories of energy to put one calorie of food on the American dinner table (25% efficient, or 400% inefficient?). Organic farmers, community supported agriculture, investors in solar energy systems, users of public transit, vegetarians. All around us, people from other cultures provide a mirror for us to see the relatively unsustainable results of our increased efficiency; they all use less energy and prosper. Instead of exporting efficient technologies to cultures that are more sustainable and less efficient than ours, we should adopt their ways, perhaps through a 'Reverse Peace Corps', by which they train us in more sustainable behaviors, instead of the other way around.

7. Resurrect non-energy-using ingenuity. When it was less efficient, early American culture had a highly respected, deep strain of thrift and frugality. Quaint, friendly, small neighborhood homes and businesses have evolved into cheap megamansions and big box stores. Relatively inefficient and handmade crafts have evolved into automated factories based on the value of the fewer employees the better. Energy constraints lead to creative, non-energy solutions, as well as less environmental damage.

8. Witness our waste. Let's spend time at landfills. Have design engineers explore the dumpsters and the ends of waste pipes coming from their manufacturing plants. MIT's Peter Senge describes how the Xerox engineering team, which was designing new digital copiers, spent time on a wilderness expedition in the New Mexico desert[8]. They found deep revelation in seeing a Xerox copier in a dump and successfully redirected their entire enterprise to "Zero to landfill, for our children." Let's make waste more visible.

9. Take back political power. We need truly conservative leaders rather than conservatives who do not value the preservation of non-renewing resources or a healthy environment. We need leaders that turn us off and slow us down by a combination of exhortation, information, regulation, taxation and incentives. The 2004 election is a grand place to start.

Summary

Our environment does not benefit from increased efficiency; it benefits from less use of non-renewing resources. Our environment does not benefit from more lumens per watt or more miles per gallon burned; it benefits from less pollution from reduced electrical generation and fewer gallons of gasoline burned.

Most electric utilities promote increased efficiency… until they understand that supply is not sufficient to meet demand. At that time, they tell their customers to turn off equipment, not to use it more efficiently. Facing diminishing, non-renewing energy resources, we ought to become just like the electric utility lacking sufficient generation capacity to meet demand. It is time to advocate using less.

I recommend making the inevitable possible, and enjoyable, by turning things off and restricting our use of valuable, non-renewing resources so they may be preserved as a treasure for generations to come, or not used at all.

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1. Earl F. Cook, *Man, Energy, Society*. W.H. Freeman and Company, 1976. ISBN 0716707241. Page 135.

2. Data tables 4 and 8 in *World Resources 2002-2004: Decisions for the Earth: Balance, voice, and power.* World Resources Institute, 2003, ISBN: 1-56973-532-8

3. http://www.discoverybangladesh.com/meetbangladesh/agriculture.html

4. Howard T. Odum, *Environment, Power, and Society*, New York: John Wiley & Sons, December 1971. ISBN 0471652709, Page 90

5. Emily Matthews et al. *The Weight of Nations: Material Outflows from Industrial Economies.* Washington, DC: The World Resources Institute, 2000. ISBN 1569734399.

6. William McDonough and Michael Braungart, *Cradle to Cradle*. New York: North Point Press, 2002. ISBN 086547-587-3. Pages 61-65.

7. Richard Heinberg, *The Party's Over: Oil, War and the Fate of Industrialized Societies*. Gabriola Island, BC, Canada: New Society Publishers, 2003. ISBN 086571482-7. Page 163

8. Peter M. Senge, "Creating Desired Futures in a Global Society" in *Northeast Sun* magazine, Spring 2004 issue, Pages 11-19.

Note: For a thorough bibliography, examine www.efficology.com.